International Trade and Regional Inequality *

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Preliminary

Abstract

This paper studies how openness to trade can increase inequality across regions and the spatial concentration of economic activity due to the endogenous sorting of heterogeneous firms and industries across space. First, I present three related stylized facts documenting that export participation is higher in more densely populated areas. To rationalize them I build an open economy economic geography model with heterogeneous firms and sectors. The model yields two novel mechanisms through which opening to trade increases the spatial concentration of economic activity. Firstly, firms in larger cities are more productive and will expand due to a fall in trade costs. Secondly, sectors located in larger cities are less labour intensive and will expand following a reduction in trade costs in capital-rich andvanced economies. I test these model predictions using exogenous changes in export market access for French firms and find strong empirical support for both mechanisms. I provide additional evidence in line with the model predictions from the rise in Chinese import competition vis-à-vis the United States. Following a trade shock economic activity reallocates to larger cities driven both by within-sector and across-sector reallocation. When comparing these two channels quantitatively I find that the firm-level mechanism is more important indicating that trade integration, even among similar countries, can substantially increase regional inequality.

Key words: Globalisation, regional inequality, spatial sorting
JEL codes: F12, F16, R12, R13

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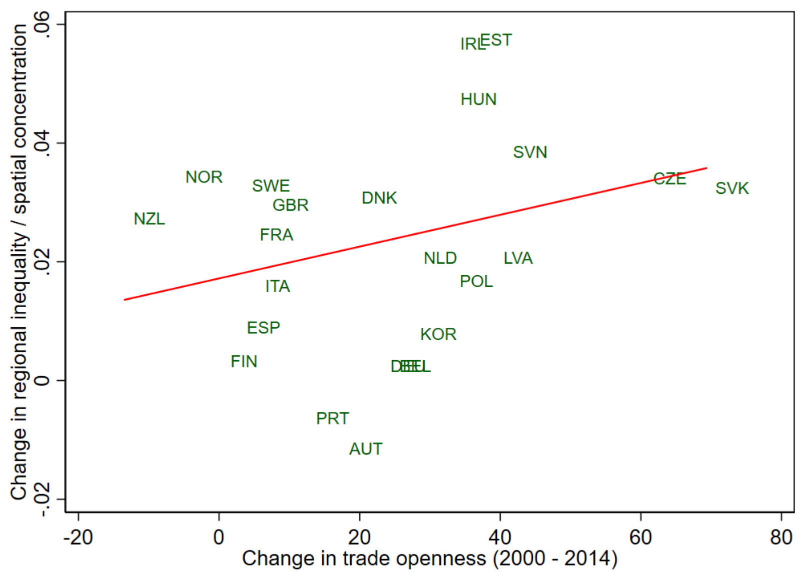
1 Introduction

The distributional effects of globalisation have come into renewed public focus in recent years. While the effects of international trade on inequality across heterogeneous workers have been studied extensively (Helpman, 2016), relatively little is known about the effect on heterogeneous regions. Are metropolitan areas like New York City differently affected by trade than countryside towns like Grand Rapids, Michigan? The positive cross-country correlation between changes in openness to trade and regional inequality presented in Figure 1 suggests they might be. Across countries, an increase in openness to trade is associated with an increase in the concentration of economic activity in bigger cities.

Figure 1: Trade openness and regional inequality across countries



Note: Change in trade openness and change in regional inequalities between 2000 and 2014 for 26 advanced economies. Change in openness is defined as the change in (exports + imports)/GDP. Change in regional inequality is defined as the change in the regional Gini coefficient.
Source: OECD Regions and Cities database.

Starting from this cross-country correlation this paper proceeds in three steps to provide evidence linking globalization to a reallocation of economic activity to larger cities. First, I present three related stylized facts documenting that export participation is higher in more densely populated areas. Second, I develop an open economy economic geography model that rationales the cross-country correlation as well as the documented stylized facts and proposes two mechanisms through which changes in trade openness affect regional inequality. Third, I employ exogenous changes in export market access to test the mechanisms proposed by the model using French micro-data. I provide additional evidence from the rise in Chinese import competition in the US studied extensively by Autor et al. (2013) and others. Both in the French and the US data I find strong support for the model mechanisms. The effects of trade shocks vary systematically across locations benefitting larger cities over smaller towns. When comparing the two mechanisms quantitatively I find that in both countries firm sorting across locations is quantitatively more important than sector sorting.

I document in the cross-section of French commuting zones that export participation is higher in more dense areas. This correlation is partly but not completely driven by within-sector heterogeneity across locations. Additionally, I find that average sectoral export intensity also increases with employment density. This suggests a role for both firm and sector heterogeneity in understanding the heterogeneous trade participation and its implications across locations.

To rationalize these stylized facts I propose a firm-level and the industry-level mechanism that both embody stylized facts from research in the fields of international trade and urban economics. First, the firm-level mechanism builds on recent research in urban economics by Combes et al. (2012) and Gaubert (2018) who provide evidence that, within narrowly defined industries, firms in larger cities are more productive. Research in international trade has shown that opening up to trade leads to a reallocation of market share from less to more productive firms within industries (Pavcnik, 2002, Melitz, 2003). Jointly, these two stylized facts suggest that a given aggregate trade shock translates into a heterogeneous local labour demand shock across different city sizes. Smaller cities host less productive firms that are affected more negatively by a given sectoral trade shock and therefore the city faces a more negative labour demand shock in this sector. This will reallocate employment from smaller to larger cities and thereby increase regional inequality.

Second, the industry-level mechanism builds on recent work by Davis and Dingel (2015) and Gaubert (2018), who provide evidence of systematic spatial sorting of heterogeneous sectors. They find that more skill and more capital-intensive sectors are over-proportionally located in larger cities. Theories of endowment-driven comparative advantage in international trade emphasize trade-induced across-industry reallocation to capital and skill-intensive industries in countries that are abundant in these factors, e.g. advanced economies. Combining these stylized facts suggests that increasing the openness to trade has a differential effect on the sectors that are located in smaller cities relative to those in larger cities. Smaller cities host sectors that are more exposed to import competition while larger cities host those that are more exposed to an export opportunity shock from trade opening. Therefore employment and economic activity will reallocate from those sectors located in smaller cities to those located in larger cities and thereby increase spatial concentration.

I formalize this intuition by integrating the multi-sector spatial general equilibrium model from Gaubert (2018) with the international trade model by Bernard et al. (2007) to open a rich economic geography to international trade. The spatial equilibrium of the model features spatial sorting of more productive firms and more capital-intensive sectors into larger cities. In the open economy equilibrium with asymmetric countries, trade occurs both across industries driven by comparative advantage, and within industries driven by firm heterogeneity and love-for-variety utility functions. I study different versions of the model to highlight the effect of the firm-based and the industry-based mechanism separately. Both mechanism can rationalize the cross-country correlation. In a version of the model with symmetric countries and therefore only within-industry trade, the city size distribution in the open economy is more concentrated than in the closed economy in line with the firm-based mechanism outlined above. In a version of the model that only features two sectors that vary in their factor intensity and homogeneous firms, the city size distribution of the country that is more capital abundant is more concentrated in the open than in the closed economy as suggested by the industry-level mechanism.

I validate the model predictions empirically using exogenous changes in market access (following Redding and Venables (2004) and Hering and Poncet (2010)) and French micro-data as well as the rise in Chinese import competition in the United States following Autor et al. (2013) and Acemoglu et al. (2016). In the empirical analysis I rely heavily on the model structure that implies that city size is a sufficient statistic for both the distribution of firms across different cities within a sector as well as the sectoral composition. I find strong support for the model predictions using the regressions implied by the model structure. Consistent with the firm-level mechanism, I show that conditional on the size of the aggregate trade shock the firms located in larger cities increase their revenue by more from a market access shock in France and employment decreases by less from an import competition shock in the US. Consistent with the industry-level mechanism, I find that the industries located in larger cities respond more to an export opportunity shock and less to an import competition shock. Comparing these two mechanisms I find that the firm-level mechanism is quantitatively more important than the sector-level mechanism. This highlights the spatial implications form trade even from a decrease in trade costs among similar countries such as within the European Union.

The remainder of this paper is organized as follows. Section 2 discusses the related literature and the contribution of this paper. Section 3 introduces the data and the stylized facts. In section 4, I describe the model that underlies the empirical analysis presented in section 5. In section 6 I provide additional evidence from the rise of Chinese import competition in the US. Section 7 concludes.

2 Related literature

This paper proposes spatial sorting as a causal mechanism through which increases in international trade affect regional inequality. This relates to a number of literatures in both international trade and economic geography.

There is a small literature that looks at how international trade affects the economic geography within a country going back to Krugman and Elizondo (1996). Recent papers include Fajgelbaum and Redding (2014), who study how an increase in openness leads to higher population densities in areas with higher access to world markets and Coşar and Fajgelbaum (2016) who document that Chinese coastal cities specialize in traded goods relative to more remote locations. This literature focuses on the importance of intra-national trade costs and looks at settings such as Argentina in the late 19th century and China where intra-national trade costs are an important transmission mechanism for the effects of external integration. This paper complements the previous literature and adds to it in three ways. Firstly, it suggests a different mechanism through which international trade effects the economic geography based on the spatial sorting behaviour of heterogeneous firms and industries. Secondly, in my empirical application I look at the economic geography of an advanced economy whose spatial distribution is governed by different forces and arguably more stable than the one of an industrialising country. Thirdly, in contrast to the previous literature that focuses more on long-term macroeconomic development issues I study the effect on regional inequality and thereby link trade to the emerging literature on regional divergence (Giannone, 2017).

Most closely related to this paper is recent work by Brülhart et al. (2015) that studies the heterogeneous effects of trade on different town sizes in Austria after the fall of the Iron Curtain. They find that larger towns tend to have larger wage and smaller employment responses than smaller towns and argue that this is driven by heterogeneity in the labour supply elasticity across different city sizes. While the focus on the heterogeneity across different city sizes is somewhat similar, the papers complement each other as they differ in the choice of model and focus of the analysis. They explicitly do not consider the endogenous sorting of sectors across city sizes and do not allow for variation in the intensity of the trade shock, such that they do not eplore the two mechanisms highlighted in this paper. While the empirical analysis in this paper allows for more heterogeneity in the effect of trade they instead use a more structural approach in order to address the welfare implications. Additionally, they do not address the effects on the spatial distribution of economic activity.

In my empirical analysis, I build on the large literature that studies the effects of trade shocks, especially the rise in Chinese import competition, on employment and other variables in local labour markets (Kovak (2013), Autor et al. (2013)) and on the industry level (Acemoglu et al., 2016). I add to this literature in a number of dimensions. Firstly, in my model I do not treat each commuting zone as an independent small open economy but rather model the economic geography of the country explicitly. This allows me to formalize and empirically highlight the heterogeneity of the effect of import competition across different commuting zones. I also let the model guide the endogenous spatial distribution of industries rather then treating them as exogenous or pre-determined. Secondly, instead of only focusing on outcomes on the commuting zone level I emphasize the effect on the aggregate spatial distribution of economic activity.

Methodologically, I build on recent empirical and theoretical advances that analyze spatial sorting of heterogeneous firms and sectors in economic geography and urban economics such as Combes et al. (2012), Davis and Dingel (2015) and Gaubert (2018). I contribute to this literature by studying the importance of spatial sorting in the open economy and how it matters for the effects of changes in trade openness. The only paper that jointly models spatial sorting and international trade is contemporaneous work by Garcia et al. (2018). Similar to this paper they also incorporate trade with heterogeneous firms into the spatial equilibrium model developed by Gaubert (2018). They study how omitting the firm decision to export might lead us to underestimate the welfare losses from sub-optimal city sizes due to zoning restrictions, as the lost agglomeration gains could have pushed firms above the Melitz (2003) threshold.

The paper also adds to the large literature on the distributional effects of trade (see Helpman (2016) for a recent survey), but rather than focusing on heterogeneous effects by skill or gender it focuses on heterogeneity across less and more populated regions. The results could also be relevant for the literature in political economy that tries to understand the regional distribution of the support for populist parties and protectionist policies.

3 Data and stylized facts

In this section I present three related stylized facts documenting differential export participation across employment densities of commuting zones. The underlying firm-level data comes from two datasets provided by the French national statistical institut (INSEE). The Unified Corporate Statistics System (FICUS) contains all French firms wih revenues over 730,00 Euros and reports information on employment, capital, value added, production, and three-digit industry classification collected for tax purposes. It is matched with establishment-level employer-employee data, which indicate the geographical location of each establishment of a given firm year. As is standard in the literature, I use commuting zones (Zones d'emploi) to measure employment density and only focus on metropolitan France. I restrict the sample to manufacturing firms that are only located in one commuting zone allowing a clear spatial assignment. I additionally complement this data with trade variables derived from the the BACI data set (Gaulier and Zignago, 2010) and the gravity dataset provided by Head and Mayer (2014).

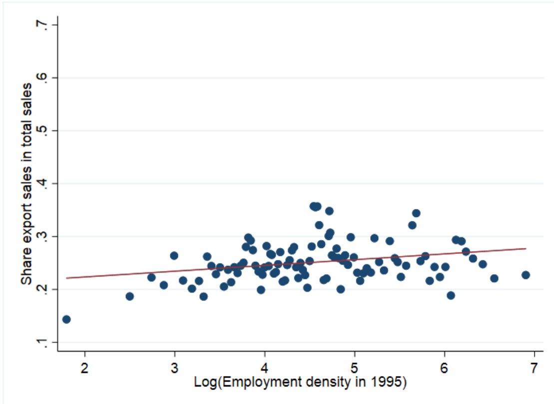
Figure 2a plots the share of export sales in total sales by employment density of commuting zones in 1995, conditional on geographical controls. The positive partial correlation indicates that firms in denser places are more export intensive, suggesting that the firms that are able to expand their activity and grow from trade are overproportionally located in larger cities. Figure 2b plots the same partial correlation now including a four-digit sector fixed effect. The correlation becomes weaker but remains significant, indicating that within-sector heterogeneity across cities contributes to the overall positive correlation (Table 7 in the appendix reports the corresponding regression coefficients). Figure 2c provides evidence on the importance of across sector heterogeneity for the overall correlation between export intensity and density. It plots the average export intensity of sectors located in different commuting zones. The positive correlation indicates that more export intensive sectors are located in larger cities.

Globalization creates unequal employment growth across and within sectors. These stylized facts document that the potential for employment growth from globalization are unequally distributed across more and less densely populated areas. Overall, export intensity is higher in denser places (figure 2a), and this holds true both within sectors (figure 2b) and across sectors (figure 2c). These stylized facts guide the development of a model that features both within and across sector mechanisms to explain the unequal effects of trade across space.

Figure 2: Trade participation across city densities

(a) Aggregate trade participation

(b) Firm trade participation



(c) Sectoral trade participation

The underlying regressions contain dummies the Atlantic and Mediterranean coast, Paris, and the deciles for distance to the Western border. They are run on the firm-level but weighted by sales value. The estimated coefficients corresponding to figures a and b can be found in table 7. The estimated slope for figure c is 0.016***

4 Theory

In this section I develop a multi-sector economic geography model with heterogeneous firms following Gaubert (2018) and integrate it with an international trade model featuring firm heterogeneity and comparative advantage (Bernard et al., 2007). Combining a rich economic geography with an international trade model allows me to capture how firm and sector heterogeneity translate an increase in openness into an increase in regional inequality. There are two countries, Home and Foreign ($k = H, F$), where Foreign can either be thought of the rest of the world or a specific country. In the empirical application I will think of Home as the United States and Foreign as China. I do not introduce any heterogeneity in terms of the economic geography of the two countries and therefore can suppress the country superscripts to ease readability when describing the spatial equilibrium.

4.1 Model setup

4.1.1 Preferences

There is a mass of N identical workers that supply one unit of labour inelastically, consume $h(L_c)$ units of housing and $c(L_c)$ units of the tradable consumption index, where L_c denotes the size of the city a given worker decides to locate in. Workers' preferences are given by:

$$U = \left(\frac{c}{\eta}\right)^{\eta} \left(\frac{h}{1-\eta}\right)^{1-\eta}$$

$$c = \prod_{j=1}^{S} c_j^{\xi_j}$$

$$c_j = \left[\int c_j(i)^{\frac{\sigma_j - 1}{\sigma_j}} di\right]^{\frac{\sigma_j}{\sigma_j - 1}}$$

where $\sum_{j=1}^{S} \xi_j = 1$. Workers maximize their utility subject to the budget constraint $Pc(L_c) + p_H h(L_c) = w(L_c)$, where P is the CES price index of the tradable consumption bundle (c), p_H is the price of housing and the income is given by the wage $w(L_c)$ given inelastic unit labour supply.

4.1.2 Housing and cities

There is a large number of ex-ante identical potential city sites in each country with an immobile amount of land normalized to one ($\gamma = 1$), that is owned by absentee landowners. There are no trade costs between cities within a country.[1]

[1]This assumption is not crucial for any of the results but eases tractability.

Housing is immobile and produced according to the following production function:

$$h^S = \gamma^b \left(\frac{\ell}{1-b} \right)^{1-b} \tag{1}$$

Given the structure on housing demand and supply the equilibrium in the housing market implies that the amount of housing consumed in equilibrium is given by:

$$h(L_c) = (1-\eta)(1-b)L_c^{-b} \tag{2}$$

The amount of housing consumed is smaller in larger cities since the increase in housing production is constrained by the fixed amount of land. If we impose spatial equilibrium, i.e. that utility is equalized across space ($V(p_H, P, w) = \bar{U}$) we can derive the equilibrium wage as a function of city size:

$$w(L_c) = \bar{w}((1-\eta)L_c)^{b\frac{1-\eta}{\eta}} \tag{3}$$

where $\bar{w} = \bar{U}^{\frac{1}{\eta}} P$ is taken as numeraire. The wage increases with city size. This acts as a congestion cost that counterbalances the gains in productivity from agglomeration.

4.1.3 Production

The economy consists of a number of tradable sectors indexed by $j = 1, .., S$. Each sector is populated by a mass of firms that differ in their exogenously given raw efficiency (z). Firms compete according to monopolistic competition and each firm produces a unique variety (i) using the following production technology:

$$y_j(z, L_c) = \psi(z, L_c)k^{\alpha_j}\ell^{1-\alpha_j} \tag{4}$$

where the Hicks-neutral productivity shifter ψ depends on the raw efficiency draw of the firm (z) and the city size the firm locates in (L_c). Sectors are also heterogeneous with respect to the factor share (α_j) of inputs capital (k) and labour(ℓ).

Firm entry and location choice Firm entry closely follows the setup in Melitz (2003). Firms initially pay a sunk market entry cost (f_{E_j}) and draw their raw efficiency z from cumulative distribution function $F_j(z)$. After the realization they decide whether to start producing or to exit immediately. If they decide to produce they choose which city size (L_c) to locate in and whether to only produce for the domestic market, paying per period fixed cost f_{P_j}, or to also export paying per period fixed cost f_{X_j}. Firms die with an exogenous probability δ. In order to match the stylized fact that more productive firms are located in larger cities Gaubert (2018) assumes there is a complementarity between raw efficiency (z) and city size (L_c) such that ex-ante more productive firms increase their productivity by more by location in a larger city. I maintain her assumption that $\psi(z, L_c)$ is strictly log-supermodular in city size (L_c) and firm raw efficiency (z), and is twice differentiable:

$$\frac{\partial^2 log\psi(z, L_c)}{\partial L_c \partial z} > 0$$

In order to ensure a unique solution for the location problem of the firm the additional regularity condition that the elasticity of productivity with respect to city size is decreasing has to be imposed.

Firm problem Firm profits can be decomposed into profits from domestic and exporting activity $\pi = \pi^d + \pi^x$. Conditional on entry the firm maximises both domestic and exporting profits such that the firm problem is given by:

$$\begin{aligned}\max_{k,\ell,p_j^d,p_j^x,L_c,n} \pi_j =&(1+T(L_c))(p_j^d \psi_j(z_i, L_c) k^{\alpha_j} \ell^{1-\alpha_j} - w_H(L_c)\ell - \rho_H k - \bar{c}_j^H f_{P_j}) \\ &+ n(1+T(L_c))(p_j^x \tau_j^{-1} \psi_j(z_i, L_c) k^{\alpha_j} \ell^{1-\alpha_j} - w_H(L_c)\ell - \rho_H k - \bar{c}_j^H f_{X_j})\end{aligned}$$

where $\bar{c}_j^H = \rho^{-\alpha_j} \bar{w}^{1-\alpha_j}$ denotes the non-city size specific marginal costs of firms in sector j. Firms choose optimal factor inputs capital (k) and labour (ℓ), whether to export or not (n), optimal prices for the home market (p_j^d) and the foreign market (p_j^x) (if applicable), and in which city size (L_c) to locate in. $T(L_c)$ is a subsidy proportional to profits paid by city developers to attract firms. Given CES demands and monopolistic competition firms set prices at a constant mark-up over marginal cost. The profit function of a firm that locates in city size L_c is given by:

$$\max_{L_c} \pi_j = \tilde{\kappa}_{1j} \rho_H^{-\tilde{\alpha}_j} (1 + T_j(L_c)) \left(\frac{\psi(z, L_c)}{w_H(L_c)^{1-\alpha_j}} \right)^{\sigma_j - 1} R_j^H P_j^{H^{\sigma_j - 1}} - (1 + T_j(L_c)) \bar{c}_j^H f_{P_j} \\ + n(1 + T_j(L_c)) \left[\tilde{\kappa}_{1j} \rho_H^{-\alpha(\sigma_j - 1)} \left(\frac{\psi(z, L_c)}{w_H(L_c)^{1-\alpha_j}} \right)^{\sigma_j - 1} \tau_j^{1-\sigma_j} R_j^F P_j^{F^{\sigma_j - 1}} - \bar{c}_j^H f_{X_j} \right] \tag{5}$$

where $\tilde{\kappa}_{1j} = \frac{((1-\alpha_j)^{1-\alpha_j} \alpha_j^{\alpha_j} (\sigma_j - 1))^{\sigma_j - 1}}{\sigma_j^{\sigma_j}}$.

4.1.4 City developers

In order to avoid a coordination failure an agent at the city-level is needed that coordinates firms, workers and land-owners. There is one city-developer per potential site that maximizes profits and opens a city of given size if there is a demand for this city size. City-developers earn income through fully taxing the income of land-owners. They pay a subsidy proportional to profits ($T(L_c)$) in order to attract firms and compete according to perfect competition. They solve the following problem:

$$\max_{\{T_j(L_c)\}_{j \in 1,\dots,S}} \Pi_{L_c} = b(1 - \eta) w(L_c) L_c - \sum_{j=1}^{S} \int_z T_j(L_c) \frac{\pi_j(z, L_c)}{1 + T_j^i(L_c)} \mathbb{1}_j(z, L_c) f_j(z) dz \tag{6}$$

where $\pi_H(L_c) = b(1 - \eta) L_c w(L_c)$ is the profit earned by the fully taxed landowners and $\mathbb{1}_j(z, L_c)$ is equal to 1 if firm z chooses to locate in this city and 0 otherwise.

4.2 Definition of the spatial equilibrium

The construction of the spatial equilibrium is qualitatively equivalent to the equilibrium in Gaubert (2018). The spatial equilibrium is given by:

(i) workers maximize utility given prices

(ii) utility is equalised across all inhabited cities

(iii) firms maximize profits given factor prices and the aggregate price index

(iv) landowners maximize profits given prices

(v) city developers maximize profits given the wage schedule and the firm problem

(vi) National capital and international goods market clear, and the housing and the labour market in each city clear

(vii) capital is optimally allocated, and

(viii) firms and city developers earn zero profits.

Since the introduction of international trade does not alter the structure of the equilibrium the existence and uniqueness proof in Gaubert (2018) still applies.

4.3 Constructing the spatial equilibrium

4.3.1 Subsidy

As the city developer problems is not affected by international trade it solves the same problem as in Gaubert (2018) such that the same lemma applies:

Lemma 1 ((Lemma 2 in Gaubert (2018))) *In equilibrium, city developers offer and firms take-up a constant subsidy to firms' profit* $T_j^* = \frac{b(1-\eta)(1-\alpha_j)(\sigma_j-1)}{1-(1-\eta)(1-b)}$ *for firms in sector* j*, irrespective of city size* L_c *or firm type* z*.*

Proof. The proof can be found in appendix C in Gaubert (2018).

4.3.2 Matching function

Whenever there is demand for a given city size, it is profitable for a city developer to open a city of that size. Workers are by the definition of the spatial equilibrium indifferent across locating in different city sizes. Firms are not indifferent across different city sizes as their profits vary with city size. The demand for cities is therefore determined by firms' location decisions. Given the subsidy derived above the variable profit of firms that only serve the domestic market and those that serve both the domestic and the foreign market are given by:

$$\max_{L_c} \pi_j^d = \tilde{\kappa}_{1j} \rho_H^{-\alpha(\sigma_j-1)} (1+T_j^*) \left(\frac{\psi(z, L_c)}{w_H(L)^{1-\alpha_j}} \right)^{\sigma_j-1} R_j^H (P_j^H)^{\sigma_j-1} \tag{7}$$

$$\max_{L_c} \pi_j^{d,x} = \tilde{\kappa}_{1j} \rho_H^{-\alpha(\sigma_j-1)} (1+T_j^*) \left(\frac{\psi(z, L_c)}{w_H(L)^{1-\alpha_j}} \right)^{\sigma_j-1} \left[R_j^H (P_j^H)^{\sigma_j-1} + \tau_j^{1-\sigma_j} R_j^F P_j^{F^{\sigma_j-1}} \right]$$

Note that the resulting first-order conditions only depend on the trade-off between gains from agglomeration ($\psi(z, L_c)$) and congestion costs ($w_H(L_c)$) and is independent of all other general equilibrium quantities. A crucial implication of this separability is that the optimal location decision is the same for exporters and non-exporters. The resulting first order condition that determines the optimal city size to locate in is given by:

$$\frac{\psi_{L_c}(z, L_c)L_c}{\psi(z, L_c)} = (1 - \alpha_j)b\frac{1 - \eta}{\eta}$$

where $\psi_{L_c}(z, L_c) = \partial\psi(z, L_c)/\partial L_c$. This "matching function" ($L^*_{cj}(z)$) implicitly defines L_c as a function of z and therefore matches firms of different productivities to different city sizes for each sector. It accounts for firm and sector heterogeneity and generates spatial sorting across both dimensions. More capital-intensive sectors experience a lower congestion cost which enters scaled by the labour-intensity of production ($1 - \alpha_j$) and the productivity of more efficient firms grows faster with city size due to the assumed complementarity. As the matching function is unaffected by trade it is the same as in the model by Gaubert (2018) and therefore inherits the following properties of that model:

$$L^*_{cj}(z) = \underset{L_c \in \mathcal{L}_c}{\operatorname{argmax}}\, \pi^*_j(z, L_c)$$

The matching function $L^*_c(z)$ is increasing in z such that there is positive assortative matching between firm raw efficiency z and city size L_c and the set of city sizes in equilibrium ($\mathcal{L}$) is efficient (see Gaubert (2018) for a more detailed discussion).

4.3.3 General equilibrium

The general equilibrium has been determined up to the following set of variables: The producitivty cut-offs of entry to the home market (z^{kd}_j) and the export market (z^{kd}_j), where $k \in \{H, F\}$, $m \in \{H, F\}$ and $k \neq m$ denote Home and Foreign and $j = 1, ..., S$ indexes industries, and the sector specific price level (P^k_j); overall expenditure on tradable goods (R^k); the rental rate of capital (ρ_k); and the wage (w_k), where the wage in Home is already pinned down by choosing $\bar{w}$ as the numeraire.

The free entry condition (equation 8) for each sector $j = 1, ..., S$ and country

$k \in \{H, F\}$ is given by:

$$\begin{aligned}\big(f_{E_j} + &(1 - F(z_j^{kd}))f_{P_j} + (1 - F(z_j^{kx}))f_{X_j}\big)\bar{c}_j^k \\ &= \tilde{\kappa_{1j}}\rho_k^{-\tilde{\alpha}_j}\big[R_j^k(P_j^k)^{\sigma_j - 1}S(z_j^{kd}) + \tau_j^{1-\sigma_j}R_j^m(P_j^m)^{\sigma_j-1}S_j(z_j^{kx})\big]\end{aligned} \tag{8}$$

where f_{E_j} is the units of the final good paid as sunk cost of entry, and z_j^{kd} and z_j^{kx} are the raw efficiency cut-offs for entering the domestic and the export market, respectively.

The zero profit cut-off condition for entering the domestic market (equation 9) and the export market (equation 10) in each sector j and country $k \in \{H, F\}$ are given by:

$$\bar{c}_j^k f_{P_j} = \tilde{\kappa_{1j}}\rho_k^{-\tilde{\alpha}_j}R_j^k(P_j^H)^{\sigma_j-1}C_j(z_j^{kd}) \tag{9}$$

$$\bar{c}_j^k f_{X_j} = \tilde{\kappa_{1j}}\rho_k^{-\tilde{\alpha}_j}R_j^m(P_j^m)^{\sigma_j-1}\tau_j^{1-\sigma_j}C_j(z_j^{kx}) \tag{10}$$

where $\tilde{\alpha}_j = \alpha_j(\sigma - 1)$.

The goods market clearing condition (equation 11) and the equilibrium price index (equation 12) for each sector j and country $k \in \{H, F\}$ are given by:

$$R_j^k = \tilde{\kappa_{1j}}\rho_k^{-\tilde{\alpha}_j}M_j^k\big[R_j^k(P_j^k)^{\sigma_j-1}S_j(z_j^{kd}) + R_j^m(P_j^m)^{\sigma_j-1}\tau_j^{1-\sigma_j}S_j(z_j^{kx})\big] \tag{11}$$

$$1 = \tilde{\kappa_{1j}}\sigma_j\big[M_j^k S(z_j^{kd}) + \tau_j^{1-\sigma_j}M_j^m S(z_j^{mx})\big](P_j^k)^{\sigma_j-1} \tag{12}$$

The factor market clearing conditions for capital (equation 13) and labour (equation 14) for each country $k \in \{H, F\}$ is given by:

$$\begin{aligned}\bar{K}_k =& \sum_{j=1}^{S}\tilde{\kappa_{1j}}\rho_k^{-\tilde{\alpha}_j}\frac{(\sigma_j - 1)(\alpha_j)}{\rho_k}M_j^k \\ &\times (R_j^k(P_j^k)^{\sigma_j-1}S_j(z_j^{kd}) + \tau_j^{1-\sigma_j}R_j^m(P_j^m)^{\sigma_j-1}S_j(z_j^{kx}))\end{aligned} \tag{13}$$

$$\begin{aligned}\bar{N}_k =& (1 - b)(1 - \eta)\bar{N}_k + \sum_{j=1}^{S}\tilde{\kappa_{1j}}\rho_k^{-\tilde{\alpha}_j}(\sigma_j - 1)(1 - \alpha_j)M_j^k \\ &\times (R_j^k(P_j^k)^{\sigma_j-1}E_j(z_j^{kd}) + \tau_j^{1-\sigma_j}R_j^m(P_j^m)^{\sigma_j-1}E_j(z_j^{kx}))\end{aligned} \tag{14}$$

where $S(z_j^A), C(z_j^A)$ and $E(z_j^A)$ are normalized values of sectoral sales and employment that are fully determined by the matching function $L^*_{cj}(z)$ for each sector:

$$E_j(z_j^A) = \int_{z_j^A} \mathbb{1}_A(z) \frac{\psi(z, L^*_{cj}(z))^{(\sigma_j - 1)}}{\left[(1-\eta)L^*_{cj}(z)\right]^{\frac{b(1-\eta)(1+(1-\alpha_j)(\sigma_j-1))}{\eta}}} f_j(z)dz$$

$$S_j(z_j^A) = \int_{z_j^A} \mathbb{1}_A(z) \left(\frac{\psi(z, L^*_{cj}(z))}{\left[(1-\eta)L^*_{cj}(z)\right]^{\frac{b(1-\eta)(1-\alpha_j)}{\eta}}} \right)^{\sigma_j - 1} f_j(z)dz$$

$$C_j(z_j^A) = \left(\frac{\psi(z_j^A, L^*_{cj}(z_j^A))}{\left((1-\eta)L^*_{cj}(z_j^A)\right)^{\frac{b(1-\eta)(1-alpha_j)}{\eta}}} \right)^{\sigma_j - 1}$$

where $A = d, x$ distinguishes between the domestic market and the export market and $\mathbb{1}_A(z)$ is equal to one if a firm with raw efficiency level z serves market A. Note that the sector-specific expenditure $R_j^k = \xi_j^k R^k$ is fully determined by R^k.

4.3.4 City size distribution

The equilibrium city size distribution is jointly determined by the matching function as determined by the firm problem and the city developers problem. Given the labour market clearing condition, the population living in a city of size L_c or smaller must equal the labour demand of all firms located in these city sizes and employment in construction:

$$\int_{L_{min}}^{L_c} u f_{L_c}(u)du = \sum_{j=1}^{S} M_j \int_{z_j^*(L_{min})}^{z_j^*(L_c)} \ell_j(z, L^*_{cj}(z)) f(z_j) dz_j + (1-\eta)(1-b) \int_{L_{min}}^{L_c} u f_{L_c}(u)du$$

where $L_{min} = inf(\mathcal{L})$ is the smallest city size in equilibrium. Differentiating this yields the city size density function:

$$f_{L_c}(L_c) = \kappa_4 \frac{\sum_{j=1}^{S} M_j \mathbb{1}_j(L) \ell_j(z_j^*(L_c)) f_j(z_j^*(L_c)) \frac{dz_j^*(L_c)}{dL_c}}{L_c}$$

where $\kappa_4 = \frac{1}{1-(1-\eta)(1-b)}$ and $\mathbb{1}_j(L_c)$ indicates whether firms of sector j are located in city size L_c or not.

4.4 Equilibrium properties

I use this model to study the effects of trade on the spatial concentration of economic activity. To simplify the analysis and to closely identify the mechanisms linking trade openness to regional inequality, I study the effects of within- and across-industry trade separately in different versions of the model.

4.4.1 Within-industry trade

To isolate the effect of within-industry trade on the city size distribution and therefore the spatial concentration of the economy I focus on the symmetric country case which does not feature any across-sector reallocations.

Proposition 1 *If both countries are symmetric, the city size distribution in the open economy first-order stochastically dominates the city size distribution in the closed economy.*

In the symmetric country case trade only happens within industries such that it does not induce any across-industry reallocations. Across firms within an industry trade induces a reallocation of market share and employment from less to more productive firms as in the standard Melitz model. Note that given the log-supermodularity of productivity and optimal firm behaviour the real productivity (productivity net of congestion cost) increases with city size. Hence, the reallocation from less to more productive firms implies a reallocation from small to larger cities for each sector j. The less productive firms that exit and shrink are located in smaller cities and the more productive firms that expand employment are located in larger cities. This spatial reallocation leads to a higher spatial concentration of sectoral employment in larger cities, in fact the spatial distribution of employment in sector j in the open economy first-order stochastically dominates the distribution of employment in the closed economy. Since this holds for all sectors the overall city size distribution shifts to the right.[2] In the open economy equilibrium, since more productive firms are located in larger cities and exporters, the export intensity is higher in larger cities in line with the stylized fact from figure 2b.

[2] A more technical discussion can be found in the online appendix.

4.4.2 Across-industry trade

To isolate the effects of across industry trade it is useful to put some bounds on the heterogeneity in the model. In particular, I analyse a version of the model wwhere differences in factor intensity are the only heterogeneity across sectors and firms are homogeneous:

Proposition 2 *In a two sector version of the model where factor intensity is the only heterogeneity across sectors and with no heterogeneity in raw-efficiencies, if the other country is relatively labour-abundant, then the city size distribution in the open economy first-order stochastically dominates the city size distribution in the closed economy.*

Opening up to trade implies a fall in the relative price of capital from cost minimization and factor market clearing. This leads to a rise in the share of both factors employed in the capital intensive industry. Since factor endowments remain unchanged employment in the capital-intensive sector increases while employment in the labour-intensive sector decreases. In spatial equilibrium more capital-intensive sectors are located in larger cities, as they are less affected by the congestion cost which is scaled by the labour intensity of production. In this version of the model the distribution of employment across city size in the capital-intensive sector first-order stochastically dominates the distribution in the labour-intensive sector. Hence, the reallocation of employment to the capital-intensive sector implies a reallocation of employment to the larger cities such that the distribution of population in the open economy first-order stochastically dominates the distribution in the closed economy. Therefore endowment-driven across-industry trade leads to spatial concentration in countries that have a comparative advantage in capital-intensive industries.[3] In the open economy equilibrium the export sector is located in larger cities in line with the stylized fact that more export intensive sectors are located in larger cities (see figure 2c)

A similar logic applies if we think about a world that uses unskilled and skilled labour in production rather than capital and labour. In this world it is sensible to assume that advanced economies have a comparative advantage in industries that use skilled labour intensively. Empirically, these are located in larger cities (Davis and Dingel, 2015) and in the model they would locate in larger cities if

[3] A more technical discussion can be found in the online apendix.

the relative price of skilled labour decreases with city size which is in line with empirical evidence (Bernard et al., 2008). Alternatively, this location pattern could be modelled based on differences in the gains from agglomeration between high- and low-skilled labour as done by Davis and Dingel (2015) rather than differences in relative wages. However, the model based on relative factor prices is isomorphic to the one based on differences in the strength of agglomeration with respect to trade-induced across-industry reallocations.

4.5 Comparative statics

Moving from autarky to a costly trade equilibrium is a very drastic change in trade openness and rarely observed in the data. Changes in trade openness τ_j provide a more realistic testing ground for the predictions of the model. In the within-industry version of the model a reduction in trade costs leads to differential effects on firm sales for firms located in smaller and larger cities. In particular, firms below the export productivity cut-off, located in smaller cities, will loose revenue relative to exporting firms located in larger cities:

$$\begin{aligned} \frac{\partial log(r_{icj}(z))}{\partial(\tau_j^{-1})} \leq 0 \qquad \text{if} \qquad z_{icj}(L) < z_j^x \iff L_c < L_{cj}(z_{ij}^x) \\ \frac{\partial log(r_{icj}(z))}{\partial(\tau_j^{-1})} > 0 \qquad \text{if} \qquad z_{icj}(L) < z_j^x \iff L_c > L_{cj}(z_{ij}^x) \end{aligned} \tag{15}$$

We get a similar comparative static for the across-sector version of the model, where the exporting sector, located in larger cities, is going to expand sales following a decrease in trade costs, such that sales originating from sectors located in larger cities will increase:

$$\frac{\partial log(r_c)}{\partial(\tau^{-1})} \begin{cases} < 0 & \text{if} \quad \alpha_j < \alpha^C \iff L_{cj} < L_c^C \\ > 0 & \text{if} \quad \alpha_j > \alpha^C \iff L_{cj} > L_c^C \end{cases} \tag{16}$$

5 Regression analysis

5.1 Estimation

So far we have highlighted how an increase in either within or across industry trade increases the spatial concentration of economic activity in simplified versions of the model. Hence, the model can replicate the cross-country evidence from figure 1 and reproduces the stylized facts presented in section 3. To provide a more rigorours test of the model mechanisms I test the model comparative statics using exogenous changes in market access following Redding and Venables (2004) using the BACI database and the gravity dataset provided by Head and Mayer (2010). I calculate changes in market access exogenous to French firms following Hering and Poncet (2010). I first estimate a standard gravity equation separately for each sector using all countries except France for the period 1995 - 2015.

$$\begin{aligned} log(x_{odt}) =& \gamma_{ot} + \delta_{dt} + \alpha_1 log(dist_{od}) + \alpha_2 \mathbb{1}[contig_{od}] + \alpha_3 \mathbb{1}[lang_{od}] + \alpha_4 \mathbb{1}[col_{od}] \\ &+ \alpha_5 \mathbb{1}[EU_{od}] + \alpha_6 \mathbb{1}[FTA_{od}] + \varepsilon_{odt} \end{aligned} \tag{17}$$

where o and d indicate origin and destination country. γ_{ot} and δ_{dt} are time-varying importer and exporter fixed effects. $dist_{od}$ is the population weighted distance between origin and destination. $\mathbb{1}[contig_{od}]$, $\mathbb{1}[lang_{od}]$, $\mathbb{1}[col_{od}]$, $\mathbb{1}[EU_{od}]$ and $\mathbb{1}[FTA_{od}]$ are a set of dummies indicating whether the origin and destination country are on the same landmass, share a language, were in a colonial relationship, are both members of the EU and have an FTA, respectively. Based on the estimates from these regressions I define the market access of a French sector j at time t (MA_{FRjt}) as:

$$\begin{aligned} MA_{FRjt} = \sum_d dist_{FRdjt}^{\hat{\alpha}_1} exp(\hat{\delta}_{djt}) exp(&\hat{\alpha}_2 \mathbb{1}[contig_{FRd}] + \hat{\alpha}_3 \mathbb{1}[lang_{FRd}] \\ &+ \hat{\alpha}_4 \mathbb{1}[col_{FRd}] + \hat{\alpha}_5 \mathbb{1}[EU_{FRd}] + \hat{\alpha}_6 \mathbb{1}[FTA_{FRd}]) \end{aligned} \tag{18}$$

Equipped with these measures of exogenous export opportunities I test the comparative statics of the model. The model equation 15 predicts that the effect of trade liberalization should be more positive for firms located in denser cities which, assuming that this interaction between city density and trade liberalization is well approximated using a linear term, can be mapped into a regression framework:

$$\begin{aligned} \Delta log(r_{ijt}) = \beta_{f0} + \beta_{f1} \Delta log(MA_{jt}) + \beta_{f2} log(dens_c) \\ + \beta_{f3} \left[\Delta log(MA_{jt}) \times log(dens_c) \right] + X_c' \gamma_f + \varepsilon_{ijt} \end{aligned} \tag{19}$$

where the model predicts $\beta_{f1} > 0$ and $\beta_{f3} > 0$. Since this prediction holds both on the firm as well as on the city level I run both an unweighted regression and one that is weighted by initial firm sales, and hence tests the prediction in dollar terms on the city level. Note that the model does not provide any guidance whether employment size or density is the correct measure, as they are isomorphic. I follow the previous literature (e.g. Combes et al. (2012)) and use employment density in the regressions rather than population size. I also control for a vector of geographic characteristics including a dummy for Paris, the Atlantic and Mediteranean coast, and individual deciles for distance to the Western border, since geography is and important determinant of trade activity, while not explicitly modelled.

The sector-level mechanism (equation 16) can be mapped into a regression framework in a similar fashion yielding:

$$\begin{aligned} \Delta log(r_c) = \beta_{s0} + \beta_{s1}\Delta log(MA_{ct}) + \beta_{s2}log(dens_c) \\ + \beta_{s3}\left[\Delta log(MA_{ct}) \times log(dens_c)\right] + X_c'\gamma_s + \varepsilon_{ct} \end{aligned} \quad (20)$$

where $\Delta log(r_c)$ and $\Delta log(MA_{ct})$ are the average change in revenue and market access for sectors located in c and X_c contains the same set of geogaphical controls as above. The model predicts that $\beta_{s1} \geq 0$ and $\beta_{s3} > 3$. More export opportunities for the average manufacturing sector in city c should increase revenues and more so in denser cities, where the export-intensive industries are located. The model that generates this prediction abstracts from firm heterogeneity so to be consistent with the model the change in the average revenue has to be defined abstracting from firm sorting and solely rely on industry-level variation in the change of sales:

$$\Delta log(r_c) = \sum_j \frac{r_{cj}}{r_c} \Delta log(r_j)$$

Note that this measure does not calculate the actual average change in sectoral sales in location c which had to be based on $\Delta log(r_{cj})$ rather than $\Delta log(r_j)$. Instead it calculates the hypothetical change in average sales only based on sectoral sorting in space in the absence of firm sorting. Analogously average market access is defined as:

$$\Delta log(MA_c) = \sum_j \frac{r_{cj}}{r_c} \Delta log(MA_j)$$

5.2 Results

The main results for the firm-level mechanism (equation 20) are displayed in tables 1 and 2. Table 1 presents results using a long difference from 1995 to 2015 and table 2 presents stacked short 5-year differences.[4] The results are in line with the predictions of the model across weighted and unweighted specifications. An increase in export opportunities increases firm sales and does significantly more so for firms located in denser cities.

Table 1: Firm-level mechanism (short-run)

	Δ_5 log(sales)			
	Unweighted		Sales weighted	
Δ_5 log(MA)	0.070**	0.068**	0.063	0.153
	(0.0356)	(0.0344)	(0.0439)	(0.0408)
Δ_5 log(MA) × log(dens emp)		0.021**		0.022**
		(0.0088)		(0.0104)
log(emp dens)		-0.003*		-0.008***
		(0.0014)		(0.0020)
Year FE	Yes	Yes	Yes	Yes
Observations	279226	279226	279226	279226
Pseudo R^2	0.01	0.01	0.01	0.02

Controls for Atl. coast dummy, Med. coast dummy, West border distance deciles and Paris dummy

^{c} p<0.10, ** p<0.05, *** p<0.01. Standard errors in parentheses.

The main results for the sector-level mechanism (equation 20) are presented in table 3. In line with the predictions of the model I find that an increase in average market access increases sales of the average sector across commuting zones. This positive association of market access with sales is stronger in denser places, indicating that the industries located in denser places are more able to take advantage of the export opportunities.

Both the firm- and the sector-level mechanism find support in the data. When

[4]In principal a long-difference is preferable as the model is based on long-run changes in equilibrium rather than short-run dynamics but given the high rate of firm attrition I present both results.

Table 2: Firm-level mechanism (long-run)

	Δ_{20} log(sales)			
	Unweighted		Sales weighted	
Δ_{20} log(MA)	0.003	0.007	0.053	0.064
	(0.0454)	(0.0395)	(0.0512)	(0.0430)
Δ_{20} log(MA)		0.043***		0.058***
× log(dens emp)		(0.0144)		(0.0168)
log(emp dens)		-0.007		-0.016
		(0.0084)		(0.0132)
Observations	23355	23355	23355	23355
Pseudo R^2	0.00	0.01	0.00	0.03

Controls for Atl. coast dummy, Med. coast dummy, West border distance deciles and Paris dummy

^{c} p<0.10, ** p<0.05, *** p<0.01. Standard errors clustered at the sector-year level in parentheses.

Table 3: Sector-level mechanism

	Δ_{20} log(sales)			
	Unweighted		Sales weighted	
Δ_{20} log(MA)	0.58***	0.75***	0.66***	0.72***
	(0.129)	(0.145)	(0.175)	(0.166)
Δ_{20} log(MA)		0.26***		0.44***
× log(dens emp)		(0.093)		(0.113)
log(emp dens)	-0.03***	-0.02***	-0.04***	-0.02**
	(0.007)	(0.006)	(0.014)	(0.010)
Observations	352	352	352	352
Pseudo R^2	0.22	0.24	0.24	0.30

Controls for Atl. coast dummy, Med. coast dummy, West border distance deciles and Paris dummy

^{c} p<0.10, ** p<0.05, *** p<0.01. Standard errors in parentheses.

comparing the magnitudes of the coeffecients the firm-level mechanism is consistently more important across the specifications when it comes to the heterogeneity across locations (see table 2 and 3). The within-industry channel benefits larger cities relatively more than the across-industry channel. This stresses the importance of firm heterogeneity for the spatial implications of globaliation relative to sector heterogeneity.

We have validated the macro predictions of the model relating to the reallocation of economic activity from smaller to larger cities due to increasing globalization. The next step is to test the micro mechanisms that drive these macro predictions. The firm-level reallocation is driven by productivity differences in the model and could alternatively also be driven by differences in variable (τ_j) or fixed (f_{xj}) trade costs. The across sector heterogeneity is driven by differences in input intensity across sectors but could also be driven by heterogeneous trade costs across locations. Testing these micro mechanisms is currently ongoing work.

6 Additional evidence from Chinese import competition in the US

6.1 Data

To provide some further evidence on the model predictions I test them on data from the United States using the increase in import competition from China between 1991 and 2007 as an exogenous shock. In my empirical strategy, as well as the data and definitions used, I closely follow the previous literature (Autor et al., 2013, Acemoglu et al., 2016). Throughout the paper I present results estimated on the stacked sub-periods 1991 to 1999 and 1999 to 2007.

Trade data I use the data on sectoral trade flows that were used and provided by Acemoglu et al. (2016) and Feenstra et al. (2017). They provide trade flows for 392 manufacturing and industries at the 4-digit SIC code level. The data of trade flows was originally downloaded form comtrade and subsequently transformed into real 2007 dollars.[5]

Employment data To get data on the employment of industry j in commuting zone c I follow the approach by Autor et al. (2013). I obtain data on local industry composition in 1991, 1999 and 2007 from the County Business Patterns (CBP). The CBP provides information on employment, payroll and firm-size distribution by county and industry. In order to avoid disclosure some establishments are

[5]A more detailed discussion on the preparation of the trade data can be found in Acemoglu et al. (2016).

not identified at the most disaggregated level and sometimes employment is only reported as an interval rather than a number. I use the algorithm developed by Autor et al. (2013) to impute employment by county and 4-digit SIC code. I then aggregate this data to the commuting zone level using cross-walks provided by David Dorn.[6] The detailed procedure of the algorithm is outlined in the online appendix in Autor et al. (2013). This gives a panel of observations at the industry-commuting zone level for 722 commuting zones and 392 industries for two periods.

While the main regressions are run on the industry-commuting zone level, for some robustness checks that require wage data not available on the industry-commuting zone level I use data at the commuting zone level provided by Autor et al. (2013). This dataset consists of commuting zone specific import competition shocks, and changes in wages and employment for the periods 1990 to 2000 and 2000 to 2007.

6.2 Estimation

There are two main differences between the specifications run on the US data relative to the previous analysis. Firstly, I study the effect of an import competition shock rather than export opportunity shock complementing the earlier analysis. Secondly, given data contraints and the customs of the literature on the China Shock I rely on different variables. Firstly, I use employment rather than sales as outcome and weighting variable following the earlier literature on the China Shock. Secondly, given the data availability I use population size rather than density for the interaction term, which is also in line with the theory. Thirdly, since I only have regional rather than firm-level data I estimate the firm-level mechanism only on the region and not on the firm level.

6.2.1 Within-industry trade and firm heterogeneity

To test the model predictions I estimate an empirical counterpart to equation (15). Analogous to equation 19 I impose a linear interaction between city size and the trade shock and estimate the following equation:

$$\Delta L_{cjt} = \beta_0 + \beta_1 \Delta Imp_{jt} + \beta_2 L_{ct} + \beta_3 \left[\Delta Imp_{jt} \times L_{ct}\right] + \epsilon_{cjt} \tag{21}$$

[6] These cross-walks can be found at www.ddorn.net/data.htm

where ΔL_{cjt} is the log change in employment in commuting zone c in sector j in period t multiplied by 100. ΔImp_{jt} denotes the change in imports from China in sector j and L_{ct} denotes the population in commuting zone c at the beginning of period t. The regressions are weighted by initial employment in each industry-commuting zone cell and standard errors are clustered at the three digit SIC level. The intuition outlined above predicts that $\beta_1 < 0$ and $\beta_3 > 0$. I estimate these equations using a 2SLS approach instrumenting endogenous trade flows from China to the US ($\Delta Imp_{jt}^{US,Ch}$) with trade flows from China to other advanced economies ($\Delta Imp_{jt}^{Ot,Ch}$) as in Acemoglu et al. (2016). The variables are defined as follows:

$$\Delta Imp_{jt}^{US,Ch} = \frac{\Delta M_{jt}^{US,Ch}}{Y_{j91} + M_{j91} - E_{j91}}$$
$$\Delta Imp_{jt}^{Ot,Ch} = \frac{\Delta M_{jt}^{Ot,Ch}}{Y_{j88} + M_{j88} - E_{j88}}$$

Import flows (ΔM_{jt}) are normalized by apparent consumption (production (Y) plus imports (M) minus exports (E)) at the beginning of the period, and before the period for the instrument, to avoid introducing any endogeneity through anticipation effects.

Results The main results are presented in Table 4.[7] The first column corroborates that the aggregate effect of an import competition shock is still negative when splitting industries into industry-commuting zone cells. Including the interaction term in column 2 yields an estimate of 1.23 which is statistically significant at the 1% level. The resulting coefficients remain highly statistically significant and the point estimate is 0.94 when controlling for regional and sectoral trends. So a one percentage point rise in industry import penetration reduces industry level employment by around three percentage points in a commuting zone with a population of a log point above the mean, while it reduces it by four percentage points in a mean-sized commuting zone.

While this evidence is in line with the predictions of the model that an import competition shock translates into a more negative labour demand shock in less populated commuting zones because of the spatial sorting of heterogeneous firms, it is also consistent with other mechanisms. The most apparent alternative explanation is based on variation in the labour supply elasticity across different city

[7] The corresponding first stage regressions can be found in Table 9 and 10 in the appendix

Table 4: FIRM-LEVEL MECHANISM: Imports from China and changes in manufacturing employment across different city sizes within an industry

	ΔL_{cj}	ΔL_{cj}	ΔL_{cj}	ΔL_{cj}
$\Delta Imp_j^{US,Ch}$	-2.77***	-6.20***	-4.03***	-3.99***
	(0.836)	(1.736)	(1.271)	(1.257)
$\Delta Imp_j^{US,Ch} \times ln(pop_c)$		1.23***	0.96***	0.94***
		(0.364)	(0.274)	(0.268)
$ln(pop_c)$		1.08***	1.35***	1.30***
		(0.245)	(0.218)	(0.208)
Time FE	Yes	Yes	Yes	Yes
Region FE	No	No	No	Yes
Industry FE (4d)	No	No	Yes	Yes
Observations	129116	129116	129116	129116
Pseudo R^2	0.02	0.04	0.20	0.20
AP F-statistic ΔImp	99.63	69.87	73.64	73.75
AP F-statistic IA	.	125.06	106.49	106.30

Note: Robust standard errors clustered at the three digit SIC level are reported in parenthesis. The regressions include fixed effects for ten sub-sectors within manufacturing and eight census regions. Regressions are weighted by initial employment in each sector-commuting zone cell. The sample includes 392 manufacturing industries in 722 commuting zones for the periods 1991 - 1999 and 1999 - 2007 that are stacked in the estimation. The population variable is demeaned such that $\Delta Imp_j^{US,Ch}$ is the effect of an import competition shock for the mean-sized commuting zone. Stars indicate significance levels the following levels *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

sizes as identified by Brülhart et al. (2015) for border towns in Austria. The empirical pattern of relative changes in employment could be generated from a uniform labour demand shock across city sizes if the labour supply elasticity was decreasing with city size. While the demand and the supply-driven explanations have identical implications for changes in employment, they have different implications for wages. A supply-driven model suggests that the effect of an import competition shock on wages would be less negative in smaller cities and more negative in larger cities. The demand driven mechanism in my model on the other hand predicts that the effect on wages should also be smaller in bigger cities or equal across city sizes depending on the elasticity of labour supply, which is constant across city sizes.

I use these differentiating predictions on changes in the wage in order to empirically rule out the labour supply driven explanation. Unfortunately, I cannot use the CBP data to do this as, due to the omissions in the data, I cannot obtain a credible average wage on the sector-commuting zone level. Instead, I rely on the wage data from the Census Integrated Public Use Micro Samples (Ruggles et al., 2017) to generate an average wage on the commuting zone level. Since census data is not available for every year before 2000 I adjust the periods to 1990 - 2000 and 2000 - 2007. In particular, I use the dataset developed by Autor et al. (2013) that provide changes in employment and wages at the commuting zone level as well changes in Chinese import competition shocks at the commuting zone level, which are defined as follows:

$$\Delta Imp^{US}_{ct} = \sum_j \frac{L_{cjt}}{L_{ct}} \frac{\Delta M^{US,Ch}_{jt}}{L_{jt}}$$

$$\Delta Imp^{Ot}_{ct} = \sum_j \frac{L_{cjt}}{L_{ct}} \frac{\Delta M^{Ot,Ch}_{jt}}{L_{jt-1}}$$

I run their baseline regression augmented with an interaction term between the import competition shock and the initial population in the commuting zone:

$$\Delta y_{ct} = \beta_0 + \beta_1 \Delta Imp^{US}_{ct} + \beta_2 L_{ct} + \beta_3 \left[\Delta Imp_{ct} \times L_{ct}\right] + \beta_4 \mathbf{X} + \varepsilon_{1cjt} \qquad (22)$$

Since there is not sufficient variation in the logged population variable to identify both first stages separately, I estimate equation (22) using a control function approach as well as using 2SLS. The results are qualitatively the same for both estimation procedures.

The main results based on the control function approach are presented in Table 8.[8] The regressions on employment corroborate the earlier findings that the employment effect of an import competition shock are larger in smaller cities even when reducing the amount of identifying variation by aggregating across industries. The regressions on changes in the average wage suggest that the effect on wages only varies marginally with city size and if anything the effect is less negative in larger cities. This is in line with the labour demand driven mechanism suggested by the model and evidence against a supply-based explanation.

6.2.2 Across-industry trade and comparative advantage

The spatial sorting of sectors across regions, driven by the factor intensity of their input use affects intensity with which an average sector in a commuting zone reacts to an increase in import competition driven by a fall in trade costs. Analogously to the market access shock we get the following estimating equation:

$$\Delta log(L_c) = \beta_0 + \beta_1 L_{ct} + \beta_2 \Delta Imp_{ct}^{US,Ch} + \beta_2 \left[\Delta Imp_{ct}^{US,Ch} \times L_{ct}\right] + \delta_r + \varepsilon_{ct} \quad (23)$$

where $\Delta I\hat{m}p_{ct}$ is a measure of changes in import competition, L_{ct} is the log population size of commuting zone c at the beginning of the period and δ_r are regional fixed effects to control for geographic features. I define the change in employment only based on sectoral rather than local changes as above and define the average import competition shock at the commuting zone level following Acemoglu et al. (2016):

$$\Delta log(L_c) = \sum_j \frac{L_{cj}}{L_c} \Delta log(L_j)$$

$$\Delta Imp_{ct}^{Ot} = \sum_j \frac{L_{cjt}}{L_{ct}} \frac{\Delta M_{jt}^{Ot,Ch}}{L_{jt-1}}$$

The main results are reported in Table 5. The results are highly statistically significant across all specifications and indicate that sectors located in more pop-

[8] The results using a 2SLS approach using either log population or absolute population as interaction can be found in table 11 and 12 in the appendix. The results are in line with those from the control function approach.

ulated region experience a smaller decline in employment from the rise in Chinese exports to other countries.

Table 5: Industry-level mechanism

	$\Delta log(L_c)$	
ΔImp_c	-0.26***	-0.23***
	(0.026)	(0.027)
$ln(pop_c)$	-0.01**	-0.01***
	(0.004)	(0.003)
$\Delta Imp_c \times ln(pop_c)$	0.02**	0.02**
	(0.008)	(0.007)
Time FE	Yes	Yes
Region FE	No	Yes
Observations	1444	1444
Pseudo R^2	0.74	0.77

Note: Robust standard errors clustered at the commuting zone level in parenthesis. Regional fixed effects for eight regions within the US. Regressions are weighted by initial employment in each commuting zone. The sample includes 722 commuting zones for the periods 1991 - 1999 and 1999 - 2007 that are stacked in the estimation. The population variable is demeaned such that the constants represent the mean trade shocks for different time periods. Stars indicate significance levels the following levels *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

I find support for both the firm and the industry mechanism propsed by the model in the US data. In line with the results for France the firm-level mechanism seems to be quantitatively more impoarten.

7 Conclusion

This paper documented a positive correlation between international economic integration and regional inequality within advanced economies. I also present three related stylized facts documenting higher trade participation in larger cities, which is both due to a within-sector and an across-sector margin. To microfound this aggregate correlation and the stylized facts I propose an economic geography model of spatial sorting of heterogeneous firms and heterogeneous sectors across different city sizes that features an open economy equilibrium with trade due to firm heterogeneity and endowment-driven comparative advantage. The model provides two mechanisms that microfound the aggregate correlation, one on the firm level and one on the industry level. Firstly, within-industry trade reallocates market share and employment from less to more productive firms, since these more productive firms benefit more from agglomeration externalities, they are relatively located in larger cities. Hence, in the model this reallocation increases spatial concentration. Secondly, specialization due to endowment-driven comparative advantage increases employment in capital and skill-intensive sectors for advanced economies. Capital-intensive sectors are relatively located more in larger cities as the relative price of capital to labour decreases with city size. Hence, in the model this reallocation increases spatial concentration.

I find support for both mechanisms using exogenous changes in export market access for French firms for identification. Firstly, firms located in larger cities increases sales more following an increase in export market access. Secondly, sectors located in larger cities increase sales by more than those located in smaller cities. I additionally test the model predictions empirically using the rise in Chinese import competition for the United States. I find strong support for both mechanisms in this context as well. Comparing them quantitatively the firm-level mechanism turns out to be larger than the industry-level mechanism. This suggests that the effect of trade on regional inequality does not only come from trading with countries, such as China, that differ in their comparative advantage, but also European countries with whom most US trade happens within industries.

In ongoing work I am testing the micro mechanisms underlying these predictions. An additional implication of the model that could be explored in future more structural work is that we overestimate the welfare effects of trade as long as we ignore its spatial implications. Estimating the gains from trade based on changes in tradables production and productivity alone does not account for the welfare losses due to the increase in congestion costs caused by increased spatial concentration.

This paper has provided causal evidence for two different theoretical mechanisms that international integration increases regional inequality and spatial concentration in advanced economies. While the previous literature has provided ample evidence for important distributional effects of trade across different skill groups, regional heterogeneity has been much less studied. These findings have important policy implications as they provide an additional margin for redistribution if the government aims to redistribute the aggregate gains from trade.

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A Additional Tables and Figures

Table 6: CROSS COUNTRY CORRELATION BETWEEN TRADE OPENNESS AND REGIONAL INEQUALITY/SPATIAL CONCENTRATION

	Regional inequality	
	Unweighted	Weighted by population
Openness	0.03***	0.04**
	(0.011)	(0.021)
Year FE	Yes	Yes
Country FE	Yes	Yes
Observations	359	351
Pseudo R^2	0.95	0.91

Note: Robust standard errors clustered by country and year in parenthesis. The sample is an unbalanced panel of 26 countries for the period 1999 to 2014. Stars indicate significance levels the following levels *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 7: Regressions corresponding to the stylized facts displayed in figures 2a and 2b

	Share of export sales			
	Unweighted		Weighted (firm sales)	
log(emp dens)	0.004***	0.003*	0.025***	0.011**
	(0.0011)	(0.0014)	(0.0078)	(0.0039)
Year FE	Yes	Yes	Yes	Yes
Industry FE	No	Yes	No	Yes
Observations	2646998	2646998	2646998	2646998
Pseudo R^2	0.01	0.11	0.04	0.33

Controls: Dummies for Atlantic and Mediterranean coast, and Paris
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses.

Table 8: Wage and employment regressions on the commuting zone level

	ΔL_c	Δw_c	ΔL_c	Δw_c	ΔL_c	Δw_c	ΔL_c	Δw_c
$\Delta Imp_c^{US,Ch}$	-0.7***	-0.7***	-4.5**	-1.3	-4.7**	-1.7	-3.9**	-1.7
	(0.10)	(0.24)	(1.93)	(1.25)	(2.10)	(1.26)	(1.71)	(1.59)
$\Delta Imp_c^{US,Ch} \times ln(pop_c)$			0.3**	0.1	0.3*	0.1	0.3*	0.1
			(0.15)	(0.11)	(0.17)	(0.11)	(0.14)	(0.14)
$ln(pop_c)$	-0.2**	-0.3	-0.8***	-0.4	-0.8***	-0.2	-1.0**	-0.8
	(0.09)	(0.16)	(0.30)	(0.35)	(0.28)	(0.34)	(0.40)	(0.74)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region FE	No	No	No	No	Yes	Yes	Yes	Yes
Additional controls	No	No	No	No	No	No	Yes	Yes
FS residual	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1444	1444	1444	1444	1444	1444	1444	1444
Pseudo R^2	0.13	0.50	0.19	0.50	0.22	0.54	0.41	0.58

Note: Robust standard errors clustered at the three digit SIC level are reported in parenthesis. The regressions are estimated using the control function approach include fixed effects for eight census regions. Regressions are weighted by initial employment in each commuting zone. The sample includes 722 commuting zones for the periods 1990 - 2000 and 2000 - 2007 that are stacked in the estimation. The population variable is demeaned such that $\Delta Imp_j^{US,Ch}$ is the effect of an import competition shock for the mean-sized commuting zone. Additional controls for the sectoral and demographic composition are included in some specifications. Stars indicate significance levels the following levels *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 9: First stage regressions of the trade shock coefficient corresponding to table 4

	$\Delta Imp_j^{US,Ch}$	$\Delta Imp_j^{US,Ch}$	$\Delta Imp_j^{US,Ch}$	$\Delta Imp_j^{US,Ch}$	$\Delta Imp_j^{US,Ch}$	$\Delta Imp_j^{US,Ch}$	$\Delta Imp_j^{US,Ch}$
$\Delta Imp_j^{Ot,Ch}$	1.22***	1.13***	1.11***	1.11***	1.21***	1.21***	1.21***
	(0.123)	(0.137)	(0.135)	(0.134)	(0.103)	(0.142)	(0.142)
$\Delta Imp_j^{Ot,Ch}$							
$\times log(pop_c)$		0.03	0.03	0.03	0.02	0.02*	0.02*
		(0.022)	(0.021)	(0.021)	(0.011)	(0.009)	(0.009)
$ln(pop_c)$		-0.01	-0.00	0.01	-0.00	-0.00	-0.00
		(0.008)	(0.008)	(0.011)	(0.005)	(0.003)	(0.003)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sub-sector FE	No	No	Yes	Yes	No	No	No
Region FE	No	No	No	Yes	No	No	Yes
Industry FE (3d)	No	No	No	No	Yes	No	No
Industry FE (4d)	No	No	No	No	No	Yes	Yes
Observations	129116	129116	129116	129116	129116	129116	129116
Pseudo R^2	0.63	0.63	0.65	0.65	0.79	0.88	0.88

Note: Robust standard errors clustered at the three digit SIC level are reported in parenthesis. The regressions include fixed effects for ten sub-sectors within manufacturing and eight census regions. Regressions are weighted by initial employment in each sector-commuting zone cell. The sample includes 392 manufacturing industries in 722 commuting zones for the periods 1991 - 1999 and 1999 - 2007 that are stacked in the estimation. The population variable is demeaned such that $\Delta Imp_j^{US,Ch}$ is the effect of an import competition shock for the mean-sized commuting zone. Stars indicate significance levels the following levels *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 10: First stage regressions of the trade shock coefficient corresponding to table 4

	$\Delta Imp_j^{US,Ch} \times ln(pop_c)$	$\Delta Imp_j^{US,Ch} \times ln(pop_c)$	$\Delta Imp_j^{US,Ch} \times ln(pop_c)$	$\Delta Imp_j^{US,Ch} \times ln(pop_c)$	$\Delta Imp_j^{US,Ch} \times ln(pop_c)$
$\Delta Imp_j^{Ot,Ch}$	-0.03	-0.10	-0.09	0.14	0.17
	(0.106)	(0.123)	(0.123)	(0.230)	(0.317)
$\Delta Imp_j^{Ot,Ch}$ $\times log(pop_c)$	1.26***	1.26***	1.26***	1.23***	1.22***
	(0.125)	(0.126)	(0.126)	(0.128)	(0.125)
$ln(pop_c)$	0.08**	0.09*	0.11**	0.10**	0.09**
	(0.038)	(0.048)	(0.050)	(0.048)	(0.046)
Time FE	Yes	Yes	Yes	Yes	Yes
Sub-sector FE	No	Yes	Yes	No	No
Region FE	No	No	Yes	No	No
Industry FE (3d)	No	No	No	Yes	No
Industry FE (4d)	No	No	No	No	Yes
Observations	129116	129116	129116	129116	129116
Pseudo R^2	0.69	0.70	0.70	0.77	0.83

Note: Robust standard errors clustered at the three digit SIC level are reported in parenthesis. The regressions include fixed effects for ten sub-sectors within manufacturing and eight census regions. Regressions are weighted by initial employment in each sector-commuting zone cell. The sample includes 392 manufacturing industries in 722 commuting zones for the periods 1991 - 1999 and 1999 - 2007 that are stacked in the estimation. The population variable is demeaned such that $\Delta Imp_j^{US,Ch}$ is the effect of an import competition shock for the mean-sized commuting zone. Stars indicate significance levels the following levels *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 11: WAGE AND EMPLOYMENT REGRESSIONS ON THE COMMUTING ZONE LEVEL USING 2SLS WITH LOG POPULATION

	ΔL_c	Δw_c	ΔL_c	Δw_c	ΔL_c	Δw_c	ΔL_c	Δw_c
$\Delta Imp_c^{US,Ch}$	-0.7***	-0.7***	-4.7***	-1.6	-4.7**	-1.8	-3.6**	-1.5
	(0.11)	(0.24)	(1.75)	(1.87)	(1.87)	(1.90)	(1.63)	(1.78)
$\Delta Imp_c^{US,Ch} \times ln(pop_c)$			0.3**	0.1	0.3**	0.1	0.2*	0.1
			(0.13)	(0.16)	(0.14)	(0.16)	(0.12)	(0.15)
$ln(pop_c)$	-0.2**	-0.3*	-0.8***	-0.4	-0.8***	-0.2	-0.9**	-0.7
	(0.10)	(0.15)	(0.26)	(0.42)	(0.24)	(0.41)	(0.38)	(0.74)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region FE	No	No	No	No	Yes	Yes	Yes	Yes
Additional controls	No	No	No	No	No	No	Yes	Yes
Observations	1444	1444	1444	1444	1444	1444	1444	1444
Pseudo R^2	0.06	0.49	0.10	0.49	0.13	0.52	0.32	0.57
AP F-statistic ΔExp	95.15	95.15	3.56	3.56	2.89	2.89	2.80	2.80
AP F-statistic IA	.	.	4.21	4.21	3.01	3.01	3.55	3.55

Note: Robust standard errors clustered at the three digit SIC level are reported in parenthesis. The regressions include fixed effects for eight census regions. Regressions are weighted by initial employment in each commuting zone. The sample includes 722 commuting zones for the periods 1991 - 1999 and 1999 - 2007 that are stacked in the estimation. The population variable is demeaned such that $\Delta Imp_j^{US,Ch}$ is the effect of an import competition shock for the mean-sized commuting zone. Stars indicate significance levels the following levels *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 12: WAGE AND EMPLOYMENT REGRESSIONS ON THE COMMUTING ZONE LEVEL USING 2SLS WITH ABSOLUTE POPULATION

	ΔL_c	Δw_c	ΔL_c	Δw_c	ΔL_c	Δw_c	ΔL_c	Δw_c
$\Delta Imp_c^{US,Ch}$	-0.66***	-0.68***	-0.87***	-0.79***	-0.89***	-0.83***	-0.85***	-0.79***
	(0.097)	(0.256)	(0.123)	(0.217)	(0.134)	(0.186)	(0.208)	(0.258)
$\Delta Imp_c^{US,Ch} \times pop_c$			0.03***	0.01*	0.03***	0.01*	0.03***	0.02**
			(0.006)	(0.008)	(0.004)	(0.008)	(0.004)	(0.009)
pop_c	0.00	-0.02***	-0.06***	-0.05**	-0.07***	-0.05*	-0.08***	-0.07*
	(0.003)	(0.004)	(0.023)	(0.023)	(0.017)	(0.028)	(0.012)	(0.037)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region FE	No	No	No	No	Yes	Yes	Yes	Yes
Additional controls	No	No	No	No	No	No	Yes	Yes
Observations	1444	1444	1444	1444	1444	1444	1444	1444
Pseudo R^2	0.06	0.51	0.24	0.52	0.29	0.54	0.46	0.59
AP F-stat: ΔImp	97.79	97.79	78.45	78.45	68.32	68.32	38.04	38.04
AP F-stat: IA	.	.	86.97	86.97	80.60	80.60	75.02	75.02

Note: Robust standard errors clustered at the three digit SIC level are reported in parenthesis. The regressions include fixed effects for eight census regions. Regressions are weighted by initial employment in each commuting zone. The sample includes 722 commuting zones for the periods 1991 - 1999 and 1999 - 2007 that are stacked in the estimation. The population variable is defined in units of 100,000 inhabitants and demeaned such that $\Delta Imp_j^{US,Ch}$ is the effect of an import competition shock for the mean-sized commuting zone. Stars indicate significance levels the following levels *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

B Appendix - Theory

B.1 Proof of proposition 1

Define real productivity of firms in city size c in sector j as the measure of productivity that incorporates the city-specific marginal cost, which is given by: $\varphi_c(z) = \psi(z, L^*_{cj}(z))/w(L^*_{cj}(z))^{1-\alpha_j}$ and is increasing in city size. This follows immediately from the firm optimization problem. Since firm productivity is log-supermodular in raw efficiency and city size, firms with higher raw efficiency are located in larger cities. If two firms with different raw efficiency levels were located in the same city the firm with the higher raw efficiency would have higher real productivity and therefore make higher profits. Since it is optimal for this firm to locate in larger cities this must imply higher profits and hence higher real productivity. Therefore real productivity increases with city size.

Note that as in the standard Melitz model the productivity cut-offs in each sector are determined independently of the sector aggregates. Writing the free entry and the zero profit cut-offs condition for the closed economy in terms of real productivity yields:

$$\tilde{\kappa}_{1j}\rho^{-\alpha_j(\sigma_j-1)}\left(\varphi_c(z_j^{dc})\right)^{\sigma_j-1}P_j^{\sigma_j-1}R_j - f_{P_j}\bar{c}_j = 0$$
$$\int_{z_j^{dc}}\left[\tilde{\kappa}_{1j}\rho^{-\alpha_j(\sigma_j-1)}\left(\varphi_c\right)^{\sigma_j-1}P_j^{\sigma_j-1}R_j - f_{P_j}P\right]f(z_j)dz_j = \bar{c}_j f_{E_j}$$

Combining these two equations we can derive the raw efficiency cut-off for entry:

$$f_{P_j}J(z_j^{dc}) = f_{E_j}$$

where:

$$J(z_j^{dc}) = \int_{z_j^{dc}}\left[\left(\frac{\varphi(z_j)}{\varphi(z_j)}\right)^{\sigma_j-1} - 1\right]f(z_j)dz$$

We can derivie a similar expression for the raw efficiency cut-offs in the open economy. We need to impose the parameter restriction that $\tau^{1-\sigma_j}f_{X_j} > f_{P_j}$ which ensures the the raw efficiency cut-off for entry is below the raw efficiency cut-off for exporting. Combining the free entry condition with the zero profit cut-off conditions for entry and exporting yields:

$$f_{P_j} J(z_j^{do}) + f_{X_j} J(z_j^{xo}) = f_{E_j}$$

Comparing the conditions from the closed and the open economy it follows directly that $z_j^{dc} < z_j^{do}$ from the fact that J is decreasing in z. Hence the raw efficiency cut-off is higher in the open economy and therefore the minimum city size is larger.

The density of people living in a city of size L_c is given by:

$$f_L(L_c) = \kappa_4 \frac{1}{\bar{N}} \sum_{j=1}^{S} \ell_j(z_j^*(L_c)) \cdot M_j f_j(z_j^*(L_c)) \frac{dz_j^*}{dL_c}$$

where $\kappa_4 = 1/((1-b)(1-\eta))$ accounts for the employment in construction. $z_j^*(L_c)$ denotes the inverse matching function in sector j that allows us to express z_j as a function of L_c. $\ell_j(z_j^*(L_c))$ is the labour demand of a firm in sector j with a productivity level such it locates in city size L_c. M_j denotes the mass of firms in sector j. $f_j(z_j^*(L_c))\frac{dz_j^*}{dL_c} = f_j(z)$ is the density of firms in sector j that decides to locate in city size L_c. It follows from the definition of this density that if the spatial distribution of employment in every sector j in the open economy first-order stochastically dominates the spatial distribution of employment in the closed economy, then the city size distribution in the open economy first-order stochastically dominates the city size distribution in the closed economy. We will now prove that this is true for every sector j using the result by Dharmadhikari and Joag-dev (1983) that $X \underset{s}{>} Y$ if the density $g(Y)$ crosses the density $f(X)$ only once and from above. So the spatial distribution of the open economy denoted by density $f_L^o(L_c)$ first-order stochastically dominates the city size distribution in the closed economy with density $f_L^c(L_c)$ if $f_L^c(L_c)$ cuts $f_L^o(L_c)$ only once and from above. The densities can be written as:

$$\begin{aligned}
f_j^c(L_c) &= \frac{1}{\bar{N}} M_j^c \ell^c(z_j^*(L_c)) f(z_j^*(L_c)) \frac{dz_j^*}{dL_c} \\
&= \frac{1}{\bar{N}} \frac{\tilde{\kappa}_{1j} \rho_c^{-\tilde{\alpha}_j} (\sigma_j - 1)(1-\alpha_j) \frac{\psi(z_j^*(L_c), L_c)^{\sigma_j - 1}}{w(L_c))^{(\sigma_j-1)(1-\alpha_j)+1}} f(z) \frac{dz_j^*}{dL_c} dz P_j^{\sigma_j - 1} R_j^c}{\sigma_j \tilde{\kappa}_{1j} \rho^{-\tilde{\alpha}_j} S_j(z_j^{dc}) P_j^{\sigma_j - 1}} \\
&= \frac{1}{\bar{N}} \frac{(\sigma_j - 1)(1-\alpha_j)}{\sigma_j} \frac{R_j^c}{S_j(z_j^{dc})} \frac{\psi(z_j^*(L_c), L_c)^{\sigma_j - 1}}{w(L_c)^{(\sigma_j-1)(1-\alpha_j)+1}} f(z_j^*(L_c)) \frac{dz_j^*}{dL_c}
\end{aligned}$$

Similarly for the open economy:

$$f_j^o(L_c) = \frac{1}{\bar{N}} M_j^o \ell^o(z_j^*(L_c)) f(z_j^*(L_c)) \frac{dz_j^*}{dL_c}$$
$$= \frac{1}{\bar{N}} \frac{\tilde{\kappa}_{1j} \rho_c^{-\tilde{\alpha}_j} (\sigma_j - 1)(1-\alpha_j) \frac{\psi(z_j^*(L_c), L_c)^{\sigma_j - 1}}{w(L_c)^{(\sigma_j-1)(1-\alpha_j)+1}} f(z_j^*(L_c)) \frac{dz_j^*}{dL_c} P_j^{\sigma_j - 1} R_j^c}{\sigma_j \tilde{\kappa}_{1j} \rho^{-\tilde{\alpha}_j} S_j(z_j^{dc}) P_j^{\sigma_j - 1}}$$

Let's define the difference function $h(L_c) = f_j^o(L_c) - f_j^c(L_c)$. To show first-order stochastic dominance it is sufficient to show that $h(L_c)$ is weakly positive at the minimum of the support and negative at the maximum, and only changes sign once.

$$h(L_c) = \frac{1}{\bar{N}} \frac{(\sigma_j - 1)(1-\alpha_j)}{\sigma_j} \frac{\psi(z^*, L_c)}{w(L_c)^{(\sigma_j-1)(1-\alpha_j)+1}} \frac{dz_j^*}{dL_c}$$
$$\times \left(\frac{(\mathbb{1}_d^o(z^*) + \mathbb{1}_x^o(z^*)\tau^{1-\sigma_j}) R_j^o}{S_j(z_j^{do})\tau^{1-\sigma_j} S_j(z_j^{xo})} - \frac{\mathbb{1}_d^c(z^*) R_j^c}{S_j(z_j^{dc})} \right)$$

Note that if $\mathbb{1}_A^k(z^*(L_c)) = \mathbb{1}_A^k(z^*(L_c + \Delta L_c))$ with $A = c, o$ and $k = d, x$ then $sign(h((L_c)) = sign(h(L_c + \Delta L_c))$. This relies on the result that the matching function is the same in the closed and the open economy. So changes in the sign of $h(L_c)$ that indicate that the density functions cut each other can only occur at the points where the indicator functions change. So we will separately analyse the sign in the four intervals intervals between the different cut-offs: $[0, z_j^{dc}), [z_j^{dc}, z_j^{do}), [z_j^{do}, z_j^{xo}), [z_j^{xo}, \infty)$.[9]

For the first interval we know that all indicator functions are zero since firms with a raw efficiency draw below z_j^{dc} will not enter any market.

$$h_1(L_c) = 0 \qquad for \quad z \in [0, z_j^{dc})$$

For values of z in the interval $[z_j^{dc}, z_j^{do})$, we know that $\mathbb{1}_d^o(z^*) = \mathbb{1}_x^o(z^*) = 0$ and $\mathbb{1}_d^c(z^*) = 1$, such that:

$$h_2(L_c) = \frac{1}{\bar{N}} \frac{(\sigma_j - 1)(1-\alpha_j)}{\sigma_j} \frac{\psi(z^*, L_c)}{w(L_c)^{(\sigma_j-1)(1-\alpha_j)+1}} \frac{dz_j^*}{dL_c} \left(\frac{-R_j^c}{S_j(z_j^{dc})} \right) < 0$$

[9]The fact that $z_j^{do} < z_j^{xo}$ follows directly from imposing $\tau^{1-\sigma_j} f_{X_j} > f_{P_j}$

For the interval $[z_j^{do}, z_j^{xo})$ firms in the open economy become active as well with $\mathbb{1}_x^o(z^*) = 0$ and $\mathbb{1}_d^o(z^*) = \mathbb{1}_d^c(z^*) = 1$:

$$h_3(L_c) = \frac{1}{\bar{N}} \frac{(\sigma_j - 1)(1-\alpha_j)}{\sigma_j} \frac{\psi(z^*, L_c)}{w(L_c)^{(\sigma_j-1)(1-\alpha_j)+1}} \frac{dz_j^*}{dL_c} \times \left(\frac{R_j^o}{S_j(z_j^{do})\tau^{1-\sigma_j} S_j(z_j^{xo})} - \frac{R_j^c}{S_j(z_j^{dc})} \right)$$

whose sign is ambiguous. I will therefore consider both possibilities that $h(L_c)$ is positive or negative on the interval $[z_j^{do}, z_j^{xo})$.

Note that $h(L_c)$ on the interval $[z_j^{xo}, \infty)$ (denoted h_4) is strictly larger than h_3:

$$h_4(L_c) = \frac{1}{\bar{N}} \frac{(\sigma_j - 1)(1-\alpha_j)}{\sigma_j} \frac{\psi(z^*, L_c)}{w(L_c)^{(\sigma_j-1)(1-\alpha_j)+1}} \frac{dz_j^*}{dL_c} \times \left(\frac{(1+\tau^{1-\sigma_j} R_j^o}{S_j(z_j^{do})\tau^{1-\sigma_j} S_j(z_j^{xo})} - \frac{R_j^c}{S_j(z_j^{dc})} \right)$$

Therefore if $h_3 > 0$ then $h_4 > 0$. This concludes the proof for first-order stochastic dominance if $h_3 > 0$.

If $h_3 < 0$, then $h_4 > 0$ has to be true because both $f_j^o(L_c)$ and $f_j^c(L_c)$ are density function over the same support such that one cannot be larger than the other for its entirety. This concludes the proof for first-order stochastic dominance if $h_3 < 0$, which concludes the proof of the proposition.

B.2 Proof of proposition 2

Note that in the absence of firm heterogeneity the model simplifies to an economic geography with trade patteners according to a Krugman (1980) and Heckscher-Ohlin type trade. To isolate the effects of differences in factor intensities we assume no differences in Hicks-neutral productivity, transport costs or the elasticity of substitution across sectors.

Under these assumptions, the model can be described by the following equations:

$$p_j^H = \frac{\sigma}{\sigma - 1} \bar{c}_j^H \tag{24}$$

The price index is given by:

$$P_j^H = \left[n_j^H (p_j^H)^{1-\sigma} + n_j^F (\tau p_j^F) \right]^{\frac{1}{1-\sigma}} \tag{25}$$

Firm quantity is given by:

$$q_j^H = q_j^F = \frac{(\sigma - 1)f}{w_{cj}^{1-\alpha_j}} \tag{26}$$

Using monopoly pricing (24), the price index (25) and the quantity in equilibrium, we can express the relative number of firms in home as follows:

$$\frac{n_j^H}{n_j^F} = \frac{(Y^H + \tau^{2-2\sigma} Y^F) - \tilde{p}\tau^{1-\sigma}(Y^H + Y^F)}{\tilde{p}(Y^F + \tau^{2-2\sigma} Y^H) - \tilde{p}\tau^{1-\sigma}(Y^H + Y^F)} \tag{27}$$

where $\tilde{p}_j = p_j^H / p_j^F$ is the relative price of varities in sector j produced in home relative to foreign, which is a function of the relative factor prices.

The share of home firms in world revenues in sector j is defined as:

$$s = \frac{n_j^H p_j^H q_j^H}{n_j^H p_j^H q_j^H + n_j^F p_j^F q_j^F}$$

Solving for s yields:

$$s = \frac{(Y^H + \tau^{2-2\sigma} Y^F) - \tilde{p}_j \tau^{1-\sigma}(Y^H + Y^F)}{(1 + \tau^{2-2\sigma})(Y^H + Y^F) - (\tilde{p}^{\sigma} + \tilde{p}^{-\sigma})\tau^{1-\tau}(Y^H + Y^F)} \tag{28}$$

The share of firms of a given sector located in Home decreases in the relative price of varieties in that sector, as can be intutitively seen by evaluating the derivative at $\tilde{p} = 1$:

$$\left.\frac{\partial s}{\partial \tilde{p}}\right|_{\tilde{p}=1} = \frac{-\sigma \tau^{1-\sigma}}{(\tau^{1-\sigma} - 1)^2} < 0$$

Note that the relative price of varieties is fully determined by the factor prices in the two countries (see equation 24), which themselves depend on the abundance of factors. Next we will show that in the trade equilibrium the locally abundant factors are relatively cheap and hence Home will capture a larger share of the market in the capital-intensive sector, while Foreign will export the labour-intensive good. The factor market clearing conditions are given by:

$$\bar{w}^H \bar{L}^H = (\alpha_1 \beta_1 w_{c1}^{-1} s_1 + \alpha_2 \beta_2 w_{c2}^{-1} s_2)(Y^H + Y^F) \tag{29}$$

$$\rho^H \bar{K}^H = ((1 - \alpha_1)\beta_1 s_1 + (1 - \alpha_2)\beta_2 s_2)(Y^H + Y^F) \tag{30}$$

$$\bar{w}^F \bar{L}^F = (\alpha_1 \beta_1 w_{c1}^{-1}(1 - s_1) + \alpha_2 \beta_2 w_{c2}^{-1}(1 - s_2))(Y^H + Y^F) \tag{31}$$

$$\rho^F \bar{K}^F = ((1 - \alpha_1)\beta_1(1 - s_1) + (1 - \alpha_2)\beta_2(1 - s_2))(Y^H + Y^F) \tag{32}$$

Home is endowed with more capital and Foreign is endowed with more labour. For the full employment conditions to hold Home has to either have a larger share of the capital-intensive industry or to use capital more intensively in each industry. From equation (28) we know that Home will only have a larger share of the capital-intensive industry if the price of varieties in the capital-intensive sector are cheaper in Home than in Foreign, which is only the case if $\rho^H/\bar{w}^H < \rho^F/\bar{w}^F$. From the cost minimization problem of the firm and the resulting factor demands it follows that Home will only use capital more intensively in any industry if $\rho^H/\bar{w}^H < \rho^F/\bar{w}^F$. Hence capital will be relatively cheaper in the Home country, which will export the capital-intensive good.

Next, we compare the factor allocation within Home across the autarky and the trade equilibrium. The factor market clearing conditions under autarky are given by:

$$\bar{w}^{HA} \bar{L}^{HA} = (\alpha_1 \beta_1 w_{c1}^{-1} + \alpha_2 \beta_2 w_{c2}^{-1}) Y^{HA} \tag{33}$$

$$\rho^{HA} \bar{K}^{HA} = ((1 - \alpha_1)\beta_1 + (1 - \alpha_2)\beta_2) Y^{HA} \tag{34}$$

Combining factor market clearings in Home across the two equilibria (equations 33, 30, 33 and 34), we can show that the price of capital relative to labour is higher under trade if the following regularity condition hold:

$$\frac{(1 - \alpha_1)}{(1 - \alpha_2)} \frac{\alpha_2}{\alpha_1} < \frac{w_{c1}}{w_{c2}}$$

which ensures that the wage premium that firms in larger cities pay is small enough so that it does not imply factor intensity reversals across sectors. This condition holds under all reasonable parameter values. Given these differences in factor prices both sectors will use labour more intensively, which implies that the capital-intensive sector has to be larger and has a higher demand for both factors under the trade equilibrium to ensure full employment of factors. From the matching function it follows that the capital-intensive sector is located in a larger city than the labour-intensive sector. Hence, the re-allocation of employment from the labour- to the capital-intensive sector implies a reallocation in space to a larger city such that the spatial distribution of population in the open economy first-order stochastically dominates the spatial distribution of population in the closed economy.