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The bell-shaped curve of international trade openness: a panel data test for OECD countries

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■ **Abstract**: By partially following Head and Mayer's (2003) suggestions, in this paper we test Puga's (1999) fundamental bell-shaped relationship between trade openness and agglomeration in the industrial sector. The main result is that concentration of both employment and production may arise if a pair of countries is involved in a process of trade liberalization.

■ **Resumen**: Siguiendo parcialmente las sugerencias de Head y Mayer (2003), en este trabajo se prueba la relación fundamental de Puga (1999) entre apertura comercial y aglomeración en el sector industrial. El resultado principal es que la concentración del empleo y la producción pueden surgir si dos países entran en un proceso de integración.

■ **Key words**: Trade openness, agglomeration, international trade cost, spatial pattern of production.

■ **JEL code**: F12, F14, F15

■ *Introduction*

A key issue for the future development of the world economy is the impact of international trade openness on the spatial pattern of production, welfare and trade (Venables, 1998; Forslid and Ottaviano, 2003). This issue, for example, was at the center of the political debate

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over the North American Free Trade Agreement (NAFTA). Most U.S. congressional representatives from districts near Mexico strongly supported it, while those from districts near Canada voted against it. Such an attitude toward NAFTA reflects the perception that firms would move away from the northern states to the south to reach new markets (Hanson, 1998).[2] Indeed, this concern is supported by Hanson (1996). Another example were the spatial implications of the European Union (E.U.) enlargement by the end of 2004 (Venables, 1995).

In this context, Puga's (1999) New Economic Geography (NEG) setting explains firms' incentives to locate in a particular country for different levels of economic integration between a pair of countries. At high levels of trade costs, firms decide to locate according to market size considerations. At low levels of such costs, nominal wage differentials drive firms' location decisions. In the case of intermediate levels, firms focus their attention on both backward and forward linkages.[3] The main implication of these outcomes is a non monotonic relationship between trade openness and industrial concentration. In particular, a bell-shaped curve arises: dispersion of both industrial and agricultural activities are predicted when trade costs are either low or high; and industrial concentration in one country and agricultural concentration in the other at intermediate trade costs levels.

Puga's model consists of two countries, home and foreign; in each there are two sectors, industrial and agricultural. The former employs labor and all products as inputs; and the latter employs only labor. The market structure associated with each sector is monopolistic competition and perfect competition, respectively. Labor migration is allowed across sectors but not across countries. Assuming that industrial firms in the foreign country face zero profits, and wages are equal across sectors in both countries, then all industrial firms in the home country face the same profits that might be different from zero.[4] If they are positive, new firms have incentives to enter. As a result of this shift, new conditions arise through four channels. On the one hand, a new firm means a new product

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2 During 2006 there was also an open opposition in the U.S. media against the Central American Free Trade Agreement.

3 Downstream firms constitute the market for upstream firms, therefore, in order to increase their sales and profits, the latter locate where the former are relatively abundant. This is the backward link. On the other hand, the concentration of upstream firms lowers downstream firm's costs through different channels: by saving trade costs, by facing lower prices due to fiercer competition in the input market; and a large variety of differentiated goods. This is the forward link.

4 This situation depends on the level of trade costs and the number of firms in the home country.

variety and stronger competition leading to a lower price index. The fact that labor demand is higher drives nominal wages up. In both cases, profits are negatively affected in the home country. On the other hand, a lower price index means lower costs that reinforces backward linkages. Furthermore, both consumers and firms, by modifying their expenditure composition in favor of local products strengthen forward linkages. Both effects push profits up. Firms stop clustering together up to where the net effect is zero. If originally profits are negative, then firms flee the market.

At the local level, Krugman's (1991) seminal core-periphery (CP) model explains industrial agglomeration as a result of pecuniary externalities that market size generate through a self-reinforcing process.[5] It predicts full agglomeration for low trade costs and dispersion for high trade costs.[6] After Krugman, some analytically solvable CP models have been developed. Baldwin (1999), on the one hand, argues that factor accumulation causes agglomeration by ruling out factor mobility. Departing from Dixit and Stiglitz (1977), on the other hand, in Ottaviano *et al* (2002), preferences are represented by quadratic utility; transport costs are not iceberg type; and equilibrium incorporates strategic interactions. The symmetric equilibrium is feasible for high levels of trade costs. They also pay special attention to welfare implications of agglomeration reached by market interactions. Without droping the essential features of CP models, Forslid and Ottaviano also develop an analytically solvable model by introducing skill and mobility heterogeneity among manufacturing workers, which mimics Krugman's outcomes. However, the final outcome might not depend on the initial distribution of the population but on the asymmetries between regions in terms of population.

At the international level, Krugman and Venables (1995) predict that for low levels of international openness, industry is evenly distributed across countries. As trade costs fall, real wages converge, however, the distribution of industry agglomerates in a single country. As Krugman also predicts, the relationship between trade costs and industry concentration is non-monotonic, non-linear and discontinuous.[7] In addition, a relevant conclusion is that industrial concentration forces, factor prices, linkages and market size weight change for different levels of trade costs. By the same token, Venables (1996) conceives agglomeration as a result

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5 The NEG literature can be divided according to two mechanisms of agglomeration. One allows labor mobility, which is a distinctive feature at the regional level. The other is incorporating backward and forward linkages but impedes labor mobility across space, which is a distinctive feature at the international level.

6 Agglomeration means that manufacturing mobile labor is concentrated in one region.

7 It is worth noticing that Krugman and Venables focus their analysis on welfare consequences of economic integration.

of links between downstream and upstream firms. Some firms produce exclusively intermediate goods and others final goods. For intermediate trade costs divergence of industry and income is a feasible outcome, whereas for both low and high trade costs even industrial distribution is the equilibrium outcome, and income converges.

Puga nests Krugman, and Krugman and Venables settings by assuming that the agricultural technology might have both a common factor (labor) with the manufacturing sector and a specific immobile factor (land), respectively. Besides, in the latter case, such a technology might be not linear with respect to labor such that the discontinuity is eliminated and the bell-shaped curve of trade openness arises. Fujita *et al* (1999) is a particular case of Puga with a concave agricultural technology and an expenditure share of manufacturing, $\mu>0.5$.

Puga and Venables (1997) cope with the locational effects of geographically discriminatory trade policies by considering three cases: global integration, free trade areas and hub-and-spoke arrangements. Under global integration, an asymmetric equilibrium arises where its precise characterization varies with the number of nations involved, and the share of industry in consumer expenditure. In the second case, the countries within the area converge in welfare but not in industrial share. The country outside the area is negatively affected in terms of welfare and industrial share. In the last case, the number of firms and welfare increases in all countries, however, the change is larger for the hub than for the spokes. As integration proceeds, welfare converges but not thoroughly. Picard and Zeng (2005) assume that agricultural goods are costly to trade and heterogeneous across regions; there is labor and mobility heterogeneity; preferences are represented by a quadratic utility. The former assumption plays a crucial role in determining industrial structure. Given sufficiently low levels of agricultural trade costs, industrial concentration might arise for intermediate trade costs in the manufacturing sector. For high levels of such costs, dispersion is the only feasible equilibrium irrespective of the level of manufacturing trade costs.

On the empirical side, Forslid *et al* (2002) apply a full scale Computable General Equilibrium (CGE) model to investigate whether the outcomes and rationale of stylized NEG models remain valid in a more complex world. By simulation they show the production pattern in different sectors as trade costs are reduced between four European regions. The most striking result is related to the textile, leather and food sectors, which show a monotonic increase in agglomeration. For example, the textile industry moves out of Central into West and South because it has relatively strong within-industry linkages. South has a comparative advantage in the production of labor intensive goods as textiles. They also simulate the location effects on industry at the aggregated level in Europe. Textiles, leather products and food products concentrate in Europe with respect to the rest of the world as trade barriers fall; while metals, machinery and chemicals decreases. In the former case, a combination of comparative advantage factors and vertical linkages explain such movements. The latter is explained basically by increasing returns to scale.

At the regional level, Combes and Lafourcade (2004) evaluate the relevance of concentration and dispersion forces contemplated in NEG models for France. They find that for the center (Paris) and its periphery (Marseille), firms' mark-ups are higher than the middle point (Lyon). In the former case, low trade costs offsets competition; in the latter case, lower competition outweighs high trade costs. Furthermore, the economy displays a mono-centric pattern where Paris has larger profits that go down as firms move out. Wen (2004) assesses the spatial pattern of the Chinese manufacturing sector from 1980 to 1995. From 1953 to 1978, industrial location was not determined by economic concerns but by military considerations. He finds that as a result of economic reforms, Chinese industry become more geographically concentrated in coastal areas triggering regional income disparity. Industry location is motivated by market size considerations and foreign-related investment.

Redding and Venables (2004), by using NEG ideas, find that variations in per capita income can be explained by the access to markets and sources of supply. Their main results are that market access is statistically significant to explain GDP per capita across countries. In the same sprit, Redding and Venables (2003) decompose South East Asian export's rate of growth into the contributions of improvements due to external demand and increased external supply.

It is worthwhile mentioning that spatial pattern of production and economic development can also be explained by first nature geography differences such as climate, global position, ecology, etc. (Fuchs, 1962; Kim, 1995; Gallup *et al*, 1998; Ellison and Glaeser, 1999; Démurger *et al*, 2002).

In this paper, we test the bell-shaped relationship between industrial gap and trade costs by partially following Head and Mayer's (2003) suggestions, who confront estimates of trade openness and the range in which agglomeration takes place.[8] More precisely, by using the

8 Brakman et al (2005) apply the equilibrium wage equation to estimate two key structural model parameters for the NUTS II EU regions to estimate a trade openness parameter. NUTS II stands for Nomenclature of Territorial Units for Statistics.

calibration method we obtain the parameters related to technology and preferences to determine the range of trade openness in which some degree of concentration is theoretically predicted. On the other hand, from a standard NEG model, an estimate of trade openness is obtained from bilateral trade and production data. Hence, we can construct a variable defined as the absolute difference between the trade openness estimate and the middle point of the agglomeration interval. The higher the level of such a variable the further the distance to intermediate costs. A relative industrial gap measure can be regressed on such a variable after controlling for country and time. The fundamental hypothesis of this work is a negative impact of the constructed variable on the concentration variable. We use information over 14 years, 28 OECD countries and 29 industrial sectors; and three proxies of industrial agglomeration: employment gap, production gap and employment share of sector gap. By using the former two dependent variables Puga's predictions are corroborated when the constructed variable comes from a pair of countries. This paper is divided into 5 sections. Section 2 is our theoretical framework. Section 3 describes how we implement the data and sets the hypotheses to be tested. Section 4 is the data description. And section 5 reports the main findings, and have some final remarks.

■ *Theory*

We outline a particular case of Puga: Fujita *et al*, which assumes a strictly concave production function in the agricultural sector with respect to labor; $\mu\varepsilon(0.5, 1]$, the expenditure share of manufactures; and no labor mobility across regions.[9] Puga removes the exotic dynamics of Krugman, particularly, the discontinuity feature. However, in both works the curve that relates trade costs and agglomeration is neither linear nor monotonic.

This model nests three interpretations of economic development. Given high levels of international trade costs, economic integration promotes industry concentration and real wage differentials. Such a perspective is consistent with the "import-substitution" paradigm that prevailed from the 1950s through the 1960s (Krueger 1997; Edwards, 1993). During the 1970s, a shift in the conventional wisdom arose and is consistent for

9 It is worth mentioning that both Puga and Fujita et al do not provide enough information to replicate their examples in a straightforward way. On the one hand, Puga does not specify the share of labor in agriculture. On the other hand, in Fujita *et al* the value of the parameter related to the specific factor in the agricultural sector is not provided. By simulation it can be obtained though.

intermediate trade costs: globalization negatively impacts living standards among advanced countries whereas in developing countries the effect is beneficial (Krugman and Venables). If integration is deepened industrial dispersion is reached and wages increase for all countries (Puga).

In a broader time span a similar story is told by Baldwin *et al* (2001). In the first stage (pre-industrial revolution), even industry dispersion is associated with high trade costs. As such costs keep falling a North-South gap arises and such situation is self-sustaining. For low trade costs the gap is reduced in terms of income.

■ *The model*

The economy consists of J countries, endowed with L_j agents (consumers/workers), respectively. In each country there are two sectors, manufacturing and agriculture. The market structure of the former is monopolistic competition and the latter perfect competition. Agents can move across sectors but not across countries. λ_j denotes the fraction of the labor force employed in the manufacturing sector and (1- λ_j) in the agricultural sector in country j, where $L_j=1$.

International trade costs are of the Samuelson (1952) type: $T_{ji}\geq 0$ denotes the amount of any manufacturing good dispatched from country j per unit received in country i.[10] If $j\neq i$, then $T_{ij}=T_{ji}=T>1$, otherwise, $T_{ji}=1$. There are no trade costs in the agricultural sector.[11]

The representative agent in country j derives her utility from the consumption of N varieties of manufactures and from the agricultural good. Her preferences are represented by

$$U_j=\left[A_j\right]^{\mu}\left[\left(\sum_{n=1}^{N}c_{nj}^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}}\right]^{1-\mu} \tag{1}$$

where c_{nj} is the consumption of variety n in country j. A_j is the consumption of the agricultural good in country j. As mentioned above, μ represents

10 For Limao and Venables (2001, p. 470), the cost of doing international business depends on geography, infrastructure, administrative barriers (eg. tariffs) and the structure of shipping industry (eg. carriage, freight and insurance).

11 Davis (1998) finds that the assumption of no trade costs in the agricultural sector 'matters a great deal". More precisely, industrial structure across space depends upon the relative size of trade costs in differentiated and homogenous industries.

the expenditure share of manufactured goods. σ is the elasticity of substitution between any pair of varieties, and also represents love for variety. For example, when $(\sigma\text{-}1)/\sigma$ is close to 1 varieties are nearly perfect substitutes. $N=n_h+n_f$ denotes the number of available varieties produced in both countries.

At the level of the firm, manufacturing exhibits increasing return to scale. The quantity of labor and inputs required to produce q units of variety n in country j is

$$F + vq_{nj} = \alpha^{-\alpha}(1-\alpha)^{\alpha-1} l_{nj}^{\;1-\alpha}\left[\sum_{r=1}^{N} x_r^{\rho}\right]^{\frac{\alpha}{\rho}}, \tag{2}$$

where F and v are fixed and marginal costs, respectively. The firm that produces variety n in country j pays a nominal wage w_{nj} for one unit of labor l_{nj}, and pays p_{nj} for one unit of variety n as an intermediate input. In order to characterize the equilibrium, $F=1/\sigma(1\text{-}\alpha)$ and $v=(\sigma\text{-}1)/\sigma$.[12] The number of firms in each country is endogenous.

The agricultural technology in country j is represented by a Cobb-Douglas function. In particular, it takes the form of

$$A(1-\lambda_j) = \frac{1}{\gamma} K^{1-\gamma}\left(1-\lambda_j\right)^{\gamma}, \tag{3}$$

where K is a fixed specific factor. γ is the share of labor in agriculture. It exhibits constant returns to scale in both factors.[13]

There are two types of prices: mill (or f.o.b) and delivered (or c.i.f.).[14] The former is charged by firms. The latter, paid by consumers, is defined as

$$p_{ji}^{n} = p_j^{n} T, \tag{4}$$

where p_j^n denotes the mill price of variety n produced in country j. p^n_{ji} is the delivered price of variety n, produced in country j and consumed in country i.

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12 To assume a particular value of F means to choose units of production such that $q^*=1/(1\text{-}\alpha)$. To assume a particular value of v allow us to characterize the equilibrium without loss of generality.

13 Puga opens the possibility of different forms of the production function.

14 f.o.b. stands for free on board and c.i.f. for carriage, insurance and freight.

The economy reaches its short-run equilibrium when both agents and firms optimize their utility and profit functions respectively such that the excess demands in the labor and product markets are zero. Nominal wages, however, may differ across the sectors.

Assumptions on agent's preferences, trade costs, technology parameters, free entry and exit of firms and a potentially unlimited value of N allow the characterization of the equilibrium as follows. Regarding the manufacturing sector, profits are zero and since there are no economies of scope, each firm produces a single variety. Every firm hires the same amount of labor irrespective of the variety they produce and its location, therefore the level of production across varieties is equal. Every firm uses all varieties as inputs; however, the optimal input combination might differ across countries. Within a country, manufacturing mill prices are equal across varieties. Regarding the agricultural sector, wages are equal to the marginal product of labor and its associated price is normalized to 1. Agents consume all varieties. Within a country consumption across agents is identical and the price index is equal for both consumers and firms. From this characterization, the short run equilibrium, given λ_h and λ_f, can be redefined as a vector:

$$\{n_j^*, w_{jm}^*, w_{ja}^*, q^*, l^*, A_{1ja}^*, A_{1jm}, A_{2ja}^*, A_{2jm}, p_j^*, c_{1ja}^*, c_{2ja}^*, c_{1jm}^*, c_{2jm}^*\}$$
for j=1 and 2 such that

(e.1) $\{c_{1jm}^*, c_{2jm}^*, A_{1jm}^*, A_{2jm}^*\}$ Max $U(c_{1jm}, c_{2jm}, A_{1jm}, A_{2jm})$

s.t. $Y_j = \lambda_j w_{jm}^* = \lambda_j(n_1^* c_{1jm} T_{1j} p_1^* + n_2^* c_{2jm} T_{1j} p_2^* + A_{1jm}^* + A_{2jm}^*)$
for j=1 and 2,

(e.2) $\{c_{1ja}^*, c_{2ja}^*, A_{1ja}^*, A_{2ja}^*\}$ Max $U(c_{1ja}, c_{2ja}, A_{1ja}^*, A_{2ja})$

s.t. $Y_j = A(1-\lambda j)A'(1\lambda j) = (1-\lambda_j)(n_1^* c_{1ja} T_{1j} p_1^* + \lambda_j n_2^* c_{2ja} T_{2j} p_2^* + A_{1ja}^* + A_{2ja}^*)$ for j=1 and 2

(e.3) $\{q^*\}$ Max $p_j^* q - p_j^*(F+vq)$ for j=1 or 2[15]

15 The quantity produced by any firm q^*, can be obtained using p_1 or p_2.

(e.4) $A(1-\lambda_1)+A(1-\lambda_2)=(1-\lambda_1)A_{ja}^*+\lambda_1 A_{jm}^*+(1-\lambda_2)A_{ja}^*+\lambda_2 A_{jm}^*$
for j=1 and 2

(e.5) $q^*=(1-\lambda_1)c_{j1a}^*+(1-\lambda_2)c_{j2a}^*+\lambda_1 c_{j1m}^*+\lambda_2 c_{j2m}^*+n_1^* x_{j1}^*+n_2^* x_{j2}^*$
for j=1 and 2

and

(e.6) $n_j^* l^*=\lambda_j$ for j=1 and 2.

If equilibrium is feasible for a given set of parameters, then any population distribution between sectors in both countries can support the short-run equilibrium. The model does not have a closed-form solution. Thus one needs to solve it numerically. The equilibrium must satisfy a system of non-linear equations. The c_{jis} and A_{jis} denote the consumption of a manufacturing variety and an agricultural good respectively, produced in country *j*, consumed in country *i* by an agent in sector *s*. w_{js} is the nominal wage in country *j* in sector *s*.

(e.1) and (e.2) are the optimal consumption of the representative agent in country 1 and 2, respectively. The maximization of her utility is subject to a budget constraint, where her income can be expressed either at the individual level w_j, or at the aggregate level, $\lambda_j w_j$. The individual consumption in location *i* of all varieties produced in country *j* is denoted by $n_j c_{ji}$. (e.3) is the optimal level of production by any firm. The assumptions of the model allow one to obtain q^* irrespective of the price and wage associated with a particular variety. (e.4) and (e.5) are the equilibrium conditions in the differentiated and homogenous product market. (e.6) is the equilibrium condition in the labor market.

For *j*=1 and 2, the equilibrium must satisfy the following system of *2x2* non-linear equations,

(5) $$G_j=\left[\sum_{s=1}^{2}\lambda_s w_s^{1-\sigma\,(1-\alpha)} G_s^{-\alpha\sigma} T_{sj}^{1-\sigma}\right]$$

and

(6) $$\frac{(w_j^{1-\alpha} G_j^{\alpha})^{\sigma}}{1-\alpha}=\left[\sum_{s=1}^{J} E_s G_s^{\sigma-1} T_{sj}^{1-\sigma}\right].$$

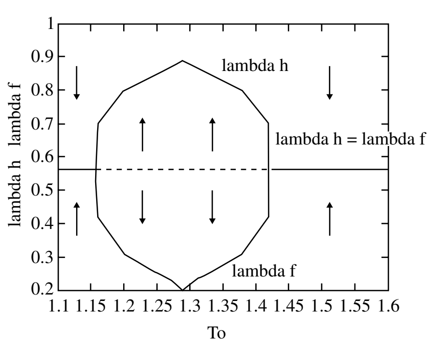
G_j is the price index in country *j*. It represents the minimum cost of purchasing a unit of the composite index *M*. E_j denotes the level of expenditure on manufactures in country s.

■ *Long-run equilibrium*

When nominal wages are different across sectors, the labor force migrates from the sector with the low nominal wage to the other sector. The long-run equilibrium must satisfy the short-run equilibrium equations; $w_{jm}=A'(1-\lambda_j)$ for $j=1,2$, nominal wages must be equal across sectors; and stability conditions must be satisfied.[16]

The parameters to depict figure 1 are $\theta=\{\sigma=5,\ \alpha=0.4,\ \mu=0.55,\ \eta=0.95,\ \gamma=0.562\}$. These values determine the range of trade costs in which agglomeration is feasible. The lower break point is 0.152 and the upper breakpoint is 0.412. Between these points, the dispersed equilibrium is unstable. For both high and low levels, the long-run equilibria are a dispersed distribution of the industrial and agricultural sectors across countries. For intermediate trade costs, industry is concentrated in one country. In either case, international trade always takes place. In the former two cases, however, the agricultural good is not traded. In the third case, the one country is partially specialized in the agricultural sector and the other country is almost specialized in the industrial sector. Trade is always balanced. Long-run equilibrium is stable, any deviation eventually returns to the original point. Industrial agglomeration means a real wage gap between countries. Beyond a threshold, real wages are equal and jointly increase as economic integration take place. Nominal wages are equal to one at any dispersed equilibrium.

Figure 1
The bell-shaped curve of international trade openness from Fujita *et al*



Simulations carried out in MATLAB

16 The stability conditions are $dw/d\lambda + A''<0$.

- *Implementation and hypotheses*

We outline the way the basic hypotheses can be stated. Particularly, implementation is divided into 4 steps, and it is applicable for any period and particular industry.

- *Step 1. Measuring trade openness*

Head and Mayer derive a measure of access to markets or trade openness from a standard CP framework.[17] The uncompensated consumer demand function in country *i* for any product from country *j* is denoted by[18]

$$(7) \qquad c_{ji} = \frac{p_{ji}^{-\sigma}}{G_i^{-(\sigma-1)}}\mu Y_i = \frac{(p_j T_{ji})^{1-\sigma}}{G_i^{-(\sigma-1)}}\mu Y_i.$$

Since in equilibrium, prices in country *i* of all varieties produced in *j* are equal, the value of the consumer demand in *i* across n_j products is

$$(8) \qquad m_{ji} = n_j p_{ji} c_{ji} = n_j \frac{p_{ji}^{1-\sigma}}{G_i^{-(\sigma-1)}}\mu Y_i = n_j \frac{(p_j T_{ij})^{1-\sigma}}{G_i^{-(\sigma-1)}}\mu Y_i.$$

By defining $T^{1-\sigma}_{ji}=\phi_{ji}\in(0,1)$ and after a little algebra the following equation holds

$$(9) \qquad \frac{m_{ji} m_{ij}}{m_{ii} m_{jj}} = \frac{\phi_{ji}\phi_{ij}}{\phi_{jj}\phi_{ii}}.$$

In order to obtain an access to market estimator, it is assumed that there is symmetric bilateral trade, $\phi_{ji}=\phi_{ij}$, and free trade within locations, $\phi_{jj}=\phi_{ii}=1$. Hence, the inferred trade openness measure is

$$(10) \qquad \hat{\phi}_{ij} = \sqrt{\frac{m_{ji} m_{ji}}{m_{ii} m_{jj}}}.$$

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17 The consumer maximizes a CES utility function subject to a budget constraint. Other NEG models assume a quadratic utility function.

18 See Fujita et al p. 46-49 to see how this demand function is obtained.

- *Step 2. Parameter calibration*

The parameters on preferences (μ and ρ), and manufacturing and agricultural technologies (α and η), are obtained by calibration in the fashion of Forslid *et al.* The parameter of expenditure in manufacturing is assumed to be $\mu>0.5$. We assume a world with *j* countries and 2 sectors, the agricultural one and the manufacturing good associated with the industry *h*. We overcome the problem of defining prices by using the mark ups calculated by Oliveira *et al* (1996). Head and Mayer obtain their parameter estimates from OECD input-output tables of a particular country instead. They assume that all inputs of industry *h* are from the same industry and the share of labor in agriculture is assumed to be 200.

- *Step 3. Break points estimation*

From Fujita's *et al* quadratic equation, the break points that define the range of trade openness, in which a dispersed equilibrium is unstable, are obtained by solving for *Z*

(11) $$\frac{dw}{d\lambda}=\frac{-Z}{\mu\Delta}\left[\frac{\alpha(1+\rho)-Z(\alpha^2+\rho)}{1-\rho}\right]=0,$$

where Δ is determined as

$$\frac{1}{(1-\rho)^2}\left\{\begin{matrix}Z^2\left[\rho(\rho-\alpha)-\alpha(1-\rho)(\alpha+\mu(1-\alpha))\right]+Z(1-\rho)\left[\alpha+\rho(\alpha+\mu(1-\alpha))\right]\\-(1-\alpha)\rho\end{matrix}\right\}.$$

and

(12) $$Z=\frac{1-T^{1-\sigma}}{1+T^{1+\sigma}}.$$

The roots of the equation, if exist, are Z^U and Z^L. From equation (8) We obtain the upper value and the lower value of the range [T^U, T^L] and consequently [ϕ^U, ϕ^L]. Between these values a partial or total agglomeration in a single location is expected. Within this range any deviation from the dispersed equilibrium, say one more worker in country *i* in the industrial sector, results in concentration of industry in country *i* and concentration of agriculture in country *j*.

- *Step 4. Variable construction*
  The constructed variable is

$$V_{ij} = \log(abs(\hat{\phi}_{ij} - \frac{[\phi^L + \phi^U]}{2})), \quad (13)$$

where V_{ij} is the log of the absolute distance between the estimated measure of access to markets among countries *i* and *j*, and the midpoint of the two breakpoints given by preferences and technology of country *h*. So far we have not considered industry and time issues. In NEG models technology and preferences are homogenous across countries.

Therefore the relationship between two countries can be established as

$$\log(\text{abs}(\textit{Industrial Gap}_{ij}))=f(V_{ij})+\varepsilon_{ij} \quad (14)$$

The industrial gap between country *i* and *j* is the independent variable. We select three different sorts of this variable: *i)* in terms of total employment in sector *s* at *t*; *ii)* in terms of the fraction of the manufacturing employment in industry *s* at *t*; and *iii)* in terms of production in sector *s* at *t*.

In order to see if Puga's predictions about industry concentration and trade openness are valid we state three hypotheses, which do not account for the direction of concentration.

Hypothesis 1. For intermediate trade costs employment concentration is expected.

Hypothesis 2. .For intermediate trade costs production concentration is expected.

Both hypotheses are connected. On the one hand, hypothesis 1 is based in terms of employment in sector *s*. In theory, the number of employees hired by firms exclusively depends on technology and preferences parameters. Therefore, more firms in one country are accompanied by more employees. On the other hand, more firms means higher production. Outside the rationale of the model, it is expected that production is more sensitive to changes in trade openness than employment because there is some degree of labor disposal and rigidities in the labor market.

Hypothesis 3. .For intermediate trade costs employment share concentration is expected.

This hypothesis says that concentration is conceived in terms of employment share in sector *s* in the whole industrial sector. We try to assess the distribution of employees across sectors. However, in the model there is room to claim that for intermediate trade costs the share is higher in one country than in other. In the model, the population in each country is normalized to one but its conclusions are spurious.

In order to test the relationship between industrial concentration and trade openness between a pair of countries, we specify the following panel data linear model

(15) $\mathbf{Y_t}=\gamma\mathbf{V_t}+\mathbf{X_t}\beta+\varepsilon_t$, where $E(\varepsilon_t)=0$, $Var(\varepsilon_t)=\sigma^2 I_N$,

where $\boldsymbol{Y_t}$ is a *nx1* vector of observations on the dependent variable at *t*. $\boldsymbol{X_t}$ is a *nxk* matrix of observations on *k* exogenous variables at *t*. $\boldsymbol{V_t}$ is a *nx1* vector on the constructed variable at *t*. ε_t is a *nx1* vector of *i.i.d* error terms at *t*. β is a *kx1* vector of regression parameters.

■ *Data*

The data set is divided into 4 parts and covers 14 years (1988-2001) of bilateral trade at the industry level, industrial production and industrial employment of 30 sectors for 28 OECD countries (see table A.1).

a) The taste and technology parameter values are obtained by the calibration method of Fujita´s *et al* model. From STAN-OECD 2002, the information associated with industry *h* in country *i* at *t* is: ***Y*** stands for the gross product in US dollars; λ is the total employment in the industry; **1-**λ is the total employment in the agricultural sector. From Oliveira *et al*(1996), we use mark ups instead of prices (see table A.2). From the World Bank Economic Indicators, we obtain ***K,*** which denotes the area of the country.

Head and Mayer obtain the technology parameters from two sources: by the input-output matrix from STAN of OECD and external sources (Hummels, 1999). In the former case two limitations arise. First the parameters depend on a particular technology (for example the Japanese). The second one is that they assume that all inputs used by a sector only come from the same sector.

b) Trade openness estimation is obtained from Bilateral Trade-OECD 2002.

b.1) m_{ji}^n denotes total exports of industry *n* from country *j* to country *i*. It is obtained from country *j* (or country *i*) bilateral trade. (Bilateral Trade 2002 of OECD)

b.2) m_{jj}^n denotes the value of all shipments of industry *n* in country *j* minus shipments to all other regions. It is defined as production of industry n minus exports of industry n (Bilateral Trade 2002 of OECD and STAN of OECD)

c.2) Industrial gap (STAN of OECD) is defined in three parts: *i)* employment in country i minus employment in country j; *ii)* production in country i minus production in country j; and *iii)* employment share in country i minus employment share in country j. The employment share is defined as the employment share of sector s in the industrial sector.

With the data obtained from *a)* we determine the breakpoints, and from the data obtained from *b)* we determine V_{ij} at t for a particular sector. Each observation corresponds to a trade bilateral relationship ij at t in sector s. Table 3 reports the range of trade openness ($\phi_{\text{lower point}}$, $\phi_{\text{upper point}}$), where trade openness is theoretically expected.

■ *Results and Final Remarks*

Tables 1-3 report the estimates when the dependent variable is the absolute value of log of employment gap, log of production gap and the log of employment share gap, respectively. These tables are divided in 9 general industry sectors and some of them are divided in subsectors. The potential number of observations for each sector is (((28x28)/2)-28)x14 = 5,096; however, there are missing observations. Each observation corresponds to a pair of countries in one particular year. The method of estimation is unbalanced OLS panel data controlling for time and country effects.

In table 1, the dependent variable is the $|$log employment gap$|$, which is negatively affected by the inferred trade openness measure and are significant. R^2' s are relative high for all sectors. The food (1), textile (2), other non-metallic products (6) and basic metals (7) sectors are highly sensitive to trade openness, whereas wood products (3) aircraft (9.22) and office (8.21) sectors are less sensitive. Table 2 reports the results related to the production gap and are similar to the previous table. In the case where the employment share is the dependent variable, the results vary across sectors in some cases like food (1), textiles (2) and wood (3), where the effects of falling in the agglomeration range are not consistent. Some other sectors as other non-metallic (6) are highly expected to agglomerate within the range.

It is worth mentioning that agglomeration is not only a result of only pecuniary consideration due to increasing returns to scale, positive trade costs and love for variety but also of comparative advantage.

Testing the hypotheses set out in this paper provides information on the forces behind industrial concentration. The analysis is conducted where each observation is related to a particular bilateral trade relationship. Deep down what this paper validates are three stories of development that have prevailed in the last decades. The "import substitution story" that argues that trade openness drives manufacturing concentration. The Krugman and Venables story, that claims that trade promotes convergence of both welfare and industrial agglomeration. And Puga's story that argues that minimum levels of trade openness results in mirror economies. In other words, geographical agglomeration arises as a result of consumer-proximity, supplier-proximity and factor market competition considerations. There are two types of results. According to Forslid *et al*, one in which the industry sector is highly sensitive to trade openness. In this case there are significant trade costs and important intra-industry linkages. The other in which trade costs are less important and trade costs have fostered specialization driven by comparative advantages. The results are consistent with Davis and Weinstein (2003) who find evidence of the home market effect for OECD countries. In sum, we find that bilateral trade at intermediate trade costs fosters agglomeration in some direction.

Table 1
Unbalanced panel data (country and time effects)

	Dependent variable: abs (log of employment gap)			
	m	Vij	R^2	# Obs.
1 Food products, beverages and tobacco	0.09	-3.32***	0.97	3147
		-24.70		
2 Textiles, textile products, leather and footwear	1.37	-2.17***	0.61	3147
		-45.71		
3 Wood and products of wood and cork	0.33	-1.46***	0.90	3097
		-37.99		
4 Pulp, paper, paper products, printing and publishing	0.47	-2.47***	0.90	3097
		-40.76		
5 Chemical, rubber, plastics and fuel products	1.38	-2.11***	0.68	3147
		-44.94		
5.1 Coke, refined petroleum products and nuclear fuel	0.40	-1.92***	0.89	2290
		-27.19		
5.2 Chemicals and chemical products	1.77	-1.77***	0.67	2636
		-38.89		
5.21 Chemicals excluding pharmaceuticals	2.19	-1.57***	0.73	1293
		-25.46		
5.22 Pharmaceuticals	2.23	-1.67***	0.76	1488
		-23.86		
5.3 Rubber and plastics products	0.97	-3.24***	0.85	2910
		-41.28		
6 Other non-metallic mineral products	0.13	-3.25***	0.96	3146
		-31.26		
7 Basic metals and fabricated metal products	0.38	-3.05***	0.88	3147
		-46.05		
7.1 Basic metals	2.01	-1.99***	0.72	1627
		-30.91		
7.11 Iron and steel	1.29	-1.43***	0.75	1121
		-25.73		
7.12 Non-ferrous metals	1.21	-1.83***	0.84	1121
		-24.36		
7.2 Fabricated metal products	0.20	-3.37***	0.96	1628
		-22.80		
8 Machinery and equipment	2.58	-1.96***	0.43	3097
		-41.90		

		Dependent variable: abs (log of employment gap)			
		m	Vij	R^2	# Obs.
8.1	Machinery and equipment, NEC	1.38	-2.20***	0.64	2983
			-43.22		
8.2	Electrical and optical equipment	2.21	-2.31***	0.50	2983
			-41.27		
8.21	Office, accounting and computing machinery	3.13	-1.00***	0.73	1310
			-21.02		
8.3	Electrical machinery and apparatus, NEC	1.94	-1.89***	0.76	1378
			-27.74		
8.4	Radio, television and communication equipment	2.69	-1.47***	0.58	1378
			-25.74		
8.5	Medical, precision and optical instruments	2.23	-1.66***	0.53	1053
			-23.01		
9 Transport equipment		1.74	-2.65***	0.65	3097
			-42.25		
9.1	Motor vehicles, trailers and semi-trailers	3	-1.77***	0.69	1750
			-28.98		
9.2	Other transport equipment	2.06	-1.72***	0.69	1750
			-30.36		
9.21	Building and repairing of ships and boats	0.31	-2.39***	0.83	1116
			-20.89		
9.22	Aircraft and spacecraft	2.94	-1.27***	0.59	734
			-17.18		
9.3	Manufacturing NEC; recycling	0.67	2.29***	0.85	3134
			-44.25		

* Calculations carried out in MATLAB; t-values reported below the estimated coefficients

* Significant at the 1 per cent level.

** Significant at the 5 per cent level.

***Significant at the 1 per cent level.

Table 2
Unbalanced panel data (country and time effects)

	Dependent variable: abs (log of production gap)			
	m	Vij	R^2	# Obs.
1 Food products, beverages and tobacco	0.19	-4.66***	0.94	3791
		-28.23		
2 Textiles, textile products, leather and footwear	2.33	-2.55***	0.51	3791
		-48.74		
3 Wood and products of wood and cork	0.56	-1.99***	0.86	3712
		-44.24		
4 Pulp, paper, paper products, printing and publishing	0.75	-3.37***	0.84	3712
		-47.26		
5 Chemical, rubber, plastics and fuel products	2.50	-2.93***	0.43	3791
		-49.96		
5.1 Coke, refined petroleum products and nuclear fuel	1.04	-3.78***	0.78	2810
		-42.47		
5.2 Chemicals and chemical products	2.73	-2.71***	0.31	3191
		-44.60		
5.21 Chemicals excluding pharmaceuticals	3.08	-2.54***	0.33	2556
		-38.83		
5.22 Pharmaceuticals	2.96	-3.05***	0.48	2827
		-38.02		
5.3 Rubber and plastics products	1.33	-4.73***	0.71	3492
		-47.92		
6 Other non-metallic mineral products	0.35	-4.48***	0.92	3791
		-32.34		
7 Basic metals and fabricated metal products	0.74	-4.05***	0.82	3760
		-51.92		
7.1 Basic metals	2.66	-3.12***	0.53	3407
		-46.06		
7.11 Iron and steel	1.47	-2.18***	0.50	2228
		-39.37		
7.12 Non-ferrous metals	1.33	-3.12***	0.42	2228
		-38.27		
7.2 Fabricated metal products	0.39	-4.37***	0.95	3407
		-27.40		
8 Machinery and equipment	4.08	-2.39***	0.23	3681
		-44.12		

		Dependent variable: abs (log of production gap)			
		m	Vij	R^2	# Obs.
8.1	Machinery and equipment, NEC	1.86	-3.00***	0.42	3199
			-46.09		
8.2	Electrical and optical equipment	3.05	-3.17***	0.13	3199
			-42.85		
8.21	Office, accounting and computing machinery	5.09	-1.67***	0.34	2817
			-31.07		
8.3	Electrical machinery and apparatus, nec	2.51	-2.76***	0.45	2913
			-41.00		
8.4	Radio, television and communication equipment	3.85	-2.02***	0.14	2913
			-37.52		
8.5	Medical, precision and optical instruments	2.94	-2.33***	0.37	2405
			-36.09		
9	Transport equipment	3.11	-3.54***	0.46	3681
			-45.96		
9.1	Motor vehicles, trailers and semi-trailers	3	-3.01***	0.38	2978
			- 41.76		
9.2	Other transport equipment	2.28	-2.77***	0.48	2978
			-41.77		
9.21	Building and repairing of ships and boats	0.52	-3.41***	0.85	2268
			-29.02		
9.22	Aircraft and spacecraft	3.32	-2.24***	0.29	1497
			-27.91		
9.3	Manufacturing NEC; recycling	1.14	-2.97***	0.80	3773
			-48.81		

* Calculations carried out in matlab; t-values reported below the estimated coefficients

* Significant at the 1 per cent level.

** Significant at the 5 per cent level.

*** Significant at the 1 per cent level.

Table 3
Unbalanced panel data (country and time effects)

	Dependent variable: abs (log of employment share gap)			
	m	Vij	R^2	# Obs.
1 Food products, beverages and tobacco	174.67	84.16*	0.95	1274
		1.62		
2 Textiles, textile products, leather and footwear	0.21	2.04	0.92	1274
		1.13		
3 Wood and products of wood and cork	59.56	17.24**	0.95	1274
		1.90		
4 Pulp, paper, paper products, printing and publishing	-60.54	-21.48	0.94	1274
		-0.73		
5 Chemical, rubber, plastics and fuel products	-13.35	-3.22	0.92	1274
		-1.50		
5.1 Coke, refined petroleum products and nuclear fuel	9.77	8.48	0.77	924
		0.28		
5.2 Chemicals and chemical products	-14.47	-3.49*	0.88	1092
		-1.77		
5.21 Chemicals excluding pharmaceuticals	-6.67	-0.10	0.90	630
		-0.02		
5.22 Pharmaceuticals	-21.19	-8.02	0.84	770
		-0.59		
5.3 Rubber and plastics products	2.17	5.82	0.90	1274
		0.37		
6 Other non-metallic mineral products	-313.24	-164.45	0.93	1274
		-1.56		
7 Basic metals and fabricated metal products	34.31	17.87	0.94	1274
		0.82		
7.1 Basic metals	-9.43	-1.69	0.95	770
		-0.65		
7.11 Iron and steel	8.17	4.12***	0.96	504
		2.24		
7.12 Non-ferrous metals	19.46	12.25	0.94	504
		1.25		
7.2 Fabricated metal products	269.07	134.00*	0.93	770
		1.56		
8 Machinery and equipment	-15.72	-4.55***	0.92	1274
		-3.27		

	Dependent variable: abs (log of employment share gap)			
	m	Vij	R^2	# Obs.
8.1 .Machinery and equipment, NEC	-3.36	0.76	0.94	1092
		0.64		
8.2 Electrical and optical equipment	-7.45	-1.20	0.88	1092
		-0.36		
8.21 Office, accounting and computing machinery	-23.00	-8.11*	0.84	294
		-1.25		
8.3 Electrical machinery and apparatus, NEC	-132.10	-57.45	0.90	294
		-1.52		
8.4 Radio, television and communication equipment	48.67	22.43**	0.87	294
		2.21		
8.5 Medical, precision and optical instruments	-1.07	2.71	0.52	210
		0.60		
9 Transport equipment	3.14	4.47**	0.92	1274
		1.78		
9.1 Motor vehicles, trailers and semi-trailers	11	7.62***	0.95	770
		3.14		
9.2 Other transport equipment	-2.35	1.78	0.92	770
		0.36		
9.21 Building and repairing of ships and boats	20.67	13.44	0.93	504
		0.95		
9.22 Aircraft and spacecraft	-8.31	-0.42	0.87	392
		-0.23		
9.3 Manufacturing NEC; recycling	-24.52	-7.52	0.94	1274
		-0.40		

* Calculations carried out in matlab; t-values reported below the estimated coefficients
* Significant at the 1 per cent level.
** Significant at the 5 per cent level.
*** Significant at the 1 per cent level.

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Table A.1.
Sample of OECD Countries

Australia
Austria
Belgium
Canada
Czech. Republic
Denmark
Finland
France
Germany
Greece
Hungary
Iceland
Ireland
Italy
Japan
Korea
Mexico
Holland
New Zealand
Norway
Poland
Portugal
Slovakia
Spain
Sweden
Switzerland
UK
USA

Table A. 2
Agglomeration Intervals

		F-middle point	F-lower point	F-upper point
1	Food products, beverages and tobacco	0.119	0.118	0.119
2	Textiles, textile products, leather and footwear	0.071	0.008	0.939
3	Wood and products of wood and cork	0.022	0.001	0.966
4	Pulp, paper, paper products, printing and publishing	0.075	0.030	0.201
5	Chemical, rubber, plastics and fuel products	0.081	0.026	0.270
5.1	Coke, refined petroleum products and nuclear fuel	0.123	0.100	0.150
5.2	Chemicals and chemical products	0.083	0.015	0.583
5.21	Chemicals excluding pharmaceuticals	0.086	0.025	0.334
5.22	Pharmaceuticals	0.176	0.146	0.212
5.3	Rubber and plastics products	0.223	0.159	0.316
6	Other non-metallic mineral products	0.154	0.091	0.266
7	Basic metals and fabricated metal products	0.112	0.104	0.122
7.1	Basic metals	0.129	0.094	0.179
7.11	Iron and steel	0.031	0.032	0.031
7.12	Non-ferrous metals	0.117	0.093	0.148
7.2	Fabricated metal products	0.129	0.094	0.179
8	Machinery and equipment	0.084	0.019	0.443
8.1	Machinery and equipment, NEC	0.096	0.095	0.096
8.2	Electrical and optical equipment	0.130	0.096	0.177
8.21	Office, accounting and computing machinery	0.160	0.155	0.165
8.3	Electrical machinery and apparatus, nec	0.112	0.104	0.122
8.4	Radio, television and communication equipment	0.087	0.021	0.403
8.5	.Medical, precision and optical instruments	0.117	0.093	0.148
9	Transport equipment	0.154	0.091	0.266
9.1	Motor vehicles, trailers and semi-trailers	0.112	0.104	0.122
9.2	Other transport equipment	0.112	0.104	0.122
9.21	Building and repairing of ships and boats	0.130	0.096	0.177
9.22	Aircraft and spacecraft	0.112	0.104	0.122
9.3	Manufacturing NEC; recycling	0.079	0.024	0.283