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Globalization and the spatial concentration of production

by

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# Globalization and the spatial concentration of production\*

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## Abstract

New trade theory models predict that freer trade increases the spatial concentration of industrial production across countries. While nations with large home markets and central geographical location become increasingly attractive business locations, small peripheral countries gradually deindustrialize. Using data for 26 industries, 20 OECD countries and 20 years, we investigate the empirical validity of this claim. Separating out the role of home market size from geographical factors, and using various panel methods, we find robust evidence in line with theory. Freer trade has indeed magnified the importance of domestic demand and geographical location for the pattern of industrial production across the globe and has therefore exacerbated spatial disparities.

*Keywords:* Home market effect, hub effect, trade liberalization, trade costs, increasing returns to scale, new trade theory, economic geography.

*JEL-Codes:* F12, F15

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# 1 Introduction

Today's general perception is that the world has moved closer together. Popular writers argue that "the world is flat" (Friedman, 2005) or proclaim the "death of distance" (Cairngross, 1997). While these claims are exaggerated, the academic literature (e.g., Hummels, 2007) leaves little doubt that trade costs have indeed fallen. Progress in transportation technologies, such as the introduction of containerization, or in communication technologies, e.g. the internet, and substantial reductions in tariff and non-tariff barriers have greatly reduced barriers between countries and have increased the freeness of trade. Indeed, the secular trend in trade costs epitomizes what is usually meant by the buzzword "globalization".

Virtually all mainstream trade theories predict that lower trade costs lead to welfare gains at the global level. However, improved allocative efficiency notwithstanding, these aggregate gains need not be evenly distributed within and across countries, so that there are losers and winners. One recurrent worry of policy makers is that higher trade freeness spurs the deindustrialization of small and peripheral countries and entrenches global inequality.<sup>1</sup> This concern has a theoretical foundation in trade models featuring increasing returns to scale at the firm level. '*New Trade Theory*' (NTT) predicts that large and/or centrally located countries increasingly dominate the production of industrial goods as trade costs fall.

Countries with large home markets are attractive places of production as firms want to save on trade costs when servicing their largest customer base. The larger a country's domestic market, the *disproportionately* more firms it attracts. Increasing freeness of trade further boosts this locational advantage, since it becomes cheaper to ship goods to foreign countries while still selling to domestic consumers at no trade costs. The first channel has been described by Krugman (1979) and Helpman and Krugman (1985). It is frequently referred to as the *home market effect* (HME). However, geography matters, too. Central countries attract industrial production since they allow cheap shipping to other countries; freer trade can magnify this advantage. This second channel has been introduced by Krugman (1993) as the *hub effect*.

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<sup>1</sup>The World Bank dedicates the forthcoming 2009 World Development Report "Reshaping Economic Geography" to the role of globalization in shaping spatial disparities.

In this paper we study empirically whether falling trade costs have indeed strengthened the advantages of large and/or central countries as locations of industrial production. To this end, we use 20 years of production and trade data for 20 OECD countries and 26 3-digit industries. We build on the important work by Behrens, Lamorgese, Ottaviano and Tabuchi (2007), henceforth BLOT, who show how to empirically isolate the home market effect from confounding geographical effects in a multi-country setup. We also use the concept of *nominal market potential*, well established in the literature since Davis and Weinstein (2003), to quantify the joint effect of the home market and the hub effect.

Our empirical results suggest that market size and geographical centrality have become more important for the distribution of industrial production across countries, thereby contributing to a stronger polarization of industrial activity over space and confirming concerns of policy-makers. We find robust evidence for the decisive role of trade costs and show that both the home market effect and the hub effect have gathered strength. Hence, evidence seems in line with the predictions from NTT.<sup>2</sup>

The present paper is related to a large and growing literature. A number of authors study changes in the industrial location and in specialization patterns across countries in episodes of trade liberalization. Middelbart-Knarvik et al. (2000) as well as Amiti (1998, 1999) look at the case of European integration, mainly focusing on concentration measures, such as the Herfindahl index. Head and Ries (2001) study how the location of Canadian-U.S. manufacturing changed as a reaction to the free trade agreement between Canada and the USA. That latter paper is close to ours, in particular because it looks at the data through the lens of NTT. However, we study a larger country sample (20 OECD countries) over a longer period of time (1988-1999) and focus on technological change rather than tariff reform.

A number of papers argue that the HME is a distinctive feature of models with increasing returns to scale and exploit this fact to assess the empirical success of those models as compared to models featuring constant returns and other sources of product differentiation (e.g. Feenstra

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<sup>2</sup>In other areas of research, empirical results are harder to square with the perceived evidence of falling trade costs. For example, in gravity models, the trade-impeding influence of distance has grown stronger over time (Disdier and Head, 2008).

et al., 2001; Head et al., 2002). Although the HME does not need to appear in all theoretical circumstances (see Davis, 1998, or Head and Mayer, 2004), it was found to be remarkably robust to alternative specifications, such as linear demand and per unit transportation costs (Ottaviano et al. (2002)), heterogeneous firms (Okobu and Rebeyrol, 2006) and even to the departure from the Dixit-Stiglitz monopolistic-competition structure (Holmes and Stevens, 2005). Davis and Weinstein (2003), Feenstra et al. (2002), Hanson and Xiang (2004) as well as Brühlhart and Trionfetti (2007) have found empirical support for HMEs in differentiated goods industries. Head and Ries (2001), who exploit time variation, find mixed evidence for industrial relocation in line with NTT.<sup>3</sup> Our paper differs from earlier approaches in that it tries to assess the *evolution* of the HME over time.

A central complication with the empirical identification of the HME arises when there are more than two countries and asymmetric trade costs across country pairs – the natural situation in many empirical studies. In that case, the hub effect confounds the HME. BLOT recently generalized the standard model to the multi-country setup with asymmetric trade costs. They show that the effect of changes in market size on industry location is different for differently located countries and depends on trade barriers with and of all countries and simultaneous demand shifts in the entire world. In our exercise, we apply the theory-based linear filter suggested by BLOT, which separates out the pure HME by correcting the data for effects from asymmetric trade costs and geography. However, since we are interested in the *total effect* of falling trade costs on industrial location, we also relate changes in production to changes in *nominal market potential* (NMP), a combined measure for a country’s attraction (attributed to its market size) and accessibility (related to its geographical location). Interestingly, across all our specifications we find that freer trade has made the distribution of industrial production spatially more concentrated.

The remainder of this paper is structured as follows. Section 2 considers the theoretical mechanisms that link the distribution of industrial production to market sizes and geographical location. Section 3 discusses the empirical strategy and presents the data together with evidence

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<sup>3</sup>For a summary on the HME literature, see Head and Mayer (2004).

on trade costs. Section 4 shows our main results. Section 5 presents caveats, robustness checks and additional results. Section 6 concludes.

## 2 What determines the international distribution of firms?

### 2.1 Setup

In this section, we describe the mechanisms through which the size of nations and their relative geographic position determines their importance as locations of industrial production. For that purpose, a setup with two sectors and three countries proves sufficiently general.<sup>4</sup>

There are two goods: a costlessly tradable outside (agricultural) good, and a differentiated (industrial) good which comes in a continuum of varieties. The outside good is typically produced under perfect competition and constant returns to scale, while variants of the differentiated good are produced by identical monopolistically competitive firms. Production involves fixed costs, but marginal costs are constant. There is only one factor of production: labor. Assuming that all countries produce both types of goods, they share the same wage rate, which we normalize to unity.<sup>5</sup> Countries are indexed by  $i$ , with  $i \in \{1, 2, 3\}$ . They may differ with respect to the size of their labor force  $L_i$  and their geographical location, but are otherwise perfectly identical. Preferences of the representative consumer are such that the elasticity of substitution between varieties (and hence the elasticity of demand) is parametrically given by  $\sigma > 1$ . Hence, monopoly markups are constant. Welfare  $W$  (i.e., the real wage) is then just inversely proportional to the ideal price level  $P_i$ .

Each differentiated variety is produced by a single firm and sold in all countries. Firms charge monopoly markups, but equilibrium profits are zero due to free entry and exit. In this theoretical setup all firms have equal size and charge identical ex-factory prices, see Feenstra

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<sup>4</sup>Our analysis is based on BLOT, who generalize the Helpman and Krugman (1985) model to the asymmetric multi-country multi-sector case. The special case of the BLOT model with two sectors and three countries has been studied in deep detail by Südekum (2007).

<sup>5</sup>Factor price equalization (FPE) is crucial, see Davis (1998) and the recent paper by Crozet and Trionfetti (2008) for the two-country case. Constant returns to scale and perfect competition in the outside good sector are, however, only *sufficient* conditions for FPE. Also note that FPE is not necessary for qualitative results discussed in this paper.

(2004) for a textbook treatment. *Intranational* trade is not affected by trade costs; *international* shipments from country  $i$  to  $j$ , however, require costly transportation so that imported varieties are by a factor  $\tau_{ij} \geq 1$  more expensive than domestic ones. Trade volumes between  $i$  and  $j$  are proportional to the *freeness of trade* between countries  $i$  and  $j$ ,  $\phi_{ij} \equiv \tau_{ij}^{1-\sigma}$ , with  $\phi_{ij} \in (0, 1]$ , where  $\phi_{ij} = 1$  corresponds to entirely free trade and a value of  $\phi_{ij}$  close to 0 implies prohibitively large trade costs. Domestic sales and profits are unaffected by trade costs. Export sales and associated profits, however, rise with  $\phi$  since exporters are more competitive.

## 2.2 The role of country size and location

Denote by  $\lambda_i$  the share of country  $i$  in global production of the differentiated good and by  $\theta_i$  its share in total world population. Since all firms have equal size in the model,  $\lambda_i$  also measures the distribution of firms across countries. Ruling out trade imbalances,  $\theta_i$  measures the distribution of expenditure (equal to income and home market size) across countries. In the following, we illustrate the role of *increasing* freeness of trade in shaping the link between the distribution of population  $\theta_i$  and that of industrial production  $\lambda_i$  and investigate whether that relationship has changed systematically as trade has become freer. More precisely, we care about the value and determinants of  $b$  in<sup>6</sup>

$$\lambda_i = b\theta_i. \tag{1}$$

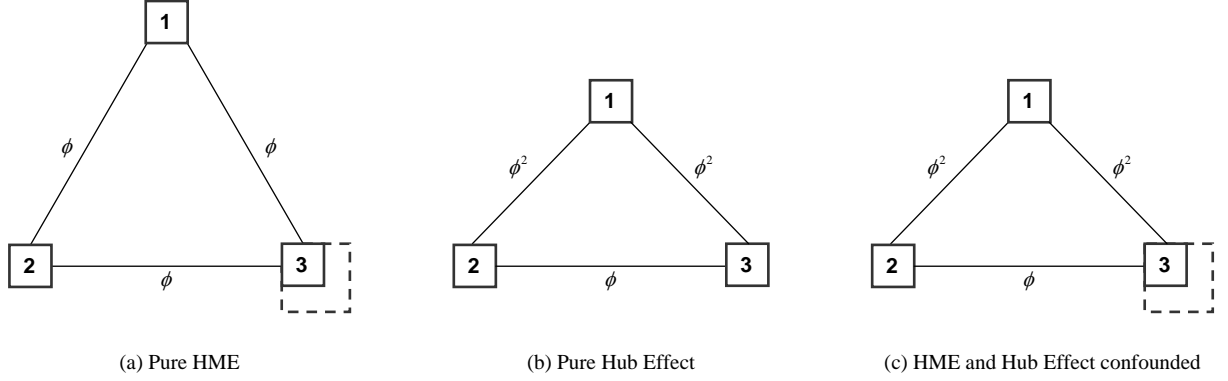
For a start, assume that all countries have equal populations  $L_1 = L_2 = L_3$  and there are no differences in the bilateral freeness of trade across country pairs so that  $\phi_{ij} = \phi \in (0, 1]$ . In this perfectly symmetric situation, economic outcomes must be symmetric, too: the differentiated goods sector is of equal size in all countries. Trade is exclusively intra-industry, and welfare levels are equalized.

**The home market effect (HME).** Now assume that country 3 becomes larger, everything else equal, so that its share in total world population goes up while that of the other countries

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<sup>6</sup>This equation is a simplification: with many asymmetric countries, it features a constant term (see BLOT); in more general setups it may not be log-linear (Crozet and Trionfetti, 2008).

falls:  $\Delta\theta_1 < 0, \Delta\theta_2 < 0, \Delta\theta_3 > 0$ . Panel (a) in Figure 1 offers an illustration. In this case one obtains  $b > 1$  in equation (1), which indicates that the larger country attracts an overproportionally large share of firms. To understand this, let us assume the contrary, i.e.,  $b = 1$ . Then, the distribution of firms and that of population coincide and  $\lambda_i = \theta_i$  for all  $i = 1, 2, 3$ . Is this an equilibrium?



**Figure 1:** Market size and trade costs in the three-country world.

In an equilibrium, firms cannot further increase their profits by changing location from one country to the other. This is, however, not the case in the situation described above. Firms in country 3 face a larger share of demand from their home country than from abroad, because the home country is bigger. Moreover, that share of demand is completely exempt from trade costs so that profits stemming from domestic sales are bigger. If  $b = 1$ , demand per firm in country 3 would be larger than elsewhere; associated profits would be, too. It follows that firms relocate from the (symmetric) countries 1 and 2 into 3. The concentration of firms leads to *market crowding* in 3, so that firms' sales and profits decline. In the small countries, the converse is true. This mechanism balances profit opportunities across the two countries. Hence,  $b = 1$  is not an equilibrium, neither is  $b < 1$  as profits would diverge further. Hence,  $b > 1$  must hold. This is the *home market effect (HME)*. It implies that an increase in a country's expenditure share causes an overproportional expansion in its share of firms. This is equivalent to stating that country 3 is a net exporter of the differentiated good while the other countries are net importers. Moreover, welfare is higher in country 3 ( $W_3 > W_1 = W_2$ ), since a smaller share of total consumption is burdened by trade costs, leaving the consumer price index lower than in the other countries.



If there were simultaneous changes of  $L_i$  in *all* countries, for example  $\Delta L_1 > \Delta L_2 > \Delta L_3$ , the home market effect would prevail in each pairwise comparison of countries. Countries could then be ranked with respect to their share of production relative to population:  $\lambda_1/\theta_1 > \lambda_2/\theta_2 > \lambda_3/\theta_3$ .

**The hub effect.** Now, we revert to identical country sizes but assume that country 1 enjoys easier access to the markets of its trading partners 2 and 3 than those partners between them. For the sake of concreteness,  $\phi_{12} = \phi_{21} = \phi_{13} = \phi_{31} = \phi^2 < \phi$ , while  $\phi_{23} = \phi_{32} = \phi$ . Panel (b) in Figure 1 illustrates this case. Country 1 has a central geographic location, or it may have concluded special trade agreements with its partners. In this situation, is  $\lambda_i = \theta_i$  for all  $i \in \{1, 2, 3\}$  an equilibrium? As above, the answer is no. However, the reason is different. On average, exporters in country 1 are less strongly affected by trade costs than exporters in countries 2 and 3 are. This implies that firms in country 1 serve consumers in country 2 (or 3) at lower prices than firms based in country 3 (or 2). Hence,  $\lambda_i = \theta_i$  is incompatible with equality of profits across countries, and firms have incentives to reallocate. It follows that in equilibrium  $\lambda_1 > \theta_1$ , while  $\lambda_2 < \theta_2$  and  $\lambda_3 < \theta_3$ . Country 3's central geographical location makes it attractive for firms to locate there. Firms export their output at low costs to the other countries, thereby turning country 3 into a net exporter of differentiated goods. This is the *hub effect* first discussed by Krugman (1993). Countries 2 and 3 are net exporters of the homogeneous good, which is costlessly tradable, and where geographical disadvantage does not matter. Welfare is larger in the central country 1 ( $W_1 > W_2 = W_3$ ) because a lower share of total consumer spending is affected by trade costs.

**HME and hub effect combined.** We can now turn to panel (c) in Figure 1. Starting from the situation of asymmetric trade costs described in panel (b), we study the effect of an increase in market size of country 3. Now, the HME in country 3 is confounded by the hub effect in country 1. It is no longer obvious that an increase in the relative size of country 3 more than proportionally boosts its share of industrial production. The reason is that the larger market size of country 3 also increases the attractiveness of country 1 thanks to its role as a preferred

location for exporters. Clearly, the strength of this effect depends on the size of trade costs between 1 and 3. It is possible that the new equilibrium features  $\lambda_1 > \theta_1$ ,  $\lambda_2 < \theta_2$ , and  $\lambda_3 \geq \theta_3$ . Hence, the hub effect confounds the HME and there need not be a clear relation between changes in own market size and industrial production any more.

BLOT provide a numerical 3-country example where all countries differ with respect to size and geography and in which the HME is dwarfed by the hub effect so that the larger country actually has a lower share of firms than the medium-sized country. They show that the hub effect dominates when trade impediments are sufficiently high and country sizes not too different. Note, however, that the hub effect can also enforce the market size effect, for example, if the large country happens to be the central one (unlike in our figure).

### 2.3 The role of higher freeness of trade

For a given level of trade costs, industrial production concentrates in large and/or central countries. Does freer trade, e.g., due to improvements of transport technology, lower communication costs, or tariff reform exacerbate the spatial disparities or attenuate them?

**The home market magnification effect (HMME).** First, we focus on a situation where countries differ only with respect to size and trade becomes uniformly freer across all country pairs. This makes the HME stronger, thereby making the distribution of industrial production across countries more skewed. The theoretical result  $\partial b / \partial \phi > 0$  is known as the *home market magnification effect* (HMME). The intuition is the following. As long as trade is not entirely costless, i.e.,  $\phi < 1$ , producing in the larger country remains advantageous, as a larger share of local firms' total sales remains untouched by international trade costs. Higher freeness does not alter this effect. However, the benefits of concentrating production in the larger country have gone up since serving the other countries through exports is now cheaper. Hence, incentives to locate in the larger market have become stronger.

One can also highlight the HMME by starting from the extreme case, where trade is entirely frictionless, i.e.,  $\phi = 1$ . Then, exporting does not come with additional costs, so that varieties sell

at the same price and firms make the same profits in all markets regardless of where they produce and sell (as long, of course, as countries still produce both the outside and the differentiated good). Hence, the distribution of firms across countries becomes essentially indeterminate. A proportional distribution of firms over countries is therefore a possibility, even if countries differ in size. However, the tiniest deviation from free trade would induce a massive reallocation of firms towards the largest country. This is so because sales to that country generate the largest share of firms' profits, so that firms benefit by locating there in order to save trade costs. However, since freeness of trade is still almost perfect, exporting to the rest of the world causes little profit losses.

**The hub magnification effect.** The hub effect can also be magnified when the freeness of trade goes up. Using panel (b) of Figure 1, any improvement in  $\phi$  has a stronger effect for the country pairs that involve the central country 1 than for the other pairs. Hence, the locational advantage of country 1 becomes stronger, it attracts even more industrial firms, and fortifies its role as a hub. As a consequence, the distribution of industrial production across countries becomes more skewed.

Figure 1 is constructed such that a change of  $\phi$  affects country pairs asymmetrically, which strengthens the peripherality of countries 2 and 3. However, even if trade costs  $\tau_{ij}$  fall *proportionally* in all pairs, so that the *relative* freeness of trade  $\phi_{ij}/\phi_{kl}$  remains unchanged, the hub effect is magnified. Krugman (1993) shows that “we expect concentration of production in transportation hubs when transportation costs are low, rather than when they are high” (p. 35). To see this, suppose that in some initial situation trade is entirely free ( $\phi_{ij} = 1$ ). Hence, it is possible that the distribution of production is proportional to country sizes. If there are small impediments to trade between countries 1 and 2 ( $\phi_{12} = \phi_{21} < 1$ ), there is strong relocation of firms towards country 1, because trade costs can be *fully* avoided by producing there. If initially countries are in autarky ( $\phi_{ij} = 0$ ), production is also evenly distributed. When trade costs involving country 1 rise to a small positive number, then country 1 becomes a hub. However, relocation is weak, since trade costs are still *almost prohibitive*. Hence, the hub effect is stronger, when the *overall* level of trade costs is low.

**Summary.** In the context of a very general setup, Behrens et al. (2004) show that the spatial distribution of production becomes generally more uneven with increasing trade freeness when both forces interact, while geography becomes relatively more important for the location of production compared to market size.<sup>7</sup> In a globalizing world, we therefore expect industrial production to move towards locations where domestic markets are large and from which trade with other markets is easy, while geography should increasingly gain weight as a determining factor. New trade theory therefore predicts that the cross-country distribution of industrial production increasingly decouples from the distribution of population. In the following empirical exercise we show that this decoupling has indeed occurred.

However, it is important to note that the implications for *cross-country welfare differences* are non-monotonic. Clearly, as soon as the freeness of trade is total, the location of production does not have any relevance on welfare since aggregate price levels and nominal income are both equalized across countries. However, when the freeness of trade is sufficiently low to start with, a further increase in trade freeness may increase global disparities, therefore justifying wide-spread policy concerns.

### 3 Empirical implementation

Equation (1) has a natural empirical counterpart

$$\lambda_{ikt} = \alpha + \beta\theta_{it} + \epsilon_{ikt}, \quad (2)$$

where  $\lambda_{ikt}$  is the production share of country  $i$  in industry  $k$  at time  $t$ ,  $\theta_{it}$  is the overall demand share for industrial goods of country  $i$  at time  $t$ ,  $\alpha$  is a constant, and  $\epsilon_{ikt}$  is an i.i.d. error term. We will follow the literature<sup>8</sup> and use data on value-added to proxy production shares. Demand shares are based on national absorption, the residual between output and net trade.<sup>9</sup>

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<sup>7</sup>See Proposition 2 in Behrens et al. (2004), p.14.

<sup>8</sup>Some of the most important recent empirical studies are Crozet and Trionfetti (2008), Behrens et al. (2007), Davis and Weinstein (2003) and Head and Ries (2001).

<sup>9</sup>For the exact calculation of the different variables as well as data sources, see the Data Appendix.

Traditionally, empirical studies run equations of the type stated above in a cross-section and test whether  $\beta > 1$ , which is understood as a test for the existence of an HME. In this study, we use three different theory-inspired specifications, which differ with respect to the exact definitions of the production and demand shares used in equation (2); see Table 1.

**Table 1:** Production-demand specifications

	$\theta^{observed}$	$\theta^{NMP}$
$\lambda^{filter}$	HME	–
$\lambda^{observed}$	Naive	HME+Hub

**The HME specification.** As argued in Section 2, in a multi-country world with asymmetric trade costs, the hub effects confounds the HME. However, BLOT offer an elegant way to isolate the effect of pure size effects. To that purpose, they propose a *linear filter*, which corrects the observed production shares  $\lambda_{ikt}$  year-by-year for asymmetric trade costs. Filtering yields those production shares  $\lambda_{ikt}^{filter}$  that one would observe if trade costs were symmetric across countries. Using filtered production shares allows identifying the HME by running Equation (2). We call this first production-demand specification *HME* specification, which uses  $\lambda_{ikt}^{filter}$  and  $\theta_{it}^{observed}$  to estimate Equation (2).  $\beta > 1$  indicates the presence of the HME, while a positive dependence of the parameter on the degree of trade freeness would reveal the home market magnification effect (HMME).

**The HME+Hub specification.** Beyond the HME and HMME, we are also interested in the hub effect and the importance of geography. In particular, we want to know whether they are augmented by rising trade freeness. However, measuring the hub effect in isolation from the home market effect is not feasible. Changes in the global trade cost structure, e.g. in form of bilateral free trade agreements or improved infrastructure, are unlikely to have a clearly measurable impact on industry location over time. This would be necessary to measure the hub effect separately in a similar fashion to the HME. However, we can use an intuitive measure,

namely *nominal market potential* (NMP), well known in the related literature, to measure the joint impact of the HME and the hub effect on industry location.<sup>10</sup> A country's nominal market potential is the sum of its domestic demand and distance-weighted demands of all other countries and thus captures a country's attractiveness due to both forces, market size and accessibility. We construct  $\theta_{it}^{NMP}$  as a country's share in world NMP (the sum of NMP over all countries) and thereby measure a country's attractiveness as a business location relative to others. The production share will be proxied by the observed production share in terms of value added,  $\lambda_{ikt}^{observed}$ . We call the specification the *HME+Hub* specification. Using  $\theta_{it}^{NMP}$  in Equation (2) and testing for  $\beta > 1$  would not be informative about the HME or hub effect *per se*. Nevertheless, this specification will reveal whether firms, as we expect, locate predominantly in countries with a high share in NMP, and whether they concentrate more and more in those comparatively attractive places when trade costs fall.

NMP does not take into account differences in prices and may therefore overestimate the market potential of large markets and underestimate it for small ones. However, as turns out, the use of NMP is unproblematic for our exercise. Overestimation of NMP for large markets would bias the estimated slope of the line relating the production to the demand shares downwards, hence stacking the cards against the predictions of theory. If we do find disproportionate responses between demand and production, then they must be sufficiently strong in the data to still show up econometrically despite the bias in NMP.

**Naïve specification.** As a third specification, which we call *Naïve* specification, we regress the unfiltered production shares  $\lambda_{ikt}^{observed}$  on uncorrected demand shares  $\theta_{it}^{observed}$ . This allows to see, how the filter helps to detect the HME, which in this specification is distorted by effects from asymmetric trade costs.

**Some notes on the data.** Our data covers twenty years, from 1980 to 1999, 20 OECD countries, and 26 three-digit ISIC industries. The country coverage is common to the literature,

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<sup>10</sup>Davis and Weinstein (2003) as well as Crozet and Trionfetti (2008) account for geography by measuring demand in terms of nominal market potential (NMP) when taking the Helpman and Krugman (1985) model to the data.

see Hanson and Xiang (2004) or BLOT. It has the advantage that countries have similar technologies and tastes which is assumed in the theory. Moreover, they share comparable access to international factor markets, which should minimize the role of comparative advantage. Also the level of industry disaggregation is standard in the literature, see Davis and Weinstein (2003), Hanson and Xiang (2004), Crozet and Trionfetti (2008), BLOT.<sup>11</sup> The units of analysis in our exercise are country ( $i$ )  $\times$  industry ( $k$ ) pairings observed over time ( $t$ ). There are, therefore a maximum of  $20 \times 26 \times 20 = 10,400$  observations, from which we actually observe about 83% ( $N = 8,679$ ).<sup>12</sup>

### 3.1 Freeness of trade

The motivation of our analysis rests on the presumption that trade costs have fallen over time, i.e., that the freeness of trade has increased. In addition to anecdotal evidence, we draw on data to check whether the expected evolution of trade costs and the freeing up of trade can be confirmed by our data.

We use a narrow and a broad measure of trade freeness. The narrow measure  $\phi_{kt}^{narrow}$  is based on freight rate data from Bernard et al. (2006) and has an industry  $\times$  time dimension. This measure captures changes in the freeness of trade solely driven by variation in freight rates over industries and over time. It suffers from the fact that it excludes other types of trade costs. Therefore, we provide a broad measure  $\phi_{kt}^{broad}$ , which can be calculated from bilateral trade data and which accounts for all types of trade costs. The shortcoming of this indicator is that it is a non-linear function of the elasticity of substitution. If the latter varies over time,  $\phi_{kt}^{broad}$  confounds changes in trade costs over time with changes in preferences, which have nothing to do with the freeness of trade as it is commonly understood.<sup>13</sup>

Figure 2 shows the evolution of the narrow and the broad measure of trade freeness for

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<sup>11</sup>Davis and Weinstein (2003) discuss the role of aggregation. It is not immediately clear, which level of aggregation is most appropriate to meet the underlying assumptions on varieties and goods. In the theoretical model, industries are categorized by factor inputs rather than by product usage as is the case for ISIC industries.

<sup>12</sup>For summary statistics, see Table 9 in the Data Appendix.

<sup>13</sup>For the exact calculation of our measures, see the Data Appendix.

homogeneous and heterogeneous industries over time. Industries are categorized following Lyons and Sembenelli (1997). Both measures indicate that the freeness of trade has increased from 1980 to 1999. In our empirical analysis, we will interpret time variation in the average freeness of trade as changes in trade costs rather than preferences. Figure 2 underlies this argumentation as it features a very similar evolution for both the narrow and broad measures as well as for both groups of industries, heterogeneous and homogeneous.

**Figure 2:** Evolution of freeness of trade for homogeneous and heterogeneous industries



## 4 Results

### 4.1 The HME

Before analyzing the role of increasing trade freeness for the spatial distribution of production, we check for evidence for the HME and/or the hub effect in our data. This allows to relate our analysis to the existing literature and to compare the performance of the three production-demand specifications. In the spirit of Head and Ries (2001), we conduct “within” and “between” regressions, the former exploiting the time-variation including country-industry fixed effects and the latter drawing on the cross-sectional variation in the data.

Columns (1)-(3) of Table 2 show within estimates for our three specifications; columns (4)-(6) present the results for between regressions using weighted least squares in order to account for the unbalanced panel. The slope coefficient  $\beta$  from Regression (2) is our parameter of interest, where  $\hat{\beta} > 1$  indicates a more than proportional response of production to the different demand



**Table 2:** Testing for overproportional response.

Dep.var.: Production share $\lambda$						
	Within estimates			Between estimates		
	(1) Naive	(2) HME	(3) HME+Hub	(4) Naive	(5) HME	(6) HME+Hub
Demand share $\theta$	0.971*** (0.0173)	1.588*** (0.350)	0.808*** (0.0209)	1.053*** (0.0146)	1.252*** (0.0443)	1.359*** (0.0208)
$R^2$ within	0.278	0.003	0.154	0.278	0.003	0.154
$R^2$ between	0.889	0.311	0.870	0.910	0.608	0.892
$R^2$ overall	0.878	0.074	0.851	0.878	0.074	0.851

Standard errors in parentheses. \*\*\*, \*\*, \* refer to  $p < 0.01$ ,  $p < 0.05$ ,  $p < 0.1$ .

8679 observations for all six regressions. Constant not reported.

Within regressions include country-industry fixed effects. Between regressions use weighted least squares.

**Naive** specification uses uncorrected variables. **HME** specification includes filtered production shares.

**HME+Hub** specification captures demand shares in terms of nominal market potential.

measures. Results differ across specifications and econometric methodologies. Within estimates only signal a disproportionate reaction of the production share for the HME specification, but not for the naive or the HME+hub specification. The failure to find evidence for the HME in the within model is in line with Head and Ries (2001). Coefficients from the naive specification also roughly correspond to their estimates for the slope coefficient. However, our analysis suggests that correcting the production data for geographical differences, as BLOT recommend, confirms the existence of an HME even in the within analysis. This is an interesting result, which points towards the overall usefulness of the methodology proposed by BLOT.

Evidence from the between regressions, which exploit the cross-sectional variation of the data, yields more consistent results. This is in line with much of the literature; Feenstra et al. (2001), Davis and Weinstein (2003), Hanson and Xiang (2004) and BLOT find that countries with large domestic markets produce disproportionately more differentiated goods than smaller countries, while the presence and the magnitude of the HME seem to be positively related to the degree of industry differentiation.

At this stage, we conclude that the evidence for disproportionate reactions of production shares to different measures of demand shares is mixed, except when the analysis is narrowed

down to the pure HME. However, in this paper, we are mainly interested in understanding the behavior of  $\beta$  as trade becomes freer.

## 4.2 Magnification effects

**Non-parametric time trend.** NTT predicts that increasing freeness of trade over time should introduce a positive time trend into estimated  $\beta$  coefficients. In order to gain a first impression of the data, we run the HME+hub specification, but include interaction terms between year fixed effects and NMP. This allows a non-parametric estimate of the time behavior of  $\beta$ . Figure 3 plots the obtained  $\beta$  coefficients over time. It also draws 2-standard deviation bands of confidence.

The result is striking: there is strong evidence that NMP has become more important for the distribution of industrial production across countries. Hence, countries' own sizes and/or their location relative to trading partners have become more important. In contrast to Table 2, Figure 3 estimates using pooled OLS, which gives weighted averages of the within and between estimates. Note, however, that the *time behavior* (unlike the level!) of  $\beta$  does not depend on the estimation technique; see below. Also note that similar pictures obtain when our other production-demand specifications are used; again see below.<sup>14</sup>

**An extended regression framework.** In a next step, we improve the rather crude graphical approach by testing the impact of time and trade freeness on the slope coefficient. We augment our regression equation by interacting the demand share  $\theta$  with the variable  $\phi_{kt}$ , which we first proxy by a linear time trend, and then by the narrow or broad measures for the freeness of trade. We estimate

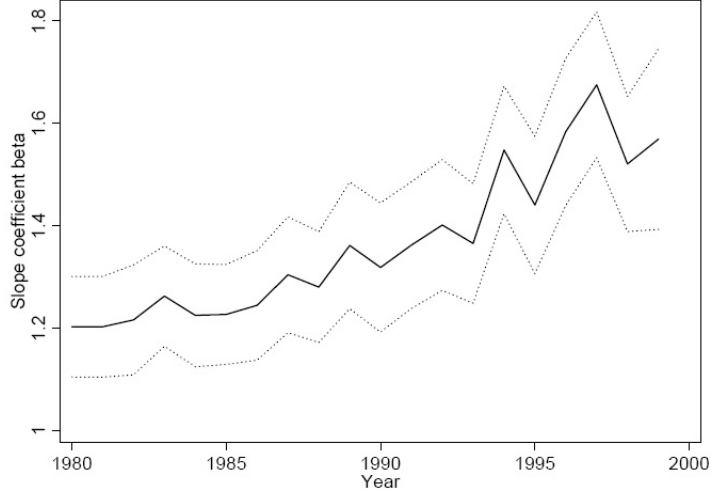
$$\lambda_{ikt} = \alpha + \beta_0 \theta_{ikt} + \beta_1 \theta_{ikt} \phi_{kt} + \beta_2 \phi_{kt} + \epsilon_{ikt}, \quad (3)$$

where we are mainly interested in the estimated coefficient  $\hat{\beta}_1$ . If magnification effects exist, we should find  $\hat{\beta}_1 > 0$ . The coefficients  $\beta_0$  and  $\beta_2$  measure the direct effects of demand and of trade

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<sup>14</sup>Running the exercise on the industry-level, estimates become obviously somewhat more imprecise. However, the general picture remains. Results are available on request.

**Figure 3:** Increasing HME+Hub effect over time



freeness on production shares.

**Linear time trend.** Table 3 reports output for the estimation of Equation (3) when a linear time trend captured by our variable *time* is used as proxy for  $\phi_{kt}$ .<sup>15</sup> Columns (1) to (3) display results from a pooled OLS regression; columns (4) to (6) show within estimates. We find evidence for a positive time trend in the slope coefficient. All estimates of the coefficients  $\beta_1$  are positive. The estimates for the slope coefficients  $\beta_0$  remain mainly in line with the estimates from the previous within regression from the pooled sample. The time trend for the HME+hub specification is more pronounced than for the HME version. Using, e.g., column (6), our estimates imply that the estimated  $\partial\lambda/\partial\theta$  is 0.925 in 1980 and 1.312 in 1999. This is a very substantial increase. Regarding columns (2) and (5), where geographical effects are fully sterilized, there is a positive time trend, too, but it is not statistically significant at standard levels of confidence. However, the estimated  $\beta_0$  is already fairly large to start with.

**Magnification effects and the freeness of trade.** We can further improve our analysis by directly exploiting the time variation of measured trade freeness on the industry level. For this purpose, we use Equation (3), and substitute  $\phi_{kt}^{narrow}$  or  $\phi_{kt}^{broad}$ . Since the broad measure has

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<sup>15</sup> $time = 0.01 (year - 1979)$ .

**Table 3:** Time trends and the demand-production nexus

Dep.var.: Production share $\lambda$						
	OLS estimates			Within estimates		
	(1) Naive	(2) HME	(3) HME+Hub	(4) Naive	(5) HME	(6) HME+Hub
Demand share $\theta$	0.958*** (0.020)	1.180*** (0.074)	1.128*** (0.025)	0.921*** (0.017)	1.547*** (0.353)	0.905*** (0.020)
$time \times \theta$	0.909*** (0.186)	0.766 (0.753)	2.245*** (0.245)	0.924*** (0.041)	0.762 (0.845)	2.034*** (0.061)
$time$	-0.048*** (0.006)	-0.046 (0.078)	-0.122*** (0.009)	-0.049*** (0.004)	-0.051 (0.090)	-0.108*** (0.005)
$R^2$ within	—	—	—	0.321	0.003	0.256
$R^2$ between	—	—	—	0.889	0.311	0.871
$R^2$ overall	0.880	0.074	0.859	0.880	0.074	0.859

Standard errors in parentheses. \*\*\*, \*\*, \* refer to  $p < 0.01$ ,  $p < 0.05$ ,  $p < 0.1$ .

8679 observations for all six regressions. Constant not reported.

Within regressions include country-industry fixed effects. OLS regressions include industry dummies and show robust standard errors.

The variable  $time$  is a measure for the time trend. **Naive** specification uses uncorrected variables. **HME** specification includes filtered production shares. **HME+Hub** specification captures demand shares in terms of nominal market potential.

been used to construct the independent variable  $\theta_{ikt}^{NMP}$  in the HME+Hub specification, and the dependent variable  $\lambda_{ikt}^{filter}$  in the HME specification, using the same measures of trade freeness in the interaction terms may seem problematic. However, this is hardly the case for the HME+Hub specification. An average decline in the degree of freeness does not affect the demand shares constructed from NMP at all. Changes in the share are really induced by bilateral changes in trade costs and thus by shifting weights, so that  $\theta^{NMP}$  does not contain information about the level of trade freeness. Problems from collinearity simply do not emerge. With regard to the filter, the mechanisms are more complicated because it is the independent variable which is manipulated. As the filtered production share is a function of the entity of bilateral trade costs, it may be inappropriate to include it on the right-hand side of the equation. Even though we are aware of this problem, we report results for this specification in order to be complete. In any case, no problem exists for the naive specification. Although it does not account for geography

effects, the magnification effect should be observable, if domestic expenditure is an increasingly important determinant for production. These issues do not arise when we use freight rates, since they have not been used to correct either  $\theta_{ikt}$  or  $\lambda_{ikt}$ .

Panel A in Table 4 reports our results when the demand share is interacted with the narrow measure of trade costs (i.e., freight rates). Across specifications and in both the within and the between models we find positive coefficients of the interaction term  $\phi^{\text{narrow}} \times \theta$ . They are large, because trade costs are measured at low scale. With the exception of the HME specification in column (2), the obtained coefficients are highly statistically significant, signaling the existence of magnification effects.

Panel B repeats the exercise, using the broad definition of trade freeness  $\phi^{\text{broad}}$  instead of the narrow one. Here, we find for every single specification and both econometric models that freer trade magnifies the effect of demand shares on the distribution of production. Our preferred specification is the one shown in column (3) of panel B, where time variance is used to identify the magnification effect based on NMP. Here, evaluating  $\partial\lambda/\partial\theta$  at the lowest realization of  $\phi^{\text{broad}}$  yields an estimate of 0.796 while at the highest realization we have 1.234. Again, this is a very substantial difference.

It is remarkable that the signs of the interaction terms and the magnitude of the coefficients are consistent for the within and between regressions. Head and Ries (2001) find reversed signs for the coefficients obtained from the within regressions (positive coefficient for the interaction of the expenditure share with trade costs). Here, the picture from the different regression exercises is unambiguous: lower trade freeness (i.e., higher freight rates), clearly decreases the responsiveness of the production share to changes in the demand share. The findings thus explicitly fit our expectations from theory and support the link between production and demand predicted by NTT.

**Table 4:** Freeness of trade and the demand-production nexus

Dep.var.: Production share $\lambda$						
<b>Panel A:</b> Narrow measure						
	Within estimates			Between estimates		
	(1) Naive	(2) HME	(3) HME+Hub	(4) Naive	(5) HME	(6) HME+Hub
Demand share $\theta$	0.805*** (0.020)	1.492*** (0.40)	0.565*** (0.023)	0.817*** (0.042)	0.564*** (5.98)	1.059*** (0.061)
$\phi^{narrow} \times \theta$	9.599*** (0.57)	5.556 (11.7)	18.19*** (0.86)	11.62*** (1.96)	33.97*** (5.98)	14.88*** (2.86)
$\phi^{narrow}$	-0.518*** (0.061)	-0.420 (1.26)	-0.977*** (0.073)	-0.625*** (0.20)	-1.836*** (0.62)	-0.796*** (0.24)
$R^2$ within	0.302	0.003	0.200	0.302	0.002	0.189
$R^2$ between	0.894	0.314	0.871	0.916	0.631	0.897
$R^2$ overall	0.884	0.075	0.857	0.885	0.076	0.860
<b>Panel B:</b> Broad measure						
	Within estimates			Between estimates		
	(1) Naive	(2) HME	(3) HME+Hub	(4) Naive	(5) HME	(6) HME+Hub
Demand share $\theta$	0.956*** (0.017)	1.265*** (0.352)	0.795*** (0.021)	0.947*** (0.022)	0.743*** (0.062)	1.226*** (0.031)
$\phi^{broad} \times \theta$	0.844*** (0.132)	18.91*** (2.658)	1.470*** (0.185)	5.154*** (0.809)	24.81*** (2.306)	6.520*** (1.165)
$\phi^{broad}$	-0.050*** (0.015)	-1.175*** (0.306)	-0.084*** (0.018)	-0.283*** (0.087)	-1.460*** (0.249)	-0.343*** (0.104)
$R^2$ within	0.282	0.009	0.161	0.916	0.680	0.898
$R^2$ between	0.891	0.344	0.874	0.225	0.008	0.145
$R^2$ overall	0.880	0.087	0.855	0.880	0.088	0.854

Standard errors in parentheses. \*\*\*, \*\*, \* refer to  $p < 0.01$ ,  $p < 0.05$ ,  $p < 0.1$ .

8679 observations for all six regressions. Constant not reported.

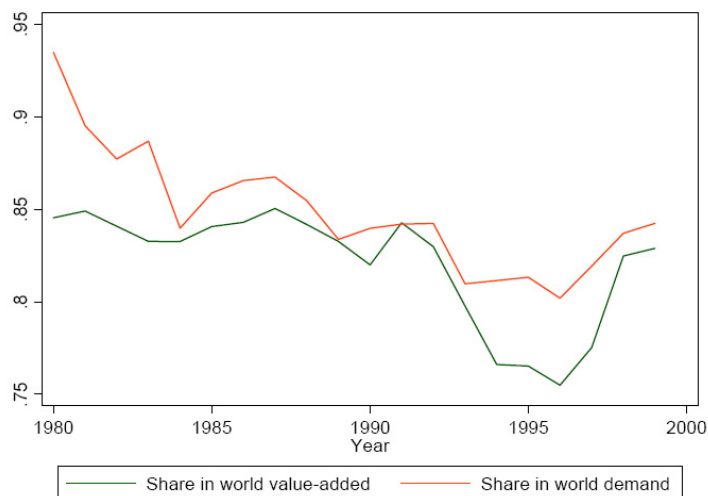
Within regressions include country-industry fixed effects. Between regressions use weighted least squares. .

**Naive** specification uses uncorrected variables. **HME** specification includes filtered production shares.

**HME+Hub** specification captures demand shares in terms of nominal market potential.

$\phi^{narrow}$  is our narrow measure for the freeness of trade calculated from underlying data on industry-specific freight rates.  $\phi^{broad}$  is the broader measure for the freeness of trade constructed from data on bilateral exports capturing all kind of impediments to trade.

**Figure 4:** Share of considered countries in total world demand and value-added



## 5 Caveats, robustness checks and additional results

### 5.1 Caveats

**Rest of the world.** One objection to our analysis may be that developments outside of our 20-country world—let us call them “rest-of-the-world” (ROW) effects—may drive results. However, it is difficult to anticipate how changes in the ROW should systematically influence the relationship of the production and the demand shares. One scenario is conceivable: Growing demand in the ROW could lead to increased production in some of the 20 countries, so that production relocates independent from changes in the distribution of demand among countries included in the sample. If in addition demand shifts in the same direction as production, then the regression will yield a high positive estimate for the slope coefficient, which is interpreted as HME, although it is entirely due to effects in the ROW. There may even be an endogeneity problem if domestic demand increases due to increased foreign demand, which would, in turn, bring with it higher domestic production and income. In order to investigate what happens in the ROW over time, we calculate the share of the 20 countries included in the dataset in world manufacturing using the complete set of 183 countries contained in the original production dataset provided by Mayer and Zignago (2005). Figure 4 shows a steady decline in the demand and production shares, while both shares move more or less in parallel. If some production and demand shifts similar to the

described scenario would be responsible for the time trend, we would expect to see diverging demand and production shares. If anything, the figure could be interpreted as support for NTT. It indicates that the gap between the production share and the demand share increases in the middle of the nineties. Therefore production seems to react over-proportionately to demand at this point.

**Table 5:** Instrumental variable regressions

Dep.var.: Production share $\lambda$			
	(1) Naïve	(2) HME	(3) HME+Hub
Demand share $\theta$	0.908*** (0.0447)	1.150*** (0.164)	0.968*** (0.0480)
$time \times \theta$	1.365*** (0.356)	0.980 (1.231)	2.866*** (0.287)
$time$	-0.0720*** (0.0140)	-0.0467 (0.140)	-0.158*** (0.0115)
$R^2$	0.874	0.061	0.862

Standard errors in parentheses. \*\*\*, \*\*, \* refer to  $p < 0.01$ ,  $p < 0.05$ ,  $p < 0.1$ .

6217 observations for all six regressions. Constant not reported.

The demand shares are instrumented with 5-year lags.

The variable  $time$  is a measure for the time trend. **Naïve** specification uses uncorrected variables. **HME** specification includes filtered production shares. **HME+Hub** specification captures demand shares in terms of nominal market potential.

**Simultaneity bias.** A general problem is simultaneity bias. When current production is regressed on current demand, simultaneity can arise from contemporaneous correlations as industry shocks may equally affect the production and the demand side. However, as absorption is overall demand for differentiated goods constructed as residual between the total value of production and net trade, whereas production is industry-specific value-added, this problem should not be too severe. Moreover, measurement errors affecting the production and the demand variables at the same time could lead to biased results. Yet if this was the case,  $\hat{\beta}_0$  and  $\hat{\beta}_1$  would be biased downwards, which for our purpose of testing  $\beta_0 > 1$  and  $\beta_1 > 0$  should not



harm conclusions either.<sup>16</sup> To mitigate simultaneity concerns, we instrument demand by lagged values and run instrumental variable regressions. Table 5 reports results for 5-year lags. The instrumental variable regression shows a similar picture as Table 3, while the time trend in the slope coefficient is even more pronounced with slightly higher estimates for  $\beta_1$ .

## 5.2 Other robustness checks

**Table 6:** Industry-specific demand shares

Dep.var.: Production share $\lambda$						
	OLS estimates			Within estimates		
	(1) Naive	(2) HME	(3) HME+Hub	(4) Naive	(5) HME	(6) HME+Hub
Demand share $\theta$	0.994*** (0.0121)	1.240*** (0.0936)	1.126*** (0.0245)	0.886*** (0.0122)	1.332*** (0.284)	0.544*** (0.0136)
$time \times \theta_k$	0.764*** (0.133)	0.735 (0.929)	1.536*** (0.250)	0.695*** (0.0359)	0.562 (0.838)	1.086*** (0.0540)
$time$	-0.0434*** (0.00444)	-0.0488 (0.0902)	-0.0919*** (0.00916)	-0.0401*** (0.00386)	-0.0451 (0.0899)	-0.0618*** (0.00495)
$R^2$ within	—	—	—	0.458	0.003	0.237
$R^2$ between	—	—	—	0.948	0.349	0.888
$R^2$ overall	0.939	0.083	0.864	0.939	0.083	0.863

Standard errors in parentheses. \*\*\*, \*\*, \* refer to  $p < 0.01$ ,  $p < 0.05$ ,  $p < 0.1$ .

8679 observations for all six regressions. Constant not reported.

Within regressions include country-industry fixed effects. OLS regressions include industry dummies and show robust standard errors.

The variable  $time$  is a measure for the time trend. Demand is proxied by the a country's industry-specific demand. **Naive** specification uses uncorrected variables. **HME** specification includes filtered production shares. **HME+Hub** specification captures demand shares in terms of nominal market potential.

Following Crozet and Trionfetti (2008), we use a modified measure of nominal market potential which varies along the sectoral dimension instead of the conventional variable which varies only across time and countries. Table 6 shows that the positive time trend perfectly survives

<sup>16</sup>Other simultaneity problems related to testing the HME and possible reversed causation problems are discussed in Head and Ries (2001) and Davis and Weinstein (2003). High national production of certain goods due to comparative advantages and low factor prices may lead to low prices, which could generate high demand. However, as the authors argue, this is unlikely to drive results.

the introduction of industry-specific demand as proxy for  $\theta$  and coefficients do not significantly change compared to Table 3. This is somewhat surprising for one would expect a positive bias because the simultaneity problem is likely to aggravate when industry production is regressed on industry-specific demand of the same period. Qualitative results survive for all regression exercises.

**Table 7:** Production share proxied by total value of production

Dep.var.: Production share $\lambda$	HME+Hub specification			
	Within estimates		Between estimates	
	(1)	(2)	(3)	(4)
	$\phi^{broad}$	$\phi^{narrow}$	$\phi^{broad}$	$\phi^{narrow}$
Demand share $\theta$	0.812*** (0.0129)	0.762*** (0.015)	1.109*** (0.028)	0.960*** (0.056)
$\phi \times \theta$	0.717*** (0.114)	4.168*** (0.54)	5.741*** (1.064)	13.16*** (2.61)
$\phi$	-0.0409*** (0.0108)	-0.210*** (0.046)	-0.287*** (0.0952)	-0.690*** (0.22)
$R^2$ within	0.334	0.336	0.280	0.329
$R^2$ between	0.878	0.880	0.896	0.895
$R^2$ overall	0.873	0.875	0.872	0.876

Standard errors in parentheses. \*\*\*, \*\*, \* refer to  $p < 0.01$ ,  $p < 0.05$ ,  $p < 0.1$ .

8679 observations for all six regressions. Constant not reported.

Within regressions include country-industry fixed effects. OLS regressions include industry dummies and show robust standard errors. Production is proxied by the total value of production.

The variable *time* is a measure for the time trend. All regressions use the **HME+Hub** specification, which captures demand shares in terms of nominal market potential.

As alternative to value-added as proxy for production, we use the total value of production as measure for the firm distribution. Table 7 presents results for the HME+Hub specification which is the one closest to the policy issue identified in the introduction. Interaction terms between trade costs and demand shares remain positive and statistically highly significant. Hence, our robustness checks indicate that there is a strong time trend in the parameter that links industrial output shares and demand shares. We feel therefore save to conclude that freer trade has indeed contributed towards decoupling the cross-country distribution of industrial production from that

of population.<sup>17</sup>

## 6 Conclusion

In this paper we have investigated the effect of lower trade costs on the distribution of industrial production across countries. New trade theory models predict that larger and/or more central countries attract an over-proportional share of firms, thereby also accounting for an over-proportionally large share of industrial production. The models further predict that the distribution of firms over countries becomes increasingly skewed as trade becomes freer.

We use a dataset of 20 OECD countries and 20 years, which covers 26 sectors of industrial production. Drawing on recent work by Behrens et al. (2007), we propose to empirically dissect the two main channels through which the freeness of trade affects the distribution of firms: the size of the firms' home market, and the so called hub effect. This allows to isolate the effect of market size from that of geographical location. This distinction is interesting and relevant; however, policy makers probably care most about the total effect of trade costs on the distribution of firms. We run three empirical specifications which correspond to a naive regression, one that isolates home market effects, and one that informs about the total role of market potential for the location of firms.

Reporting results for pooled OLS, within, and between regressions, we discover how trade costs condition the link between market shares and production shares: when trade is freer, production becomes more concentrated. This finding is strikingly robust: it turns up regardless of the precise way by which trade freeness is measured. Hence, the empirical picture suggests that policy makers have some reason to worry that falling trade costs (globalization) do indeed increase spatial disparities in the distribution of industrial production.

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<sup>17</sup>We have also carried out our empirical work industry-by-industry. In most differentiated industries we find a positive trend in the  $\beta$  coefficient. Results are available on request.

## Data Appendix

### 6.1 The dataset

Data on production and bilateral trade comes from the Trade, Production and Bilateral Protection Database provided by Mayer and Zignago (2005) from CEPII (Centre d'Études Prospectives et d'Informations Internationales)<sup>18</sup>. It provides detailed data for three-digit ISIC Rev.2 manufacturing industries.

**Time period:** from 1980 to 1999.

**Countries:** Australia, Austria, Denmark, Finland, France, Germany, Great Britain, Greece, France, Ireland, Italy, Japan, Spain, the Netherlands, New Zealand, Norway, Portugal, Sweden, Turkey and the United States.

**Industries:** Data on industry classifications were directly taken from Behrens et al. (2007), who classify industries using information from Lyons and Sembenelli (1997) into homogeneous and heterogeneous industries according to R&D expenditure and expenditure on advertisement. Table 8 displays industries and their classification.

Observations with negative absorption (hence, higher exports than production plus imports) were dropped from the beginning, which is in line with the handling of Hanson and Xiang (2004) and Behrens et al. (2007). In order to maintain as much information as possible, we work on an unbalanced dataset and use regression techniques for unbalanced panels when it is adequate to do so. We keep all observations, which are available for all three production-demand specifications and for which we have information on freight rates. This yields a total of 8679 observations.

### 6.2 Definitions and data sources of different variables

#### Three specifications

We use three different production-demand specifications:

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<sup>18</sup><http://www.cepii.fr/anglaisgraph/bdd/TradeProd.htm>

**Table 8:** Industries and their classification

ISIC (Rev.2)	Industry name	Type of good
311	Food products	homogeneous
313	Beverages	heterogeneous
314	Tobacco	heterogeneous
321	Textiles	homogeneous
323	Leather products	homogeneous
324	Footwear	homogeneous
331	Wood products except furniture	homogeneous
332	Furniture except metal	homogeneous
341	Paper and products	homogeneous
342	Printing and publishing	homogeneous
351	Industrial chemicals	heterogeneous
352	Other chemicals	heterogeneous
353	Petroleum refineries	-
355	Rubber products	heterogeneous
356	Plastic products	homogeneous
361	Pottery china earthenware	-
362	Glass and products	homogeneous
369	Other non-metal min. prod.	homogeneous
371	Iron and steel	homogeneous
372	Non-ferrous metals	homogeneous
381	Fabricated metal products	heterogeneous
382	Machinery except electrical	heterogeneous
383	Machinery electric	heterogeneous
384	Transport equipment	heterogeneous
385	Prof. and sci. equipment	heterogeneous
390	Other manufactured products	-

- 1) **Naive** specification: Independent variable  $\lambda_{ikt}^{observed}$ , dependent variable  $\theta_{it}^{observed}$ ,
- 2) **HME** specification: Independent variable  $\lambda_{ikt}^{filter}$ , dependent variable  $\theta_{it}^{observed}$ ,
- 3) **HME+hub** specification: Independent variable  $\lambda_{ikt}^{observed}$ , dependent variable  $\theta_{it}^{NMP}$ .

The four different variables are constructed as follows:

$\lambda_{ikt}^{observed}$ :

$$\lambda_{ikt} = \frac{Q_{ikt}}{\sum_j Q_{jkt}}, \quad (4)$$

where  $Q_{ikt}$  is production of country  $i$  in industry  $k$  at time  $t$ , proxied by data on value-added.

$\lambda_{kt}^{\text{filter}}$  (the vector of filtered production shares with dimension  $i$ ):

$$\lambda_{kt}^{\text{filter}} = b_{kt} W_{kt}^{-1} \left( \lambda_{kt} - \left(1 - \frac{1}{b_{kt}}\right) \lambda_{kt}^{\text{hub}} \right), \quad (5)$$

where

$$b_{kt} = \frac{1 + (M-1)\phi_{kt}}{1 - \phi_{kt}}, \quad \lambda_{kt}^{\text{hub}} = \frac{1}{M} W_{kt} \mathbf{1} \quad \text{and} \quad W_{kt} = [\text{diag}((\Phi_{kt})^{-1} \mathbf{1}) \Phi_{kt}]^{-1},^{19} \quad (6)$$

with the trade costs matrix  $\Phi_{kt}$  containing the elements  $\phi_{ijkt}$ . The mathematical relation presented in Equation (5) has been derived by BLOT from their theoretical model.  $\phi_{kt}$ , the average degree of trade freeness in industry  $k$  at time  $t$  is computed as

$$\phi_{kt} = \frac{1}{M(M-1)} \sum_{i=1}^M \sum_{j \neq i} \phi_{ijkt}. \quad (7)$$

Assuming costless internal trade and symmetric bilateral trade costs, such that  $\phi_{iikt} = 1$  and  $\phi_{ijkt} = \phi_{kjit}$  for all industries  $k$  and all point in time  $t$ , we calculate  $\Phi_{ijkt}$  as follows:

$$\phi_{ijkt} = \sqrt{\frac{X_{ijkt} X_{jikt}}{X_{iikt} X_{jjkt}}}, \quad (8)$$

where  $X_{ijkt}$  are exports of country  $i$  to country  $j$  in industry  $k$  at time  $t$ .<sup>20</sup>

$\theta_{it}^{\text{observed}}$ :

$$\theta_{it} = \frac{\sum_k D_{ikt}}{\sum_j \sum_k D_{jkt}}, \quad (9)$$

where  $D_{ikt}$  is absorption in country  $i$  and industry  $k$  at time  $t$ . It is constructed as  $D_{ikt} = Y_{ikt} + M_{ikt} - X_{ikt}$ , where  $Y_{ikt}$  is the total value of production,  $M_{ikt}$  the value of imports and  $X_{ikt}$  the value of exports respectively.

$\theta_{it}^{\text{NMP}}$ :

$$\theta_{it}^{\text{NMP}} = \frac{\sum_k \text{NMP}_{ikt}}{\sum_j \sum_k \text{NMP}_{jkt}}, \quad (10)$$

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<sup>19</sup>Note matrix notation here.  $\mathbf{1}$  is the unit vector.

<sup>20</sup>The expression is formally derived by Head and Mayer (2004). As Behrens et al. (2007) argue, it is imperfect as it should rather be the geometric mean of the  $\phi_{ijkt}$ 's. However, since there are zeros and missing values for bilateral trade flows at the industry level in the data, this is not feasible.

where NMP is the nominal market potential of country  $i$  in industry  $k$  at time  $t$ . It is constructed as the distance-weighted sum of market shares:

$$NMP_{ikt} = \sum_j D_{jkt} \phi_{ijkt}, \quad (11)$$

where  $D_{jkt}$  is absorption and  $\phi_{ijkt}$  the average freeness of trade.

## Time and freeness of trade

**Variable time:**  $time = t/100$  for  $t = 1, 2, \dots, 20$ . The magnitude of the estimates were adjusted to level the estimate from our measures for trade freeness.

**Narrow measure  $\phi_{kt}^{narrow}$ :** Freight rate data has been produced by Bernard et al. (2006) and is available on Schott's International Economics Resource Page<sup>21</sup>. Data is provided at the four-digit usSIC87 industry level and is calculated from product-level US import data. Ad-valorem freight rates are calculated as the mark-up of the cost-insurance-freight (c.i.f.) value over the f.o.b. value. For the translation of the data to ISIC Rev.2, we have used the industry concordance tables provided by Statistics Canada<sup>22</sup> and the United Nations Statistical Division.<sup>23</sup> data, we have aggregated freight rates by taking means over the four-digit industries. The resulting freight rates were used to construct the freeness of trade as  $\phi_{kt}^{narrow} = (freight\ rate)_{kt}^{-1}/1000$ , assuming a constant elasticity of substitution of 2 for all industries. The magnitude of the estimates were adjusted to level the estimate from our broad measure.

**Broad measure  $\phi_{kt}^{broad}$ :** constructed as described by Equation (7) and (8).

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<sup>21</sup>[http://www.som.yale.edu/faculty/pks4/sub\\_international.htm](http://www.som.yale.edu/faculty/pks4/sub_international.htm)

<sup>22</sup><http://www.maclester.edu/research/economics/PAGE/HAVEMAN/Trade.Resources/TradeConcordances.html>

<sup>23</sup><http://unstats.un.org/unsd/cr/registry/regot.asp?Lg=1>In order to finally obtain three-digit level

## Summary statistics

**Table 9:** Summary statistics

Variable	Mean	Std. Dev.	Min.	Max.
Demand share $\theta^{observed}$	0.053	0.089	0.002	0.433
Industry-specific demand share $\theta^{observed*}$	0.054	0.091	0.001	0.648
Demand share $\theta^{NMP}$	0.052	0.069	0.003	0.358
Industry-specific demand share $\theta^{NMP*}$	0.054	0.073	0	0.492
Value-added $\lambda^{observed}$	0.054	0.100	0.000	0.718
Total value of production $\lambda^{observed*}$	0.054	0.090	0	.622
Filtered value-added $\lambda^{filter}$	0.053	0.412	-24.379	13.003
Filtered total value of production $\lambda^{filter*}$	0.053	0.494	-33.076	14.281
<i>time</i>	0.103	.057	0.01	0.2
Freeness of trade $\phi^{narrow}$	0.020	0.008	0.005	0.048
Freeness of trade $\phi^{broad}$	0.020	0.024	0.001	0.312

Dataset covers 20 years, 20 countries, 26 industries. Number of observations is 8,679.

\* indicates variables used for robustness checks.



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