Testing the 'home market effect' in a multi-country world

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Abstract

We extend Krugman's (1980) two-country two-sector model to a setup with arbitrary numbers of countries and sectors. The extended model predicts an adequately defined 'home market effect' only after controlling for cross-country differential accessibility through a theory-based linear filter.

We bring that prediction to data by running a battery of non-parametric sign- and rank-tests that are closely related to those used in factor proportions theory. When applied to production and trade data on a cross-section of OECD and non-OECD countries, we find support for the presence of 'home market effects' in a broad number of industries.

Keywords: home market effect; new trade theory; multi-country models; market potential; economic geography

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1 Introduction

What determines the structure of world trade? Two main explanations have been put forth in the literature (see, e.g., Helpman, 1998). The first one highlights the role of relative cost differences between countries: a country exports the goods that it is able to produce at relatively lower costs. The uneven international distribution of technology (Ricardian model) and/or relative factor endowments (Heckscher-Ohlin model) would generate those differences (Dixit and Norman, 1980). The second explanation stresses the role of increasing returns to scale, product differentiation, and market structure: a country exports the goods for which it offers a relatively large local demand, an outcome known as the 'home market effect' (henceforth, HME; Krugman, 1980). Although some kind of imperfect competition is needed for an industry to possibly exhibit a HME, both oligopoly and monopolistic competition may serve the purpose, provided entry and exit of firms are unrestricted (Feenstra *et al.*, 2001; Head *et al.*, 2002; Feenstra, 2003).

As shown by Helpman and Krugman (1985), the two explanations are not incompatible. Yet, the first seems better fit for explaining inter-sectoral trade between somewhat different countries, whereas the second looks more suited to account for intra-sectoral trade between similar countries. In particular, it has been argued that the former would explain North-South trade, whereas the latter would account for North-North trade, together more than 80 per cent of world trade flows. Nonetheless, the relative merits of the two explanations are still largely debated, as highlighted by recent empirical works (see, e.g., Davis and Weinstein, 1996, 1999, 2003; Trionfetti, 2001; Antweiler and Trefler, 2002; Brülhart and Trionfetti, 2005). The reason is that relative costs matter also for North-North flows, and product differentiation is relevant also for North-South flows.

A major obstacle to assessing the empirical relevance of explanations based on economies of scale, product differentiation, and market structure is the fact that the inherent richness of the corresponding models has not yet been much explored (Helpman, 1998). A recent example of how theory still lags behind empirics is provided by the investigation of the HME by Davis and Weinstein (2003). Their point of departure is the framework developed by Krugman (1980), which features a two-country economy with one factor of production (labor) and two sectors. One sector supplies a freely-traded homogeneous good under constant returns to scale and perfect competition, whereas the other sector produces a horizontally differentiated good under increasing returns and monopolistic competition à la Dixit and Stiglitz (1977). For each differentiated variety, fixed and marginal input requirements are constant and international trade is hampered by frictional trade costs of the 'iceberg' type. Preferences are Cobb-Douglas across the two goods and symmetric CES between varieties of the differentiated good. Due to the fixed input requirement, the larger country supports in equilibrium the production of a *more than proportionate number of differentiated varieties*, thus being a net exporter of this good (Helpman and Krugman, 1985). In other words, Krugman's (1980) model displays a HME.

Trionfetti (2001) and Davis and Weinstein (2003) point out that no HME would arise instead in a Ricardian or Heckscher-Ohlin world. Specifically, when there are trade costs, increases in market size map into a less than proportional increase of production, since a fraction of the additional demand is served by imports from the rest of the world. Accordingly, Davis and Weinstein suggest to compare the predictive power of the two alternative explanations by estimating the impacts of aggregate demand on the output of different sectors. A more than proportional causation from demand to supply would support the HME as a driving force for specialization and trade, whereas a less than proportional causation would support relative cost and/or endowment driven patterns.

The problem with applying the foregoing idea to real data is that Krugman's clear-cut result has been derived in a two-country setup only. Hence, the question arises as to whether it generalizes to the case of multiple countries. As recently argued by Head and Mayer (2004, p. 2634, our emphasis), this issue is difficult to tackle and poses some important problems:

> "How do we construct demand measures in the presence of more than two countries? Indeed *how does one even formulate the home market effect hypothesis*? The ratios and shares of the theoretical formulations neglect third country effects."

The main reason why it is hard to formulate the HME hypothesis in a multi-country world is that the appeal of a country as a production site seems to depend on both the relative size of its domestic market ('attraction') and its relative proximity to all other foreign markets ('accessibility'). This is highlighted by the empirical results in Davis and Weinstein (2003) who show that firms are attracted towards countries exhibiting larger values of a composite index of attraction and accessibility (which they call IDIODEM). This index is a heuristic measure of the *idiosyncratic demand* facing producers in a certain country that takes into account not only local demand but also demand from neighboring countries. Davis and Weinstein (2003) try to interpret such finding in the light of Krugman's (1980) model. Specifically, *by analogy with the two-country case*, they conjecture that a larger than one estimate of the elasticity of output to the IDIODEM index would provide evidence of the presence of the HME.[1]

The aim of the present paper is to take theory and empirics one step further by proposing a theory-based approach to testing the HME prediction. By extending Krugman's (1980) model to many countries, we show that the appeal of a country as a production site for firms indeed depends on both attraction and accessibility. This happens because in equilibrium the endogenous international distribution of firms is such that better attraction and accessibility are offset by fiercer competition ('repulsion'), until operating profits are equalized across countries. Some properties of the two-country setup survive the multi-country extension. The so-called 'dominant market effect' and the 'magnification effect' (see, e.g., Head *et al.*, 2002; Baldwin *et al.*, 2003) remain valid, thus suggesting that several of the underlying mechanisms are quite robust. Yet, *the HME itself may not arise in the multi-country setting*, thus refuting the 'Davis-Weinstein conjecture'. This is due to the fact that, once 'third country effects' are taken into account, an increase in one country's expenditure share may well map into a less than proportionate increase in its output share as other countries 'drain away' some firms. In more extreme cases, an increase in the expenditure share may even lead to a decrease in industry share.

These results suggest a different route for testing the HME that focuses on a definition in terms of 'country rankings', which seems to be the only one that generalizes from a two-country to a multi-country setting. In particular, we show that, according to the extended model, the HME should be observed in reality only after correcting the actual industry distribution from the impact of accessibility. We further show that such a correction can be achieved through a simple theory-based linear filter. When applied to a cross-section of OECD and non-OECD countries, the filter does improve the performance of HME predictions in terms of both 'sign' and 'rank' tests.

All this is reminiscent of old debates in HOV theory: "the Heckscher-Ohlin theorem is derived from a model of only two of each of goods, *countries*, and factors of production. It is unclear what the theorem says should be true in the real world where there are many of all three" (Deardorff, 1984, p. 468, our emphasis). This inevitably affects applied work, since most "papers that claim to present tests of the hypothesis have used intuitive but inappropriate generalizations of the two × two model to deal with a multidimensional reality" (Bowen *et al.*, 1987, p. 791). As a solution, some authors have indeed suggested to use 'sign' and 'rank' tests

[1] Analogously, building on the observation that home-biased demand plays an important role in the real world (see, e.g., Trefler, 1995), Trionfetti (2001) as well as Brülhart and Trionfetti (2005) argue that the HME should be identified as a disproportionate output reaction to *idiosyncratic home-biased demand*.

of the predictions based on comparative advantage and factor proportions (see, e.g., Bowen *et al.*, 1987; Feenstra, 2003; Choi and Krishna, 2004).

Our contribution should be seen as complementary to these works in that our main objective is not to discriminate between 'old' and 'new' trade theory. Indeed, it is our contention that, in order to discriminate between competing paradigms, one first needs to test the predictive power of each paradigm per se. While this has been abundantly done in the case of the factor proportions model (see, e.g., Deardorff, 1984; Bowen *et al.*, 1987; Trefler, 1995; Antweiler and Trefler, 2002), we still lack clear theory-based tests of new trade theory. One could argue that the estimation of so-called gravity equations provides strong support in favor of the latter, but this is hardly so since many alternative models will lead to gravity-like relationships (Deardorff, 1998; Anderson and van Wincoop, 2004). Further, it should be kept in mind that imperfect competition and increasing returns to scale may generate an uneven spatial distribution of production factors, which themselves then generate a pattern of trade consistent with HOV predictions (see, e.g., Amiti, 1998). Put differently, it may be quite hard to determine from ex post trade data alone whether 'old' or 'new' theories explain the observed flows.[2]

The remainder of the paper is divided into five sections. The first presents the multi-country extension of the model by Krugman (1980) and characterizes the spatial equilibrium. The second provides a definition of the multi-country HME, first in a dynamic and then in a static sense. We show that only the static definition generalizes appropriately to the multi-country setting. The third relates the multi-country HME to the concepts of market potential and market size. We discuss the effects of geography and present a methodology that allows us to separate 'attraction' from 'accessibility'. The fourth presents some empirical results that support the existence of a HME for a large number of industries, which highlights the importance of correcting for accessibility. The fifth finally concludes.

2 The model

The world economy consists of M countries and $S+1$ industries, indexed by $i = 1, 2, \ldots, M$ and $s = 1, 2, \ldots, S+1$. In what follows, subscripts and superscripts refer to countries and industries respectively.[3] Country i hosts an exogenously given mass of $L_i > 0$ consumers, each of them supplying one unit of labor inelastically. Hence, both the world population and the world endowment of labor are given by $L = \sum_i L_i$. Labor is the only factor of production and it is assumed to be internationally immobile.

2.1 Preferences and technologies

Preferences are defined over a set of $S+1$ differentiated goods, each provided as a continuum of horizontally differentiated varieties. The preferences of a typical resident of country i are represented by the following utility function:

$$U_i = \prod_s \left(D_i^s\right)^{\mu^s}, \quad 0 < \mu^s < 1, \quad \sum_s \mu^s = 1, \tag{1}$$

where

$$D_i^s = \left[\sum_j \left(\int_{\omega \in \Omega_j^s} d_{ji}^s(\omega)^{(\sigma^s-1)/\sigma^s} \, \mathrm{d}\omega \right) \right]^{\sigma^s/(\sigma^s-1)}$$

[2] Several empirical studies have shown that "the standard HOV theory performs miserably" (Davis and Weinstein, 2001, p. 1444; see also Bowen *et al.*, 1987; Trefler, 1995). Although a modified version allowing for differences in technologies and tastes performs better (Trefler, 1995; Davis and Weinstein, 2001; Antweiler and Trefler, 2002; Choi and Krishna, 2004), tests discriminating between 'old' and 'new' trade theory remain inconclusive until now.

[3] To simplify notation, summation ranges are henceforth omitted whenever there is no possible ambiguity.

is a CES sub-utility defined over the varieties of the horizontally differentiated good s. In the above expression, $d^s_{ji}(\omega)$ is the consumption in country i of variety ω of good s produced in country j, and Ω^s_j is the set of varieties produced in country j. The parameter $\sigma^s > 1$ measures both the own- and cross-price elasticities of demand for any variety of good s.

The production of any variety of the differentiated good s takes place under internal increasing returns to scale by a set of monopolistically competitive firms. This set is endogenously determined in equilibrium by free entry and exit. We denote by n^s_i the mass of industry-s firms located in country i, by $N^s = \sum_i n^s_i$ the total mass of industry-s firms, and by $N = \sum_s N^s$ the total mass of all firms in the global economy. The production technology of each industry-s variety requires the same fixed and constant marginal labor requirements, labeled F^s and c^s respectively. The fact that these labor requirements are *industry specific* allows us to capture the different technological constraints characterizing different industries.[4] Increasing returns to scale and costless product differentiation yield a one-to-one relationship between firms and varieties, so we will use the two terms interchangeably. As to trade barriers, the international trade of any industry-s variety is subject to 'iceberg' trade costs. Specifically, $\tau^s_{ji} > 1$ units have to be shipped from country i to country j for one unit to reach its destination.

2.2 Market equilibrium

Given our assumptions, in equilibrium firms in each industry will differ only by the country they are located in. Accordingly, to simplify notation, we drop the variety label ω from now on. Then, the maximization of utility (1) subject to the budget constraint yields the following demand in country j for an industry-s variety produced in country i:

$$d^s_{ij} = \frac{(p^s_{ij})^{-\sigma^s}}{(P^s_j)^{1-\sigma^s}} \mu^s E_j, \tag{2}$$

where p^s_{ij} is the delivered price of the variety, E_j is expenditures in country j, and P^s_j is the industry-s CES price aggregate given by

$$P^s_j = \left(\sum_k n^s_k (p^s_{kj})^{1-\sigma^s} \right)^{1/(1-\sigma^s)}. \tag{3}$$

Note that since (2) and (3) do not depend on industry $r \neq s$, *the cross-price elasticities between any two varieties of two different goods r and s are zero.* Although this is obviously a somewhat strong result, it matches the classical definition of industries used in industrial organization (see, e.g., Triffin, 1941). From an empirical point of view, such a property has the drawback that it requires the data to be sufficiently aggregated to make inter-industry cross-price elasticities negligible. Yet, it offers the advantage of allowing for an analysis on an industry-by-industry basis.

Because of the iceberg trade costs, a typical industry-s firm established in country i has to produce $x^s_{ij} = d^s_{ij}\tau^s_{ij}$ units to satisfy final demand d^s_{ij} in country j. The firm takes (2) into account when maximizing its own profit:

$$\begin{aligned} \Pi^s_i &= \sum_j \left(p^s_{ij} d^s_{ij} - w_i c^s x^s_{ij} \right) - F^s \qquad (4) \\ &= \sum_j \left(p^s_{ij} - w_i c^s \tau^s_{ij} \right) \frac{(p^s_{ij})^{-\sigma^s}}{(P^s_j)^{1-\sigma^s}} \mu^s E_j - F^s. \end{aligned}$$

[4] Note that fixed and variable costs are *not country specific* in our setup. Hence, we do not directly control for either comparative or Ricardian advantages that play an important role in explaining some world trade flows (see, e.g., Deardorff, 1984; Trefler, 1995). Such a setup is partly justified by the fact that technological differences seem to be too weak an explanation for intra-industry trade flows of the magnitude observed between the major OECD countries (Grubel and Lloyd, 1975).

Profit maximization with respect to p_{ij}^s, taking P_j^s as given because of the continuum assumption, then implies that the price per unit delivered is:

$$p_{ij}^s = \frac{\sigma^s}{\sigma^s - 1} w_i c^s \tau_{ij}^s. \tag{5}$$

Since, due to free entry and exit, profits have to be non-positive in equilibrium, (4) and (5) also imply that industry-s firms' equilibrium scale of operation must satisfy:

$$\sum_j d_{ij}^s \tau_{ij}^s \leq \frac{F^s(\sigma^s - 1)}{c^s}, \tag{6}$$

i.e., total firm production inclusive of the amount of output lost in transit must be large enough to cover fixed costs.

Let $\phi_{ij}^s \equiv (\tau_{ij}^s)^{1-\sigma^s}$ be a measure of trade freeness, valued one when trade is free and limiting zero when trade is prohibitively costly. Replacing (2) as well as (3) into (6), multiplying both sides by $p_{ii}^s > 0$, and using (5) as well as the identity $E_j = L_j w_j$, we then get:

$$\sum_j \frac{w_i^{-\sigma^s} \phi_{ij}^s L_j w_j}{\sum_k w_k^{1-\sigma^s} \phi_{kj}^s n_k^s} \leq \frac{\sigma^s F^s}{\mu^s} \tag{7}$$

for $i = 1, 2 \ldots, M$ and $s = 1, 2, \ldots, S+1$. Note that if (7) holds as a strict inequality for country j, $(n_j^s)^* = 0$ in equilibrium since no industry-s firm can break even there.

The conditions (7) define $M \times (S+1)$ equations in $M \times (S+2)$ unknowns (the industry distributions n_i^s and the wages w_i). To solve them requires either one of the following two approaches:

(i) to introduce M additional trade balance conditions which allow then to pin down all variables; or

(ii) to assume there is a costlessly tradable good that allows for factor price equalization (henceforth, FPE).

The first approach is more realistic as it would allow us to account for the well-documented empirical fact that factor prices are not equalized across countries. Taking such an approach, however, would require us to analyze the so-called 'wage equations', which are transcendental and cannot be solved analytically (see, e.g., Fujita *et al.*, p.55).[5] Hanson and Xiang (2004) have recently used the wage equations in a two-country setting to derive theoretical predictions about the HME when there is a continuum of industries that differ with respect to the degree of product differentiation and trade costs. Unfortunately, it is unclear whether any general results can be derived once we allow for an arbitrary number of countries. Thus, after stressing the usual caveat about FPE assumptions, we prefer to restrict ourselves to the second approach. Accordingly, our findings should be considered as complementary to those derived by Hanson and Xiang (2004).

Assume that good $S+1$ can be freely traded, i.e., $\tau_{ij}^{S+1} = \phi_{ij}^{S+1} \equiv 1$ for all countries i and j.[6] By symmetry, all firms then charge the same mill price everywhere. Given (5), this implies that the equilibrium wage is the same everywhere as long as sector $S+1$ operates in all countries (see Appendix 1 for the formal conditions). We can then set $w_i \equiv 1$ for all i by choice of numéraire, which allows us to get rid of the wages in equation (7).

[5] Recent empirical work in international trade and economic geography drawing on the wage equations include Redding and Venables (2004), Hanson and Xiang (2004), and Hanson (2005).

[6] In modeling sector $S+1$ as frictionless, we have in mind some IT related activities, e.g. internet services, that face almost zero transportation costs for delivering their (mostly digital) differentiated products. Trade costs for such activities are subsumed in the fixed costs of operating expensive telecommunication systems, whereas marginal transport costs are almost equal to zero. Yet, one should note that such firms may face 'indirect' trade impediments under the form of VAT and sales taxes.

Multiplying both sides of (7) by the positive n_i's and summing across countries, we get $N^s = \mu^s L/F^s\sigma^s$: in equilibrium the world mass of industry-s firms is constant and proportional to world population (note that this does not necessarily hold for industry $S+1$). This allows us to rewrite (7) in terms of shares. In particular, after defining $\theta_i \equiv L_i/L$ and $\lambda_i^s \equiv n_i^s/N^s$, condition (7) for non-positive profits becomes:

$$\mathrm{RMP}_i^s \equiv \sum_j \frac{\phi_{ij}^s \theta_j}{\sum_k \phi_{kj}^s \lambda_k^s} \leq 1, \qquad i = 1, 2, \ldots, M \qquad s = 1, 2, \ldots S \tag{8}$$

where RMP_i^s denotes the *real market potential* (henceforth, RMP) in country i and industry s (see Head and Mayer, 2004). The equilibrium conditions (8) can then be expressed as follows:

$$\begin{array}{lllll} \mathrm{RMP}_i^s & = & 1 & \text{if} & \lambda_i^{s*} > 0, \\ \mathrm{RMP}_i^s & \leq & 1 & \text{if} & \lambda_i^{s*} = 0. \end{array} \tag{9}$$

Stated differently, in equilibrium the RMP is equalized across all countries hosting a positive measure of firms. The reason is that free entry and exit make sure that the cross-country variations in attractiveness to firms in terms of distance-weighted demand are exactly capitalized in the cross-country variations of local price indices.[7] Specifically, in (8) the expenditures in countries $j = 1, 2, \ldots, M$ that can be tapped from country i are assigned weights that decrease with bilateral distance (inversely measured by ϕ_{ij}^s) and with the intensity of local competition (directly measured by $\sum_k \phi_{kj}^s \lambda_k^s$, itself an inverse transformation of the local price index defined in (3)). Therefore, (8) and (9) show that in equilibrium lower local price indices (i.e. tougher local competition) must offset any locational advantage in terms of proximity to consumer demand.

2.3 Matrix notation and spatial equilibrium

A spatial equilibrium in industry s is a vector λ^{s*} satisfying conditions (9). The firm shares λ_i^s are M endogenous unknowns whereas the expenditure shares θ_i, as well as the trade freeness measures ϕ_{ij}^s, are exogenous parameters. From now on, we set $\phi_{ii}^s = 1$ meaning that trade is free within countries. We also set $\phi_{ij}^s = \phi_{ji}^s$, thus implying that trade flows between any given pair of countries are subject to the same frictions in both directions.

Let us make notation of (9) more compact by recasting it in matrix form. Specifically, let

$$\Phi^s \equiv \begin{pmatrix} \phi_{11}^s & \phi_{12}^s & \cdots & \phi_{1M}^s \\ \phi_{21}^s & \phi_{22}^s & \cdots & \phi_{2M}^s \\ \vdots & \vdots & \ddots & \vdots \\ \phi_{M1}^s & \phi_{M2}^s & \cdots & \phi_{MM}^s \end{pmatrix}, \quad \lambda^s \equiv \begin{pmatrix} \lambda_1^s \\ \lambda_2^s \\ \vdots \\ \lambda_M^s \end{pmatrix} \quad \text{and} \quad \theta \equiv \begin{pmatrix} \theta_1 \\ \theta_2 \\ \vdots \\ \theta_M \end{pmatrix},$$

where $(\lambda^s)^T \mathbf{1} = \theta^T \mathbf{1} = 1$ (in what follows, $\mathbf{1}$ stands for the M-dimensional vector whose components are all equal to one and T denotes the transpose operator). Using these definitions, the M equilibrium conditions (9) can be expressed in matrix notation as follows:

$$\mathrm{RMP}^s = \Phi^s \mathrm{diag}(\Phi^s \lambda^s)^{-1} \theta \leq \mathbf{1}, \tag{10}$$

with the complementary slackness conditions

$$(\mathrm{RMP}_i^s - 1)\lambda_i^s = 0 \qquad i = 1, 2, \ldots M.$$

[7] For any (interior) equilibrium distribution λ^{s*}, firms have no incentive to relocate because the RMP is the same everywhere. Yet, the RMP differs across countries for off-equilibrium distributions. In this case, firms relocate from low to high RMP countries, which is the usual adjustment dynamics used in new economic geography (see, e.g., Fujita *et al.*, 1999).

In expression (10), the 'numerator' term $\Phi^s\theta$ highlights the role of the distance-weighted expenditure that can be served from each country. This measure is our counterpart to Davis and Weinstein's (2003) IDIODEM index. The 'denominator' term $\text{diag}(\Phi^s\lambda^s)$ captures the role of the distance-weighted supply that can serve each national market, which is a measure of the intensity of local competition. Then, in equilibrium, the cross-country distribution of firms is such that endogenous average supply exactly matches exogenous average expenditure for all countries hosting some firms, whereas the latter falls short of the former for countries hosting no firms.

It is of interest to note that (10) depends on industry-s variables only, which allows for an industry-by-industry analysis. In Appendix 2, we prove the following result:

Proposition 1 (existence, uniqueness and stability) *Assume that factor prices are equalized. Then a unique and globally stable equilibrium exists for all industries $s = 1, 2, \ldots S$ for all admissible values of θ and Φ^s.*

Note that Proposition 1 encompasses both interior *and* corner equilibria. To the best of our knowledge, such a result has not been formally shown to hold for Krugman's (1980) model until now.

Since any general characterization of the corner equilibria leads to a prohibitively complex taxonomy, even in 'low dimensional' cases, in what follows we focus on *interior equilibria* only (i.e. equilibria in which $\lambda_i^{s*} > 0$ for all countries $i = 1, 2, \ldots, M$ and all industries $s = 1, 2, \ldots, S+1$). Thus, condition (10) holds as an equality for all industries except $S+1$.

Let $\varphi^s \equiv (\Phi^s)^{-1}\mathbf{1}$, which can be interpreted as a vector of inverse measures of countries' average accessibility in industry s.[8] Using condition (10), an interior spatial equilibrium λ^{s*} is then as follows:

$$\theta = \text{diag}(\varphi^s)\Phi^s\lambda^{s*}. \tag{11}$$

If we denote by f_{ij}^s the cofactor of ϕ_{ij}^s and by $|\Phi^s|$ the determinant of Φ^s, (11) can finally be written component by component as

$$\theta_i = \varphi_i^s \sum_j \phi_{ij}^s \lambda_j^{s*} = \frac{\sum_k f_{ik}^s}{|\Phi^s|} \sum_j \phi_{ij}^s \lambda_j^{s*}, \tag{12}$$

which is simply the i-th row of expression (11). A necessary condition for an interior solution to exist can then be obtained by rewriting (12) as:

$$\theta_i = \varphi_i^s \sum_j \phi_{ij}^s \lambda_j^{s*} < \varphi_i^s \sum_j \lambda_j^{s*} = \varphi_i^s,$$

where the inequality results from $0 < \phi_{ij}^s < 1$ and where the last equality is due to the fact that the λ_i^{s*}'s sum up to one. Provided such an interior equilibrium exists, the *equilibrium distribution* of firms is given by

$$\lambda^{s*} = \left[\text{diag}((\Phi^s)^{-1}\mathbf{1})\Phi^s\right]^{-1}\theta, \tag{13}$$

or, component by component, by:

$$\lambda_i^{s*} = \sum_j \frac{f_{ij}^s}{\sum_k f_{jk}^s}\theta_j^s. \tag{14}$$

Since Φ^s is by assumption a symmetric matrix, $f_{ij}^s = f_{ji}^s$ holds for all i and j. Observe that (14) shows that the relationship between λ^{s*} and θ is *linear* for any interior solution.

[8]See Behrens *et al.* (2004) for sufficient conditions for the freeness of trade matrix Φ^s to be invertible.

Finally, the industry share of the numéraire industry $\lambda_i^{(S+1)*}$ is computed as a residual as follows:

$$\lambda_i^{(S+1)*} = \frac{1}{\mu^{S+1}} \left(\theta_i - \sum_s \mu^s \lambda_i^{s*} \right). \tag{15}$$

Of course, since FPE is assumed to hold and since the shares sum to one, we then have $0 < \lambda_i^{(S+1)*} < 1$ for all i (see Appendix 1).

3 Defining the multi-country HME

Although the concept of HME has been widely used in both theory and applications, *we still lack a clear and general definition of what exactly a HME is in a multi-country context.* In Krugman's (1980, p. 955) own words, in sectors characterized by Dixit-Stiglitz monopolistic competition "countries will tend to export those kinds of products for which they have relatively large domestic demand". This property is neatly implied by two-country models. Indeed, Helpman and Krugman (1985) show in such a model that *the larger country hosts a more than proportional share of the monopolistically competitive industry.* Given preferences that are homothetic and identical across countries, such a pattern of production makes the larger country a net exporter of the differentiated good.

The disproportionate positive causation from demand to supply has become the standard definition of the HME. Thus, a natural starting point is to investigate whether we can generalized it from both a *dynamic* (i.e., time-series) and a *static* (i.e., cross-sectional) point of view. Head *et al.* (2002) have shown that the static and dynamic definitions are equivalent in the symmetric 2×2-setting, thus making the choice immaterial in this case. As we will show, only the static definition can be meaningfully generalized when there are more than two countries.

3.1 Dynamic definition

A *dynamic* definition of the HME is often presented in two-country models and has been used in the empirical literature. It builds on the observation that, in the presence of the HME, *changes in expenditure shares map into more than proportional changes in industry shares*, i.e., there is "a more than one-for-one movement of production in response to idiosyncratic demand" (Davis and Weinstein, 2003, p.7).

More formally, assume that country i hosts an industry share at period t that is proportional to its expenditure share, which can be expressed as $(\lambda_i^*)^t = k^t \theta_i^t$ (we omit the industry index s to alleviate notation). Assume that in the following period $t+1$, all θ_j's have changed such that

$$\theta_i^{t+1} - \theta_i^t > 0 \qquad \text{and} \qquad \sum_j \left(\theta_j^{t+1} - \theta_j^t \right) = 0,$$

so that the new equilibrium industry share is given by $(\lambda_i^*)^{t+1} = k^{t+1} \theta_i^{t+1}$. In the presence of a dynamic HME, the disproportionate positive causation from demand to supply requires that $k^{t+1} > k^t$ whenever $\theta_i^{t+1} > \theta_i^t$. Hence,

$$\frac{(\lambda_i^*)^{t+1}}{\theta_i^{t+1}} = k^{t+1}, \quad \frac{(\lambda_i^*)^t}{\theta_i^t} = k^t \quad \text{and} \quad k^{t+1} > k^t \quad \Rightarrow \quad \frac{(\lambda_i^*)^{t+1}}{\theta_i^{t+1}} > \frac{(\lambda_i^*)^t}{\theta_i^t}.$$

Switching to differential notation, the last condition can be expressed as

$$\frac{\lambda_i^* + \mathrm{d}\lambda_i^*}{\theta_i + \mathrm{d}\theta_i} > \frac{\lambda_i^*}{\theta_i} \quad \Rightarrow \quad \frac{\mathrm{d}\lambda_i^*}{\mathrm{d}\theta_i^*} \frac{\theta_i}{\lambda_i^*} > 1.$$

This suggests quite naturally the following definition for the dynamic HME (henceforth, DHME):

Definition 1 (Dynamic Home Market Effect) *A monopolistically competitive industry exhibits a DHME in country i at the distribution θ and for the perturbation* $\mathrm{d}\theta$ *if and only if*

$$\frac{\mathrm{d}\lambda_i^*}{\mathrm{d}\theta_i}\frac{\theta_i}{\lambda_i^*} > 1, \tag{16}$$

where $\mathrm{d}\theta$ *is a small variation satisfying* $\mathrm{d}\theta_i > 0$ *and* $\sum_j \mathrm{d}\theta_j = 0$.

Unfortunately, condition (16) is an inappropriate definition of the HME when there are more than two countries since, as shown in Appendix 3, there always exists a perturbation $\mathrm{d}\theta$ such that it does not hold. Therefore, it is generally 'impossible' to define the HME in terms of changes in expenditure shares in a multi-country world, i.e., the disproportionate causation from demand to supply may not show up in the data even though it may be generated by the theoretical model. We hence discard this definition and adopt an alternative one in the remainder of this paper.

3.2 Static definition

While the DHME relates to the *time-series disproportionality* between two periods in the same country, the static HME (henceforth, SHME) relates to the *cross-sectional disproportionality* between two countries at the same time. Accordingly, we derive the static definition in a way analogous to the one used in the previous section.

Assume that countries i and j host an industry share that is proportional to their expenditure share, i.e.,

$$\lambda_i^* = k_i\theta_i \qquad \text{and} \qquad \lambda_j^* = k_j\theta_j,$$

where k_i and k_j are positive coefficients. In the presence of a SHME, the disproportionate positive causation from demand to supply requires that $k_i \geq k_j$ whenever $\theta_i \geq \theta_j$. Hence,

$$\frac{\lambda_i^*}{\theta_i} = k_i, \;\; \frac{\lambda_j^*}{\theta_j} = k_j \quad \text{and} \quad k_i \geq k_j \quad \Rightarrow \quad \frac{\lambda_i^*}{\theta_i} \geq \frac{\lambda_j^*}{\theta_j}.$$

This suggests the following definition:

Definition 2 (Static Home Market Effect) *A monopolistically competitive industry exhibits a SHME in country i at the expenditure distribution θ if and only if*

$$\theta_i \geq \theta_j \quad \Rightarrow \quad \frac{\lambda_i^*}{\theta_i} \geq \frac{\lambda_j^*}{\theta_j}, \quad \forall j = 1, \ldots, M \tag{17}$$

with $\lambda_i^*/\theta_i > \lambda_j^*/\theta_j$ *if and only if* $\theta_i > \theta_j$.

In what follows, we say that the global economy exhibits a SHME if condition (17) holds for all countries i. Specifically, assuming, without loss of generality, that country labels are ordered such that $\theta_1 \geq \theta_2 \geq \ldots \geq \theta_M$, the global economy exhibits a SHME when

$$\frac{\lambda_1^*}{\theta_1} \geq \frac{\lambda_2^*}{\theta_2} \geq \cdots \geq \frac{\lambda_M^*}{\theta_M}. \tag{18}$$

Stated differently, under a SHME there is no 'industrial leap-frogging' in the global economy, in the sense that smaller countries always host a relatively smaller share of the monopolistically competitive industry. This implies that the ordering in terms of industry shares reflects the 'natural' ordering in terms of countries' economic sizes.[9]

[9] A similar 'no leap-frogging property' has been used in tests of the factor proportions theory. As noted by Bowen *et al.* (1987, p.795), "for each country and factor, the ranking of adjusted net factor exports should conform to the ranking of factors by their abundance". Quite surprisingly, this formal analogy between 'classical' and 'new' trade theory has not been noticed until now.

4 Looking for the HME: a linear 'accessibility'-filter

In bringing the model to data, it is crucial to understand that the model does not predict that the equilibrium industry distribution λ^* should always satisfy (18).[10] The reason is that the appeal of a country as a production site depends not only on the relative size of its domestic market ('attraction') but also on its relative proximity to all other foreign markets ('accessibility'). Yet, we show now that (18) will hold provided that all countries have the same access to world markets. Stated differently, once we correct for countries' differential accessibility, the model predicts a SHME. This finding will guide our empirical investigation in Section 5.

To see that the SHME arises in a world without accessibility differences, assume that all trade costs are symmetric and equal to the average trade cost among all countries. Denoting the average freeness of trade in industry s by ϕ^s and setting $\phi^s_{ij} = \phi^s$ for all $i \neq j$, all countries then have the same accessibility. In this case, expression (14) reduces to

$$(\lambda^s_i)^{\text{size}} = \frac{1 + (M-1)\,\phi^s}{1-\phi^s}\theta_i - \frac{\phi^s}{1-\phi^s}, \tag{19}$$

which is the share of firms that would locate in country i were all countries evenly spaced at the same average distance from one another.[11] It is readily verified that $\theta_i > \theta_j$ implies $(\lambda^s_i)^{\text{size}}/\theta_i > (\lambda^s_j)^{\text{size}}/\theta_j$. This result shows that *one should expect the SHME to appear in the data only after controlling for cross-country differences in accessibility.*

But how can we control for these differences in the first place? We proceed as follows. First, we define a measure of accessibility, second we use it to sterilize the equilibrium firm distribution from the impact of cross-country differences in accessibility. Let us start by considering a hypothetical world in which expenditures are equally spread across countries so that the location of firms is solely driven by trade cost considerations. In this case $\theta_i = 1/M$ for all i, so that (14) reduces to

$$(\lambda^s_i)^{\text{hub}} = \frac{1}{M}\sum_j \frac{f^s_{ij}}{\sum_k f^s_{ik}} = \frac{1}{M|\Phi^s|}\sum_j \frac{f^s_{ij}}{\varphi^s_j}. \tag{20}$$

Since $(\lambda^s_i)^{\text{hub}}$ depends on the ϕ^s_{ij}'s only, we choose it as our *theory-based definition of accessibility.* It is the share of firms that would locate in country i were world expenditures evenly distributed across countries.

We are now equiped to decompose the equilibrium distribution of firms in terms of accessibility $(\lambda^s)^{\text{hub}}$ and attraction $(\lambda^s)^{\text{size}}$. In so doing, let

$$W^s \equiv \left[\text{diag}((\Phi^s)^{-1}\mathbf{1})\Phi^s\right]^{-1} \quad \text{and} \quad \beta^s \equiv \frac{1-\phi^s}{1+(M-1)\phi^s}.$$

Then, since $\lambda^{s*} = W^s\theta$ and

$$(\lambda^s)^{\text{size}} = \frac{1}{\beta^s}\left(\theta - \frac{1-\beta^s}{M}\mathbf{1}\right) \quad \text{and} \quad (\lambda^s)^{\text{hub}} = \frac{1}{M}W^s\mathbf{1},$$

[10] See Behrens *et al.* (2004) for simple counterexamples.

[11] It is easy to show that

$$(\lambda^s)^{\text{size}} = \theta + \frac{M\phi^s}{1-\phi^s}\left(\theta - \frac{1}{M}\mathbf{1}\right),$$

which is reminiscent of the estimating equation (3) by Davis and Weinstein (2003, p.7). The first term stands for the autarky share of industry, whereas the second term captures the idiosyncratic component of local demand. Note, however, that the coefficient capturing the idiosyncratic impact $M\phi^s/(1-\phi^s)$, though positive, need not be larger than one in theory (see also Brülhart and Trionfetti, 2005). This undermines the restriction proposed by Davis and Weinstein (2003, p.8) to identify the HME.

we get the following *exact theoretical decomposition*:

$$\lambda^{s*} = \beta^s W^s (\lambda^s)^{\text{size}} + (1-\beta^s)(\lambda^s)^{\text{hub}}. \tag{21}$$

Expression (21) is particularily appealing from an empirical point of view. Since W^s depends on the freeness of trade only, it can be interpreted as a *spatial weight matrix* capturing the complex interrelations between national market sizes. Therefore, (21) can be seen as providing some theoretical foundation to the so far ad-hoc inclusion of spatial weight matrices in empirical models.

To control for accessibility, we can invert the relationship (21) to obtain the value of λ^s predicted by the model in the absence of differences in trade costs:

$$(\lambda^s)^{\text{size}} = (\beta^s W^s)^{-1} \left[\lambda^{s*} - (1-\beta^s)(\lambda^s)^{\text{hub}} \right]. \tag{22}$$

Together with (20), expression (22) gives us a *theory-based linear accessibility-filter* to be applied to the observed λ^{s*}. Stated differently, before testing for the SHME, which is predicted by the model only in terms of the unobserved $(\lambda^s)^{\text{size}}$, we have to filter the effect of differential accessibility.

5 Non-parametric tests of the HME

Our dataset consists in trade flows, industry-level value added, and GNP for 40 (resp., 52) countries and 25 (resp., 27) manufacturing industries at the 3-digit ISIC level for the year 1990 (resp., 2000) (see Appendix 4 for a more detailed description of the dataset). Following Hanson and Xiang (2004), we split the set of countries into two sub-groups which we label the *treatment* and *control group*, respectively. The treatment group for 1990 consists of 20 OECD countries, whereas the control group consists of 20 newly industrializing and developing countries that were not members of the OECD in that same year. For the 2000 dataset, we also extract a treatment group of 20 OECD countries. Due to problems of data availability, a reasonable control group is not available for that year.

Our empirical strategy is to implement two analyses: (i) one focusing on the treatment groups in 1990 and 2000; and (ii) one focusing on the control group in 1990. The underlying logic is the following. Countries in the treatment group are characterized by roughly similar high levels of economic development and relative factor endowments. According to the theory (see, e.g., Dixit and Norman, 1980; Helpman and Krugman, 1985), trade flows between them should mostly be of the intra-industry type and thus be better explained by increasing returns and imperfect competition as featured by the model developed in the previous sections. The countries of the control group exhibit both a lower average level of development and higher heterogeneity in terms of relative factor endowments and per-capita GDP. Thus, with respect to the treatment group, the importance of inter-industry trade in the control group should rise and the explanatory power of our model should fall as it neglects the effects of technological differences and factor endowments.

5.1 Sign tests

In the empirical literature on international trade, non-parametric 'sign tests' have been repeatedly used to check the predictive power of the factor proportions theory, according to which countries export the goods that use relatively intensively their relatively abundant factors (see Bowen *et al.*, 1987; Feenstra, 2003). As noted by Trefler (1995, p. 1029), the main conclusion that must be drawn is that the basic factor proportions theory "performs horribly [since] factor endowments predict the direction of factor service trade about 50 percent of the time, a success rate that is matched by a coin toss". More recently, Choi and Krishna (2004) used another 'sign test' based on Helpman's (1984) result that the bilateral pattern of trade should reflect the fact that countries, on average, import the factors that are relatively more expensive at home and export the factors that are relatively cheaper. Although the authors find some strong empirical support for this prediction, they acknowledge that their "tests provide only a statement regarding the direction and magnitude of trade flows on average" (Choi and Krishna, 2004, p. 895).

In this section, we show that a similar methodology to the one used by Bowen *et al.* (1987) as well as by Choi and Krishna (2004) may be used to test the predictive power of new trade theory. Observe that, as shown in Sections 3 and 4, once we control for differences in accessibility

$$Z_{ij}^s \equiv \left(\frac{(\lambda_i^s)^{\text{size}}}{\theta_i^s} - \frac{(\lambda_j^s)^{\text{size}}}{\theta_j^s} \right) \left(\theta_i^s - \theta_j^s \right) \geq 0 \tag{23}$$

should hold for all country pairs i and j if industry s is subject to a SHME. The formal analogy of (23) with the sign tests used in factor proportions theory is striking. Quite surprisingly, this has been overlooked until now probably because all empirical work on the HME has focused on the disproportionate causation from demand to supply in terms of intertemporal variations. The use of condition (23) for a formal test offers two distinct advantages: (i) it circumvents the theoretical difficulties of the DHME highlighted in Section 3.1; and (ii) its results are more easily comparable with the ones established in the factor proportions literature. While this does not allow us, of course, to discriminate between the two paradigms, we may get a rough idea of how good their relative predictions are.

As a first indicator of the predictive power of the HME model, we use a similar approach to the one adopted by Choi and Krishna (2004).[12] Building on condition (23), the *weakest* sign test of the HME theory is that

$$Z^s \equiv \sum_{i=1}^{M} \sum_{j=1}^{M} \left(\frac{(\lambda_i^s)^{\text{size}}}{\theta_i^s} - \frac{(\lambda_j^s)^{\text{size}}}{\theta_j^s} \right) \left(\theta_i^s - \theta_j^s \right) \geq 0$$

should hold at the industry level. Stated differently, on average countries with larger expenditure shares on good s host more than proportionate shares of industry s. We call the corresponding check the 'world average Z-test'. We compute Z^s for all 25 industries using both the 'unadjusted' observed shares λ as constructed from the data (see Appendix 4) and the 'adjusted' unobserved shares λ^{size} that control for accessibility as in (22). Results for both the treatment and the control group (not shown here) reveal that this weak prediction almost always holds when we control for differences in market access. Indeed, for the 1990 sample, whereas Z^s is negative in 6 out of 25 cases when we use the unadjusted value of λ, it is only insignificantly negative in 1 out of 25 cases when we use λ^{size}. For the 2000 sample, whereas Z^s is negative in 11 out of 25 cases when we use the unadjusted value of λ, it is only insignificantly negative in 6 out of 25 cases when we use λ^{size}. The theory is therefore strongly supported at such a weak test level.

A slightly stronger test of the HME prediction can be expressed as follows:

$$Z_i^s \equiv \sum_{j=1}^{M} \left(\frac{(\lambda_i^s)^{\text{size}}}{\theta_i^s} - \frac{(\lambda_j^s)^{\text{size}}}{\theta_j^s} \right) \left(\theta_i^s - \theta_j^s \right) \geq 0 \tag{24}$$

which states that on average, if country i has a larger expenditure share on good s than the other countries, then it hosts a more than proportionate share of industry s. We call the corresponding check the 'country average Z-test'. The industry-level results for (24) are given in Tables 1 and

[12] See Appendix 5 for the distributional properties of all the test statistics we use.

4, respectively. As can be seen from Table 1, when we control for accessibility, the trade weighted average percentage of correct signs is 81.7 per cent for the treatment group in 1990 (resp., 76.0 per cent in 2000), while it drops to 70 per cent for the 1990 control group. Thus, in the case of OECD countries, there is strong support for the theoretical prediction that, on average, trade in manufactures flows from countries with relatively larger local demand to countries with relatively smaller local demand. Our percentages of correct signs are of the same order of magnitude as those in Choi and Krishna (2004) for the 1990 sample, whereas the results are slightly worse, but still good, for the year 2000. Therefore, *on average both factor proportions and HME theories deliver results that are roughly equally backed by the data at an aggregate level.*

Unfortunately, the foregoing average sign tests are rather crude indicators of the explanatory power of the theory. This is because many small negative observations that violate it may be more than offset by a few large positive ones. To get rid of this potential problem, we push disaggregation one step further. As shown in Sections 3 and 4, the theory predicts that the observed industry distribution λ should reflect the country rankings in terms of expenditure θ once differential accessibility is appropriately controlled for. Hence, the strongest sign test of the HME prediction is

$$Z_{ij}^s \equiv \left(\frac{(\lambda_i^s)^{\text{size}}}{\theta_i^s} - \frac{(\lambda_j^s)^{\text{size}}}{\theta_j^s} \right) \left(\theta_i^s - \theta_j^s\right) \geq 0, \tag{25}$$

which is (23) for $M(M-1)/2$ distinct country-combinations. It states that for each pair of countries, if one country has a larger expenditure share on good s, then it hosts a more than proportionate share of industry s. We call the corresponding check the 'pairwise Z-test'. Notice that passing from the 'country average Z-test' (24) to the 'pairwise Z-test' (25) amounts to passing from average tests à la Choi and Krishna (2004) to disaggregated tests à la Bowen *et al.* (1987). The crucial question then becomes: *Does the success rate of HME-based predictions exceed that of a coin toss?*

Table 2 displays the industry-level results for the pairwise Z-tests (25) for the treatment and control group in 1990, whereas Table 4 displays the analogous results for the 2000 treatment group. Note first that, quite surprisingly, even without controlling for differences in accessibility, the average percentage of correct predictions is about 64.4 (resp., 66.9) per cent for the trade weighted mean. Therefore, it exceeds the success rate of a coin toss. Note further that, after controlling for differences in accessibility, the trade weighted mean of correct predictions is of 69.3 and 69.7 percent for the 1990 and the 2000 sample. Stated differently, *the spatially filtered HME model correctly predicts the net trade flows of more than two-thirds of the observations.* For 18 out of 25 industries, the percentage of correct predictions with the filtered data significantly exceeds 0.5 at the 5 per cent level in 1990 (resp., for 24 out of 27 industries in 2000). As can be further seen from Table 2, the share of correct predictions decreases as expected for the control group. Indeed, the arithmetic and the trade weighted percentages of correct predictions decrease to 55.0 and 62.0 per cent respectively, which is closer to the coin-toss outcome than for the treatment group. There are only 7 industries in which the correct predictions exceed the 'coin-toss' 50 per cent threshold at a 5 per cent significance level for the unadjusted data, whereas the number increases to 11 for the spatially filtered data. This shows that the average rate of correct predictions is lower for pairs of non-OECD countries, which probably reflects the relative importance of technological differences and relative factor endowments.

5.2 Rank tests

The *strongest* test of the SHME we develop in this paper goes beyond the sign tests by building on Definition 2 in Section 3.2: *Does the ranking of relative industry shares (λ_i^s/θ_i) match the ranking of expenditure shares (θ_i) after controling for differences in accessibility?* To answer this question, we compute the Spearman rank-correlation coefficients between those two series for all 25 industries on both the treatment and the control samples. The results are summarized in Tables 3 and 4.

As can be seen from Table 3, for the OECD sample only five coefficients are slightly negative after controlling for accessibility. The other 20 rank-correlation coefficients are positive. Among them, 15 are statistically greater than zero at the 5 per cent level. In other words, *the SHME prediction is strongly supported for OECD countries after controlling for accessibility.* The comparision with the control group is of particular interest: it shows that *for the control group without controlling for accessibility, there is almost no correlation between market-size and the pattern of trade* (only 5 out of 25 coefficients are statistically positive at the 5 per cent level). Table 3 also shows that the prediction gets better once we control for accessibility. Yet, the correlations remain much weaker than for the treatment group: only 7 coefficients out of 25 are statistically greater than zero at the 5 per cent level, whereas 11 are even negative, which runs plainly against the HME theory. Hence, expenditures predict the location of industry much less effectively in the control than in the treatment sample, which may again signal the role of technological differences and relative factor endowments.

5.3 Sectoral patterns

So far, our data seem to provide strong support for the presence of the HME after correcting for cross-country accessibility differences, as required by the theoretical model. We now make a further step and challenge the model in terms of its cross-sector predictions. Specifically, our model predicts that the HME should arise in sectors characterized by imperfect competition, product differentiation, and scale economies. Moreover, given the definition of trade freeness ϕ, the HME should vary in intensity across industries depending crucially on the degree of product differentiation (σ) and the level of trade costs (τ).[13]

Table 5 summarizes some industry-level characteristics concerning the type of goods as well as their R&D- and advertising-intensities building on existing taxonomies developed by Pagano and Schivardi (2003), Rauch (1999), and Lyons and Sembenelli (1997). These taxonomies represent our point of departure for a tentative classification of sectors in terms of their propensity to exhibit a HME. In particular, sectors reported as homogenous or reference-priced by either Rauch (1999) or Lyons and Sembenelli (1997), and exhibiting small R&D intensity according to Pagano and Schivardi (2003), are classified as exhibiting 'low HME-propensity'. Sectors reported as differentiated or heterogeneous, and having high R&D intensity, are classified as exhibiting 'high HME-propensity'. The remaining sectors are a priori uncertain.[14] The outcome is the three groups of sectors appearing in Table 6:

(i) 'low HME-propensity': ISIC 311, 321, 322, 323, 324, 341, 342, 361, 369, 372 ('low');

(ii) 'high HME-propensity': ISIC: 351, 352, 353, 355, 382, 383, 384, 385 ('high');

(iii) 'uncertain': ISIC 313, 314, 331, 332, 356, 362, 371, 381, 390 ('uncertain').

How do these classifications match our empirical findings? Table 6 summarizes our results. Columns 4–6 ('Observed') indicate for the 1990 and 2000 treatment (and the 1990 control) groups whether the sign tests are at least significant at a 5% level, before and after correcting for accessibility. Column 7 is then constructed by applying a simple majority rule to columns

[13] See, e.g., Amiti (1998) and Hanson and Xiang (2004).

[14] In our classification we have exploited the fact that the correlation between the average trade freeness ϕ^s in each industry and the first two columns in Table 5 is 0.702 and 0.616 respectively. In other words, high values of R&D employment to total employment or R&D expenditure to value added also proxy high trade freeness.

4–6.[15] First, we note that 10 sectors do not seem to exhibit a HME (ISIC 311, 313, 314, 321, 322, 323, 324, 331, 361, 369). These include sectors such as Food, Beverages, Textiles and Footwear, which is in line with what one would expect. Note that the overlap with the a priori expectations is strong, except for a few sectors. Second, 10 sectors can be unambiguously associated with HMEs (ISIC 332, 351, 355, 356, 371, 382, 383, 384, 385, 390). These include Industrial chemicals, Rubber products, Plastic products as well as Machinery, Transport equipment, and Scientific instruments. Again the findings conform to what we would expect a priori and the overlap is significant. Finally, 7 sectors remain uncertain (ISIC 341, 342, 352, 353, 362, 372, 381), which include Other chemicals, Petroleum refineries, Glass and Products and Fabricated metal products.

To conclude, we compare our sectoral findings with related results in the literature. As can be seen from the last two columns in Table 6, our predictions for HME sectors overlap significantly with the recent results by Brülhart and Trionfetti (2005), whereas the overlap with Davis and Weinstein (2003) is much weaker. Since Brülhart and Trionfetti (2005) also rely on an estimating equation that is shown to hold in a multi-country world, we view this as evidence for the importance of correcting for accessibility and accounting for the global structure of world trade when testing the importance of market size for trade patterns and industry location.

6 Conclusion

We have started with what we called the 'Davis-Weinstein conjecture' (Davis and Weinstein, 2003). According to this conjecture, the HME uncovered in two-country models may be extended to a multi-country world in a fairly straightforward way. Specifically, with two countries, firms are disproportionately located in the country offering the larger local demand. With many countries, the same should happen with respect to some index of local 'effective' demand. Such index should take into account not only local demand per se but also demands derived from other countries, weighted by some adequate measure of distance.

By developing a multi-country model à la Krugman (1980), we have shown that things are unfortunately not that simple. In particular, as shown by Proposition 2 in Appendix 3, it is quite difficult, perhaps impossible, to build an index of 'effective' demand whose changes always generate disproportionate responses with respect to output. The reason being that, with many countries, the location of firms is determined by the interaction between spatial ('accessibility') and non-spatial ('attraction') effects, which are crucially influenced by what happens to the entire distribution of demand across all countries ('third country effects'). These conceptual difficulties, however, do not imply the impossibility of assessing the role of product differentiation and market structure in shaping the structure of world trade. We propose, indeed, a series of new theory-based non-parametric tests of the HME that are similar to the sign- and rank-tests used in the applied factor proportions literature. Our main finding is that the empirical evidence strongly backs the HME prediction: *local market size crucially matters in explaining and predicting observed trade flows, especially between OECD countries.*

As our preliminary results do not allow us to reject the HME model as a possible explanation for the structure of world trade, the next logical step is to take the model to the data with the help of a more complete econometric analysis. In particular, our decomposition of the geographical distribution of firms into 'attraction' and 'accessibility' components may turn out to be useful for future econometric investigations.

[15]Sectors with more no's than yes' are of type (i); sectors with more yes' than no's, but not only yes, are of type (iii); and sectors with only yes are of type (ii).

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Appendix 1: Factor price equalization

Factor price equalization requires any $M-1$ dimensional subset of countries to be unable to satisfy world demand for the numéraire good (see, e.g., Baldwin *et al.*, 2003). Let ℓ_i^s be the amount of labor employed by a representative industry-s firm in country i. For the numéraire production to take place everywhere, the total mass of workers in each country should be greater than the total labor requirement in all industries except $S+1$, i.e.,

$$L_i > \sum_s n_i^s \ell_i^s \qquad \forall i.$$

Therefore, since $L_i = \theta_i L$ and

$$\begin{aligned} \sum_s n_i^s \ell_i^s &= \sum_s \lambda_i^{s*} N^s \left(F + c \sum_j x_{ij}^s \right) \\ &= \sum_s \lambda_i^{s*} \frac{\mu^s L}{F^s \sigma^s} \left[F^s + c^s \frac{F^s(\sigma^s - 1)}{c^s} \right] = L \sum_s \lambda_i^{s*} \mu^s \end{aligned}$$

in equilibrium, the condition for factor price equalization reduces to:

$$\theta_i > \sum_s \lambda_i^{s*} \mu^s \qquad \forall i. \tag{26}$$

Thus, the expenditure shares μ^s must be small enough for the numéraire good to be produced everywhere. Alternatively, since $\mu^{S+1} + \sum_s \mu^s = 1$, this implies that the expenditure share on the numéraire good is large enough.

Appendix 2: Existence of a unique equilibrium

Since all RMP_i's are continuous functions of λ (and, therefore, of n), Proposition 1 in Ginsburgh *et al.* (1985) shows that an equilibrium always exists. Rewrite the profit function in country i as follows:

$$\begin{aligned}\Pi_i(n) &= \sum_j \left(p_{ij}d_{ij} - cx_{ij}\right) - F \\ &= \frac{\mu}{\sigma}\sum_l \frac{\phi_{il}L_l}{\sum_k \phi_{kl}n_k} - F \\ &= F\left(\text{RMP}_i - 1\right).\end{aligned}$$

Assume that firms relocate in response to profit differentials, so that n_i increases (resp. decreases) if $\Pi_i(n) > 0$ (resp. < 0). Hence, the dynamics of the relocation process is given by

$$\dot{n_i} = \xi_i \Pi_i(n), \tag{27}$$

where $\dot{n_i} \equiv dn_i/dt$ and where $\xi_i > 0$ stands for the speed of the adjustment in country i.

We first show that the Jacobian of Π, denoted by J, is negative definite. Note that

$$\frac{\partial \Pi_i(n)}{\partial n_j} = -\frac{\mu}{\sigma}\sum_l \frac{\phi_{jl}\phi_{il}L_l}{\left(\sum_k \phi_{kl}n_k\right)^2},$$

so that, by symmetry of the ϕ_{ij}'s, the matrix J is symmetric. Then, for any nonzero vector x, we have

$$\begin{aligned}x^T Jx &= -\frac{\mu}{\sigma}\sum_i\sum_j \xi_i x_i \xi_j x_j \sum_l \frac{\phi_{jl}\phi_{il}L_l}{\left(\sum_k \phi_{kl}n_k\right)^2} \\ &= -\frac{\mu}{\sigma}\sum_l \frac{\sum_i \xi_i\phi_{il}x_i \sum_j \xi_j\phi_{jl}x_j L_l}{\left(\sum_k \phi_{kl}n_k\right)^2} \\ &= -\frac{\mu}{\sigma}\sum_l \frac{\left(\sum_i \xi_i\phi_{il}x_i\right)^2}{\left(\sum_k \phi_{kl}n_k\right)^2} L_l < 0,\end{aligned}$$

thus implying that J is negative definite. According to Rosen (1965, Theorem 8), if J is negative definite for every $\lambda \in \Delta$, the system (27) is globally stable on Δ. Because existence and global stability of an equilibrium implies uniqueness, our result follows.

Appendix 3: Third country effects

The DHME requires that the industry share λ_i^* of country i is sufficiently elastic with respect to the expenditure share θ_i, which clearly captures the idea that changes in expenditure map into disproportionate changes in industry. Differentiating the equilibrium industry share of country i allows us to rewrite expression (16) as follows:

$$\sum_j \frac{\partial \lambda_i^*}{\partial \theta_j}\frac{\mathrm{d}\theta_j}{\mathrm{d}\theta_i}\frac{\theta_i}{\lambda_i^*} > 1. \tag{28}$$

We can now show that (28) need not hold in a multi-country world.

Proposition 2 (Third country effects) *Unless trade costs are the same between any pair of countries, for every distribution θ there exists a perturbation $\mathrm{d}\theta$, with $\mathrm{d}\theta_i > 0$ and $\sum_j \mathrm{d}\theta_j = 0$, such that the disproportionate causation from demand to supply does not hold.*

Proof. Because $\lambda_i^* > 0$, $\theta_i > 0$, and $\mathrm{d}\theta_i > 0$, a necessary condition for (16) to hold requires $\mathrm{d}\lambda_i^*$ to be strictly positive. However, by linearity,

$$\mathrm{d}\lambda_i^* = \lambda_i^*(\theta + \mathrm{d}\theta) - \lambda_i^*(\theta) = \sum_j g_{ij}\mathrm{d}\theta_j = \sum_{j \neq i}(g_{ij} - g_{ii})\mathrm{d}\theta_j \tag{29}$$

where the g_{ij}'s are coefficients as given in (14), and where the last equality stems from the constraint that the perturbations sum-up to zero. Except in the case where trade costs are are the same between any pair of countries, we can always find perturbations $\mathrm{d}\theta_j$ such that (29) is negative, in which case the DHME does not hold for all perturbations satisfying $\mathrm{d}\theta_i > 0$ and $\sum_j \mathrm{d}\theta_j = 0$. It is sufficient to note that in the general asymmetric case $\min_j\{g_{ij}\} < \max_j\{g_{ij}\}$ and that at least one $\mathrm{d}\theta_j$, $j \neq i$, must be strictly negative. ■

Appendix 4: Data description and construction

Our data comes from two sources. First, we use the dataset developed at CEPII to obtain bilateral trade flows as well as intra-country absorption at the 3-digit level for the years 1990 and 2000.[16] Second, we use the World Bank Trade and Production Database as well as the CEPII dataset to obtain industry specific value-added at the 3-digit ISIC level.

We retain only countries which have positive trade flows in at least half of the industries. This leaves us with 40 countries in 1990, which we split into two equally sized samples. The countries in the *treatment group* are as follows: Australia, Austria, Canada, Denmark, Spain, Finland, France, Great Britain, Germany, Greece, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Sweden, Turkey, and the United States. The countries in the *control group* are as follows: Argentina, Bangladesh, Chile, China, Columbia, Egypt, Hong Kong, Hungary, India, Indonesia, Korea, Mexico, Pakistan, Peru, Philippines, Poland, Romania, Thailand, Taiwan, and Venezuela.

From the 2000 dataset, we extract the following *treatment group*: Australia, Austria, Belgium/Luxembourg, Canada, Czech Republic, Germany, Spain, France, Great Britain, Greece, Italy, Japan, South Korea, Mexico, Netherlands, Poland, Portugal, Sweden, Turkey, and the United States. Unfortunately, due to data availability we cannot extract a sufficiently large control sample. Thus, we restrict ourselves to the treatment group for this year.

Turning to industries, we focus on 25 3-digit ISIC manufacturing industries in 1990 (see Tables 1 to 3 for the industry list), whereas the number of industries is 27 for the 2000 sample. This level of aggregation makes our results comparable with previous works on the HME such as Trionfetti (2001), Head and Ries, (2001), and Brülhart and Trionfetti (2005); it also minimizes the potential impacts of intersectoral cross-price elasticities that may distort the analysis, as argued in Section 2.1.[17]

The construction of the variables requires only few data: value-added or some other measure to construct the firm distribution λ^s; production, absorption and import/export data for all countries and industries to construct the expenditure distribution θ and the trade cost matrix Φ^s. We use value-added (henceforth, VA) as an indicator of the distribution of production and industry across countries. As is well known, using employment data would lead to substantial bias since differences in countries' labor productivities and capital-labor ratios cannot be easily controlled for. We proxy country i's share of industry s as follows:

$$\lambda_i^s = \frac{\mathrm{VA}_i^s}{\sum_j \mathrm{VA}_j^s}.$$

[16] See Mayer and Zignago (2004) for more details on the CEPII dataset. It can be obtained at: http://team.univ-paris1.fr/teamperso/mayer/data/data.htm

[17] See Davis and Weinstein (2003) for a discussion of possible aggregation biases.

Let Y_i, M_i^s and X_i^s stand for country i's total value of production, as well as imports and exports in industry s from and to the rest of the world, respectively. The expenditure share can then be expressed as follows:

$$\theta_i = \frac{Y_i + \sum_s (M_i^s - X_i^s)}{\sum_j (Y_j + \sum_s (M_j^s - X_j^s))},$$

which is domestic absorption in country i relative to world absorption (GDP corrected for the trade balance). Note that since intermediate goods are included, both firms and consumers are buyers. Let

$$X_{ij}^s \equiv n_i^s p_{ij}^s x_{ij}^s$$

stand for the trade cost inclusive value of industry-s goods produced in country i and shipped to country j. The values X_{ii}^s for intra-country trade flows (i.e., own-absorption) are directly taken from the CEPII database.[18]

We further need an estimate of the trade cost matrix Φ^s. This can be obtained as in Head and Mayer (2004, p. 2618). Specifically, given (2) as well as (5) and assuming that the theoretical model is true, we have

$$\frac{X_{ij}^s X_{ji}^s}{X_{ii}^s X_{jj}^s} = \frac{\phi_{ij}^s \phi_{ji}^s}{\phi_{ii}^s \phi_{jj}^s}.$$

Assuming, moreover, that bilateral trade barriers are symmetric and internal trade costs $\hat{\phi}^s$ are the same across countries, the estimate of $\phi_{ij}^s/\hat{\phi}^s$ is given by:[19]

$$\frac{\phi_{ij}^s}{\hat{\phi}^s} = \sqrt{\frac{X_{ij}^s X_{ji}^s}{X_{ii}^s X_{jj}^s}}.$$

Table 7 summarizes the values of $\phi_{ij}^s/\hat{\phi}^s$ for the country pairs US-Canada and France-Germany. As can be seen from the table, our estimates are roughly in line with those obtained by Head and Mayer (2004).

Finally, the implementation of (22) requires one last piece of information in that to calculate β we need to know ϕ^s. This is the 'average freeness of trade' in industry s. In what follows, we approximate ϕ^s as:

$$\phi^s \equiv \frac{1}{M(M-1)} \sum_{i=1}^{M} \sum_{j \neq i} \phi_{ij}^s. \tag{30}$$

Note that (30) is not entirely satisfactory since, from a theoretical point of view, ϕ^s should be the geometric mean of the ϕ_{ij}^s's. Unfortunately, it is impossible to compute ϕ^s meaningfully this way because of a significant proportion of zero flows between countries in the sample. This stresses the relevance of the 'Haveman and Hummels criticism', which points out that although the CES model implies trade among all countries for each sector, the reality is largely dominated by zero flows (see Anderson and van Wincoop, 2004, p.732).

[18] An alternative is to construct them from the World Bank database as the total value of production of country i, minus its exports to the world: $X_{ii}^s = Y_i^s - X_i^s$ for $i = 1, 2, \dots M$. Our results do not significantly change when using this alternative approach. In both cases the measure of X_{ii}^s does not correct for re-exports. Although the problem of re-exports is well-known in the literature (see, e.g., Feenstra and Hanson, 2004), only few countries actually have good aggregate indicators of re-export shares. Yet, even these countries generally do not provide detailed information at the industry level. To complicate things, re-exports need to be corrected for re-export mark-ups, which are even more difficult to obtain. Given the lack of quality data, we choose to disregard the re-export problem in our analysis. Accordingly, in some rare cases total exports may actually exceed domestic production for some countries and industries. This feature of small open economies in the data is well-known. Following Head and Ries (2001), we exclude countries with negative values of domestic absorption from our industry-level analysis.

[19] It is readily verified that $\hat{\phi}^s$ can take any value and that this does not change the equilibrium conditions (8).

Appendix 5: Distributions of test statistics

Table 1 lists the percentage:

$$\mathcal{S}_1^k = \frac{1}{M}\sum_i \text{sgn}\left[\max\left\{0, \sum_j Z_{ij}^k\right\}\right],$$

which is binomially distributed. Hence, the null hypothesis is given by $H_0 : \mathcal{S}_1^k = 1/2$, whereas the alternative hypothesis is given by $H_1 : \mathcal{S}_1^k > 1/2$. The 0.01 and 0.05 critical values for this unilateral test can be computed for each M. For example, for $M = 20$, $\mathcal{S}^k$ is significantly greater than 1/2 at the 1 percent (resp. 5 percent) level when $Z_i^k > 0$ in 16 (resp. 15) or more out of 20 countries. These critical values depend on M.

Table 2 lists the percentage:

$$\mathcal{S}^k = \frac{2}{M(M-1)}\sum_i \sum_{j<i} \text{sgn}\left[\max\left\{0, Z_{ij}^k\right\}\right],$$

which is also binomially distributed so that the same null hypothesis applies. However, the number of pairs $M(M-1)/2$ is large enough that we may use the normal approximation to the binomial distribution, as in Choi and Krishna (2004, p. 903). That is, $\mathcal{S}^k$ is significantly greater than 1/2 at the 1 percent (resp. 5 percent) level when

$$z \equiv \frac{\frac{M(M-1)}{2}\mathcal{S}^k + \frac{1}{2} - \frac{M(M-1)}{4}}{\sqrt{\frac{M(M-1)}{16}}}$$

exceeds 2.33 (resp. 1.645).

Table 3 finally gives the Spearman rank-correlation coefficients. The significance levels can be found in Kendall and Gibbons (1990).

Table 1 — 'Country-average Z-tests' (Z_i^s) and accessibility-adjusted 'country-average Z-tests' (1990 sample)

ISIC	Industry classification	Treatment group			Control group		
		M	% with λ	% with λ^{size}	M	% with λ	% with λ^{size}
311	Food products	20	20.0	40.0	20	0.0	0.0
313	Beverages	19	10.5	21.1	20	25.0	25.0
314	Tobacco	19	47.4	36.8	20	45.0	45.0
321	Textiles	20	40.0	65.0	20	25.0	45.0
322	Wearing apparel except footwear	19	47.4	94.7**	18	72.2*	72.2*
323	Leather products	19	57.9	68.4	18	55.6	66.7
324	Footwear except rubber or plastic	19	31.6	63.2	19	21.1	26.3
331	Wood products except furniture	19	21.1	26.3	20	30.0	30.0
332	Furniture except metal	19	52.6	89.5**	18	55.6	55.6
341	Paper and products	19	57.9	84.2**	20	20.0	40.0
342	Printing and publishing	20	70.0	85.0**	20	40.0	45.0
351	Industrial chemicals	19	84.2**	94.7**	20	50.0	95.0**
352	Other chemicals	20	90.0**	95.0**	20	0.0	10.0
355	Rubber products	20	95.0**	95.0**	19	78.9**	89.5**
356	Plastic products	20	100.0**	95.0**	20	65.0	85.0**
362	Glass and products	18	83.3**	88.9**	20	30.0	40.0
369	Other non-metallic mineral products	19	15.8	26.3	19	52.6	52.6
371	Iron and steel	18	77.8*	94.4**	20	80.0**	80.0**
372	Non-ferrous metals	16	31.3	81.3*	18	11.1	16.7
381	Fabricated metal products	20	90.0**	80.0**	20	50.0	70.0
382	Machinery except electrical	20	85.0**	80.0**	19	89.5**	89.5**
383	Machinery electric	20	95.0**	90.0**	20	100.0**	100.0**
384	Transport equipment	20	95.0**	90.0**	20	85.0**	90.0**
385	Professional and scientific equipment	18	94.4**	100.0**	17	76.5*	82.4**
390	Other manufactured products	18	94.4**	88.9**	19	100.0**	94.7**
	Arithmetic mean		63.5	74.9		50.3	57.8
	Trade weighted mean		76.2	81.7		61.0	70.0

Notes: $*$ = significant at 5% level; $**$ = significant at 1% level

Table 2 — 'Pairwise Z-tests' (Z_{ij}^{s})and accessibility-adjusted 'pairwise Z-tests' (1990 sample)

ISIC	Industry classification	Treatment group			Control group		
		M	% with λ	% with λ^{size}	M	% with λ	% with λ^{size}
311	Food products	20	43.2	50.0	20	25.3	26.3
313	Beverages	19	34.5	39.2	20	44.7	45.3
314	Tobacco	19	40.4	40.9	20	45.8	46.3
321	Textiles	20	51.6	50.0	20	43.2	48.9
322	Wearing apparel except footwear	19	50.3	67.8**	18	51.0	51.0
323	Leather products	19	59.1*	60.2**	18	42.5	49.0
324	Footwear except rubber or plastic	19	51.5	50.9	19	38.6	41.5
331	Wood products except furniture	19	49.1	53.2	20	47.9	54.7
332	Furniture except metal	19	60.2**	74.9**	18	54.2	57.5*
341	Paper and products	19	53.8	75.4**	20	41.6	45.3
342	Printing and publishing	20	55.3	60.5**	20	36.8	38.4
351	Industrial chemicals	19	57.3*	80.1**	20	49.5	68.9**
352	Other chemicals	20	62.1**	77.4**	20	25.8	30.5
355	Rubber products	20	72.1**	77.9**	19	53.8	56.7*
356	Plastic products	20	70.5**	75.8**	20	56.8*	61.1**
362	Glass and products	18	61.4**	68.6**	20	47.9	54.2
369	Other non-metallic mineral products	19	32.7	44.4	19	46.2	47.4
371	Iron and steel	18	68.6**	83.7**	20	60.0**	62.6**
372	Non-ferrous metals	16	47.5	69.2**	18	43.1	43.8
381	Fabricated metal products	20	66.3**	67.9**	20	54.2	57.4*
382	Machinery except electrical	20	64.7**	63.7**	19	71.9**	79.5**
383	Machinery electric	20	72.6**	71.1**	20	68.4**	78.4**
384	Transport equipment	20	80.5**	78.4**	20	66.3**	75.3**
385	Professional and scientific equipment	18	68.6**	73.9**	17	66.9**	72.1**
390	Other manufactured products	18	72.5**	75.8**	19	67.3**	77.2**
	Arithmetic mean		57.9	65.2		50.0	54.8
	Trade weighted mean		64.4	69.3		55.0	62.0

Notes: $*$ = significant at 5% level; $**$ = significant at 1% level

Table 3 — Spearman rank correlations and 'adjusted' Spearman rank correlations (1990 sample)

ISIC	Industry classification	Treatment group			Control group		
		M	R with λ	R with λ^{size}	M	R with λ	R with λ^{size}
311	Food products	20	-0.203	-0.020	20	-0.701	-0.680
313	Beverages	19	-0.433	-0.260	20	-0.107	-0.102
314	Tobacco	19	-0.316	-0.296	20	-0.114	-0.089
321	Textiles	20	-0.036	-0.017	20	-0.214	-0.060
322	Wearing apparel except footwear	19	0.030	0.460^{*}	18	0.088	0.088
323	Leather products	19	0.275	0.279	18	-0.183	-0.007
324	Footwear except rubber or plastic	19	0.028	0.005	19	-0.302	-0.181
331	Wood products except furniture	19	-0.091	0.079	20	-0.098	0.141
332	Furniture except metal	19	0.304	0.688^{**}	18	0.129	0.216
341	Paper and products	19	0.089	0.677^{**}	20	-0.275	-0.143
342	Printing and publishing	20	0.182	0.314	20	-0.349	-0.293
351	Industrial chemicals	19	0.212	0.649^{**}	20	0.014	0.535^{**}
352	Other chemicals	20	0.274	0.577^{**}	20	-0.654	-0.547
355	Rubber products	20	0.639^{**}	0.746^{**}	19	0.116	0.182
356	Plastic products	20	0.505^{*}	0.614^{**}	20	0.192	0.325
362	Glass and products	18	0.292	0.534^{*}	20	-0.095	0.108
369	Other non-metallic mineral products	19	-0.496	-0.226	19	-0.100	-0.068
371	Iron and steel	18	0.571^{**}	0.831^{**}	20	0.320	0.400^{*}
372	Non-ferrous metals	16	-0.071	0.468^{*}	18	-0.216	-0.185
381	Fabricated metal products	20	0.462^{*}	0.445^{*}	20	0.183	0.250
382	Machinery except electrical	20	0.377^{*}	0.323	19	0.605^{**}	0.742^{**}
383	Machinery electric	20	0.564^{**}	0.522^{*}	20	0.507^{*}	0.738^{**}
384	Transport equipment	20	0.820^{**}	0.741^{**}	20	0.411^{*}	0.630^{**}
385	Professional and scientific equipment	18	0.424^{*}	0.657^{**}	17	0.485^{*}	0.569^{**}
390	Other manufactured products	18	0.505^{*}	0.622^{**}	19	0.474^{*}	0.693^{**}

Notes: $*$ = significant at 5% level; $**$ = significant at 1% level

Table 4 — Sign tests, rank tests, and correlation coefficients for the treatment group (2000 sample)

ISIC	Industry classification		Z_i^s sign tests		Z_{ij}^s sign tests		Rank correlations	
		M	% with λ	% with λ^{size}	% with λ	% with λ^{size}	% with λ	% with λ^{size}
311	Food products	20	85.0^{**}	95.0^{**}	61.1^{*}	74.7^{**}	0.292	0.656^{**}
313	Beverages	19	31.6	42.1	51.5	56.7^{*}	0.035	0.196
314	Tobacco	19	89.5^{*}	89.5^{**}	59.6^{**}	63.7^{**}	0.237	0.381
321	Textiles	17	58.8^{*}	94.1^{**}	54.1	80.1^{**}	0.091	0.787^{**}
322	Wearing apparel except footwear	15	26.7	73.3	46.7	54.3	-0.046	0.129
323	Leather products	16	37.5	25.0	43.3	51.7	-0.224	0.056
324	Footwear except rubber or plastic	16	12.5	50.0	39.2	58.3^{*}	-0.371	0.285
331	Wood products except furniture	18	44.4	44.4	47.1	58.8^{*}	-0.096	0.251
332	Furniture except metal	18	66.7	72.2^{*}	52.9	62.1^{**}	0.106	0.401^{*}
341	Paper and products	18	83.3^{**}	88.9^{**}	63.4^{**}	70.6^{**}	0.342	0.523^{*}
342	Printing and publishing	19	89.5^{**}	100.0^{**}	62.6^{**}	73.1^{**}	0.347	0.625^{**}
351	Industrial chemicals	16	93.8^{**}	87.5^{**}	66.7^{**}	71.7^{**}	0.468^{*}	0.653^{**}
352	Other chemicals	15	100^{**}	86.7^{**}	75.2^{**}	74.3^{**}	0.711^{*}	0.600^{**}
353	Petroleum refineries	16	62.5	75.0^{*}	61.7^{**}	71.7^{**}	0.421	0.629^{**}
355	Rubber products	17	58.8^{*}	64.7	61.8^{**}	59.6^{*}	0.275	0.301
356	Plastic products	19	89.5^{**}	94.7^{**}	66.7^{**}	73.1^{**}	0.437^{*}	0.656^{**}
361	Pottery china earthenware	17	5.9	11.8	39.7	40.4	-0.279	-0.206
362	Glass and products	19	42.1	63.2	52.6	60.8^{**}	0.053	0.284
369	Other non-metallic mineral products	19	47.4	63.2	50.9	59.1^{*}	0.009	0.205
371	Iron and steel	18	38.9	72.2^{*}	52.3	60.1^{**}	0.040	0.325
372	Non-ferrous metals	16	56.3	93.8^{**}	54.2	73.3^{**}	0.094	0.624^{**}
381	Fabricated metal products	16	88.2^{*}	88.2^{**}	64.7^{**}	66.2^{**}	0.382	0.449^{*}
382	Machinery except electrical	14	92.9^{**}	85.7^{*}	78.0^{**}	70.3^{**}	0.705^{**}	0.516^{*}
383	Machinery electric	17	88.2^{*}	82.4^{**}	66.2^{**}	76.5^{**}	0.368	0.630^{**}
384	Transport equipment	18	88.9^{**}	50.0	73.2^{**}	64.1^{**}	0.643^{**}	0.408^{*}
385	Professional and scientific equipment	13	92.3^{**}	84.6^{*}	71.8^{**}	73.1^{**}	0.538^{*}	0.522^{*}
390	Other manufactured products	14	85.7^{**}	100.0^{**}	59.3^{*}	82.4^{**}	0.204	0.842^{**}
	Arithmetic mean		65.1	73.3	58.4	66.0		
	Trade weighted mean		82.5	76.0	66.9	69.7		

Notes: $*$ = significant at 5% level; $**$ = significant at 1% level

Table 5 — Industry level break down of R&D, types of goods and other indicators

ISIC	Industry classification	Pagano and Schivardi (1)		Rauch (2)		Lyons and Sembenelli (3)	
		R&D personnel / employment	R&D expenditure / value added	conservative	liberal	type of good	intensive
311	Food products	0.59	1.17	w	w	hom.	adv.
313	Beverages	0.59	1.17	n	n	het.	adv.
314	Tobacco	–	–	r	r	het.	adv.
321	Textiles	0.29	0.60	w	w	hom.	–
322	Wearing apparel except footwear	0.11	0.60	n	n	hom.	–
323	Leather products	0.29	0.60	n	n	hom.	–
324	Footwear except rubber or plastic	–	–	n	n	hom.	–
331	Wood products except furniture	0.09	2.66	n/r	n/w	hom.	–
332	Furniture except metal	0.09	2.66	n	n	hom.	–
341	Paper and products	1.69	1.11	–	–	hom.	–
342	Printing and publishing	0.24	1.11	–	–	hom.	–
351	Industrial chemicals	9.67	9.70	n	n	het.	R&D.
352	Other chemicals	9.67	9.70	r	r	het.	R&D., adv.
355	Rubber products	0.91	3.17	n	n	het.	R&D.
356	Plastic products	–	–	r	r	hom.	–
362	Glass and products	0.08	2.04	n	n	hom.	–
369	Other non-metallic mineral products	0.08	2.04	w/r	w/r	hom.	–
371	Iron and steel	1.11	1.51	n/r	n/r	hom.	–
372	Non-ferrous metals	1.11	1.51	w	w	hom.	–
381	Fabricated metal products	0.71	1.41	n	n	hom.	–
382	Machinery except electrical	3.33	12.27	n	n	het.	R&D.
383	Machinery electric	3.21	7.10	n	n	het.	R&D.
384	Transport equipment	7.03	22.76	n	n	het.	R&D.
385	Professional and scientific equipment	11.68	17.99	n	n	het.	R&D., adv.
390	Other manufactured products	–	–	–	–	–	–

Notes: (1) – Industries 384 and 385 are averages of a finer subdivision.
(2) – w=homogenous, r=reference priced, n=differentiated
(3) – hom.=homogenous, het.=heterogenous, adv.=advertising

Table 6 — Industry level predictions and realizations of the HME

ISIC	Industry classification	Expected	Observed			Overall HME	Brülhart and	Davis and
			1990†	2000†	Control†	(adjusted)	Trionfetti (2005)	Weinstein (2003)
311	Food products	low	no	yes	no	−		strong support
313	Beverages	uncertain	no	no/yes	no	−		weak support
314	Tobacco	uncertain	no	yes	no	−		
321	Textiles	low	no	no/yes	no	−	strong support	strong support
322	Wearing apparel except footwear	low	no/yes	no	no	−		
323	Leather products	low	no/yes	no	no	−		strong support
324	Footwear except rubber or plastic	low	no	no	no	−		
331	Wood products except furniture	uncertain	no	no/yes	no	−	strong support	
332	Furniture except metal	uncertain	yes	no/yes	no/yes	HME		
341	Paper and products	low	no/yes	yes	no	+		
342	Printing and publishing	low	no/yes	yes	no	+		
351	Industrial chemicals	high	no/yes	yes	yes	HME	weak support	weak support
352	Other chemicals	high	yes	yes	no	+	weak support	
353	Petroleum refineries	high	—	yes	—	+		
355	Rubber products	high	yes	yes	no/yes	HME	weak support	
356	Plastic products	uncertain	yes	yes	yes	HME	weak support	
361	Pottery china earthenware	low	—	no	—	−		
362	Glass and products	uncertain	yes	no/yes	no	+		
369	Other non-metallic mineral products	low	no	no/yes	no	−		
371	Iron and steel	uncertain	yes	no/yes	yes	HME		
372	Non-ferrous metals	low	no/yes	no/yes	no	+	strong support	
381	Fabricated metal products	uncertain	yes	yes	no	+	strong support	weak support
382	Machinery except electrical	high	yes	yes	yes	HME	strong support	
383	Machinery electric	high	yes	yes	yes	HME	strong support	
384	Transport equipment	high	yes	yes	yes	HME	strong support	
385	Professional and scientific equipment	high	yes	yes	yes	HME	strong support	
390	Other manufactured products	uncertain	yes	yes	yes	HME	strong support	

Notes: † – First value refers to unadjusted, second to adjusted.
A single value indicates that both are the same.
In column 7, a + indicats more support, a − indicates less support.

Table 7 — Freeness of trade values ϕ_{ij} for selected country pairs

ISIC		USA–CAN		FRA–GER	
		1990	2000	1990	2000
311	Food products	0.019	0.035	0.023	0.023
313	Beverages	0.018	0.033	0.031	0.044
314	Tobacco	0.003	0.003	0.016	0.025
321	Textiles	0.028	0.141	0.077	—
322	Wearing apparel except footwear	0.011	0.056	0.037	0.041
323	Leather products	0.076	0.203	0.083	—
324	Footwear except rubber or plastic	0.036	0.078	0.052	0.042
331	Wood products except furniture	0.092	0.145	0.024	—
332	Furniture except metal	0.074	0.093	0.03	0.017
341	Paper and products	0.120	0.258	—	0.017
342	Printing and publishing	0.017	0.05	0.015	0.016
351	Industrial chemicals	0.147	0.344	—	0.222
352	Other chemicals	0.034	0.104	0.06	0.099
353	Petroleum refineries	—	0.088	—	0.013
355	Rubber products	0.128	0.199	0.123	0.131
356	Plastic products	0.04	0.105	0.032	0.037
361	Pottery china earthenware	—	0.125	—	—
362	Glass and products	0.116	0.271	0.089	0.1
369	Other non-metallic mineral products	0.025	0.038	0.025	0.015
371	Iron and steel	0.068	0.110	0.083	0.093
372	Non-ferrous metals	0.238	—	0.09	0.12
381	Fabricated metal products	0.057	0.184	0.039	0.036
382	Machinery except electrical	0.198	0.244	0.097	0.122
383	Machinery electric	0.197	0.490	0.058	0.085
384	Transport equipment	0.3	0.525	0.143	0.168
385	Professional and scientific equipment	0.170	—	0.908	—
390	Other manufactured products	0.051	0.244	0.126	0.346