Testing for the Home Market Effect in Inter-Regional Trade in Korea

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Abstract

This study attempts to test the HME hypothesis in inter-regional Korean trade. For this purpose, we draw on the multi-regional model recently developed by Behrens *et al*. (2009). In particular, we utilize Behrens *et al.*'s (2009) simple linear filter, which allows us to separate the "pure HME" from "the third-country effect". Our contribution includes converting the theoretical simple linear filter into an empirical framework for testing HME. We apply the empirical linear filter to inter-regional trade data of 100 manufacturing industries for 16 Korean regions. Our tests identify the presence of HME in inter-regional trade and its strength appears to be greater than that observed in the international context of earlier studies. Furthermore, important third-country effects are observed across Korean regions

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1. Introduction

The most distinctive feature of observable spatial economic activity configurations is "agglomeration," in which certain economic activities are concentrated within a geographical region. Many studies have attempted to explain the sources of agglomeration. Until the 1990s, the most widely accepted theories were those of natural advantages (Ellison and Glaeser, 1997, 1999) and human capital and knowledge spillovers (Marshall, 1920; Krugman, 1991b; Helsley and Strange, 1990). However, since the seminal work of Krugman (1991a), theoretical economists familiar with *general equilibrium frameworks* have developed a new approach to understanding why some regions seem to attract a disproportionate share of economic activity. Widely known as "New Economic Geography" (NEG), this approach emphasizes the interaction between trade costs (including transportation costs) and firm-level scale economies as a source of agglomeration. More specifically, NEG outlines the forces pulling firms towards or pushing them away from a core. Examples of pulling (i.e., agglomeration) forces include lower transportation costs and a larger market size, which are conducive to firm-level scale economies. Pushing or dispersion forces include high transport costs, factor prices, and congestion. The relative strength of agglomeration versus dispersion forces partly explains why some regions attract a disproportionate share of economic activity.

In contrast to conventional location theories, the NEG focus on the relation between agglomeration and trade costs overlaps significantly with the New Trade Theory (NTT). Key overlaps arise in the case of the *home market effect* (HME). The HME states that, in equilibrium, the economic region with the larger demand for a good shall produce a more than proportionate share of that good, *ceteris paribus*. That is, the production of a good will tend to concentrate in the region with the higher demand for that good. Hence, the HME can be interpreted as *agglomeration* in the context of NEG, as described by Krugman (1991).

Since the introduction of the HME hypothesis (Krugman, 1980; Helpman and Krugman, 1985), there have been several attempts to test it empirically. Examples include Davis and Weinstein (1996, 1999, 2003), Head and Ries (2001), Trionfetti (2001), Brülhart and Trionfetti (2002), and Crozet and Trionfetti (2008). Many of these studies confirm the presence of the HME using international trade data, especially in a two-country framework. However, there have been few tests for the HME in inter-regional trade within an economy.

The objective of this study is to test the HME hypothesis in inter-regional Korean trade. For this purpose, we draw on the multi-regional model developed recently by Behrens et al. (2009). In particular, we utilize their simple linear filter, which allows me to separate the "pure HME" from “positional advantages”, as the third-country effect. Our contribution includes converting the theoretical simple linear filter into an empirical framework we can use to test for the HME. we apply the empirical linear filter to inter-regional trade data of 100 manufacturing industries across 16 Korean regions.

The remainder of this paper is organized as follows. In the following section, we review previous studies relevant to empirically testing the HME. Section 3 introduces the simple linear filter developed by Behrens et al. (2009) and describes how to modify the filter for empirical application. Our empirical testing is detailed in Section 4. The final section summarizes and concludes the paper.

2. Literature review

The HME is generally defined as “*a more than proportional relationship between a country's share of world production of a good and its share of world demand for the same good*” (Crozet and Trionfetti, 2008). Since the HME hypothesis was initially proposed by Krugman (1980), and later modified by Helpman and Krugman (1985), as an integral part of an alternative theory of trade, NTT literature has considered the HME to be one of determinants of patterns of trade, particularly intra-industry trade, between countries. On the other hand, in the wake of the seminal work of Krugman (1991), NEG literature has utilized the HME in a different way, even though NEG is partly based on the NTT and shares several common concepts, including the HME. In the context of NEG, the HME states that, in equilibrium, the scale-free spatial unit (including countries and regions within a country) with the larger demand for a good shall produce a more than proportionate share of that good, *ceteris paribus*. That is, the production of a good will tend to concentrate in the region with the higher demand for that good. Hence, the HME can also be interpreted as *agglomeration* in the context of NEG.

Despite both research fields’ common theoretical use of the HME, only NTT theorists have made an effort to test the HME hypothesis empirically. Among these, the most salient work is that of Davis and Weinstein (1996), which has since been regarded as the archetype of HME empirical research. In both their original study and in their follow-up work, Davis and Weinstein (1996) introduced a specification for an HME test. The test is a kind of linear approximation of the theoretical model proposed by Krugman (1980), particularly with an underlying two-country framework. In this specification, they formulated a so-called “*IDIODEM*” index, which is a heuristic measure of the “idiosyncratic” demand for a producer in a certain country, inclusive of the demand within the country and those around it. They conjectured that this *IDIODEM* index provides evidence of the presence of the HME. More specifically, the HME exists if the estimated ratio of the output elasticity to the *IDIODEM* index is greater than one.

Indeed, it is fair to say that, notwithstanding various modifications and improvements, most of the empirical work on the HME emerged after the specification by Davis and Weinstein (1996) for a two-country framework. For example, the study of Head *et al.* (2001) closely followed that of Davis and Weinstein (1996), except they utilized the variables as shared notations instead of in absolute terms, based mainly on the work of Krugman and Helpman (1985). Trionfetti (2001) and Brülhart *et al.* (2002) attempted to decompose the HME into a magnification effect and home-biased effect, following the specifications of Head *et al.* (2001) and Davis and Weinstein (1996), respectively. Then, Crozet *et al*. (2008) extended the specification of Davis and Weinstein (1996) by introducing a product differentiation model, based on Armington (1969), including the outside good sector with an iceberg-type trade cost. This led to a simple linear relation between production and demand able to encompass more general features, such as the non-linearity of the relation. Admittedly, it is undeniable that all such works based on that of Davis and Weinstein (1996) have made notable contributions to verifying the HME hypothesis and to providing a variety of implications in regard to the HME, mostly within the context of the NTT. However, particularly in the sight of NEG empirists, these studies do have limitations as follows:

First, their theoretical basis reflects a simple two-country world, which is not robust in the context of empirical research that needs to deal with a real multi-country world (or a country with many regions). Head and Mayer (2003) and Behrens *et al*. (2009) both noted that trade and agglomeration can take place in the interactive processes among more than two spatial units in the real world. Therefore, without considering a third unit, or more, evidence of the presence of the HME may be biased. Considering this limitation, Behrens *et al*. (2009) proposed a theoretical framework in a multi-country setting, extended the work of Krugman and Helpman (1985). This will be explained further in the next section.

Second, their applications are restricted to a national spatial scale, even though their theoretical predictions could be applied to any spatial scale by including a scale-free parameter for trade costs(τ). In contrast to NTT research, this issue is arguably more critical within an NEG context, which has to deal with data at various and heterogeneous spatial scales. For instance, Monroe *et al*. (2003) listed two attributes of inter-regional trade within a country that distinguish it from international trade: higher trade freeness and more homogeneous spatial units. Firstly, in comparison with international trade, inter-regional trade generally has few or no frictions, such as physical distances, cultural/institutional differences, uncertainty over currency exchange rates, and explicit trade barriers such as tariffs or custom duties. In addition, inter-regional trade usually takes place between or among more homogeneous spatial units with less variation in technology or resource endowments. Applying predictions within empirical research to spatial units at a regional level must consider these differences.

In this study, we test the HME hypothesis empirically while considering the aforementioned limitations. In particular, we focus on inter-regional trade within Korea, basing our study on the multi-country setting of Behrens *et al*. (2009), which we believe might be superior to previous studies based on a simple two-country setting.

3. Methodology

3.1. The multi-regional HME test

In this section, we first describe the multi-regional model for the HME test recently developed by Behrens *et al.* (2009) to introduce a simple linear filter. This allows us to separate the "pure HME" from "the third-country effect" .

Indeed, the model of Behrens *et al.* (2009) includes the following underlying assumptions, also typical of NEG theoretical models. A national economy consists of M regions, indexed as i = 1, 2,…, M. Region i hosts an exogenously given mass of L_i (>0) consumers, each of whom supplies one unit of labor inelastically, which is the only factor of production.[2] With z_i units of labor producing one unit of goods, a homogenous conventional sector good (A) is produced under constant returns. In the manufacturing sector, all varieties are produced with the same cost function, as follows:

$$l_\omega = \alpha + \beta x_\omega \tag{1}$$

The production of any variety of the differentiated good takes place under increasing returns to scale by a set of monopolistically competitive firms.[3] In what follows, we denote the mass of firms located in country i as n_i.

Following the typical assumptions of NEG/NTT literature, the preferences of a representative consumer in region i are defined using a two-tier utility function. The upper tier of the utility function is defined over a homogenous conventional sector good (A) and over a continuum of varieties of a horizontally differentiated good (C) in a manufacturing sector, as follows:

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[2] Hence, both the whole population and the whole labor endowment of the national economy are given by $L = \sum_i L_i$.

[3] This set is endogenously determined in equilibrium by free entry and exit. This condition is one of the assumptions that differs between NTT and NEG, and supposes that the size of operating firms in a region is not determined by free entry and exit but by relocation processes of firms across regions. Recently, both conditions were incorporated in the NEG framework by Okubo *et al.* (2010).

$$U_i = A_i^{1-\mu} C_i^{\mu} \tag{2}$$

C_i in equation (2) is a CES lower tier utility defined over the varieties of the horizontally differentiated good as follows:

$$C_i = \left(\sum_j \left(\int_{\omega \in \Omega_j} c_{ji}(\omega)^{\sigma-1/\sigma} d\omega\right)\right)^{\frac{\sigma}{\sigma-1}} \tag{3}$$

where cji(ω) is the consumption in country i of variety ω produced in country j, and Ωj is the set of varieties produced in country j with j=1, 2, ⋯, M. The parameter σ >1 measures both the constant own price elasticity of demand for any variety and the elasticity of substitution between any two varieties.

Next, we suppose two regions with sizes of L_i and L_j, sharing the same preferences and technologies, and being open to trade. Trade is perfectly free for homogenous conventional sector goods, but there are trade costs (of the iceberg type) for manufacturing goods. In other words, to sell one unit of the good to consumers in another region, the firm has to produce $\tau_{ij} > 1$ units, because $\tau_{ij} - 1$ units are lost during transportation.

Given these assumptions, and adding the firms' profit maximization condition under the free entry and exit condition, assuming an interior equilibrium, Behrens et al. (2009) showed that the cross-region distribution of firms in equilibrium is given by

$$n^* = \frac{\mu}{\sigma r} \Phi^{-1} diag(\Phi^{-1} 1)^{-1} \Xi l \tag{4}$$

where $n^* (= (n_1^*, n_2^*, \cdots, n_M^*)^T)$ is an interior spatial equilibrium vector of firm distribution across regions, r ($\equiv \alpha/\beta$) measures the intensity of increasing returns to scale, which is assumed to be the same across regions, and $\Xi \left(\equiv \mathrm{diag}(1/z_1, \cdots, 1/z_M)\right)$ is the diagonal matrix of absolute productivity (i.e., the nominal wage in equilibrium) in the homogeneous conventional sector. In addition, the matrix of bilateral trade freeness, Φ, in equation (4) is defined as

$$\Phi = \begin{pmatrix} \phi_{11} & \phi_{12} & \cdots & \phi_{1M} \\ \phi_{21} & \phi_{22} & & \phi_{2M} \\ \vdots & & \ddots & \vdots \\ \phi_{M1} & \phi_{M2} & \cdots & \phi_{MM} \end{pmatrix}$$

where $\phi_{ij} (\equiv \tau_{ij}{}^{1-\sigma})$ is a measure of trade freeness, taking the value one when trade is free and zero when trade is prohibitively costly.4 Then, let the cross-region distribution of firms in terms of the mass of firms in equation (4) be transformed to one in share notation, given by

[4] Behrens *et al.* (2009) imposed the condition that trade was free within a region, $\phi_{ii} \equiv 1$, and that trade flows between any given pair of regions were subject to the same frictions in both directions ($\phi_{ij} \equiv \phi_{ji}$). Since they intentionally adopted these assumptions on the freeness of trade to simplify their analysis, it does not seem that these conditions are strictly necessary in an empirical approach.

$$\lambda^* = (diag(\Phi^{-1}\,\mathbf{1})\Phi)^{-1}\theta\ . \quad (5)$$

In equation (5), θ and λ* respectively denote the vector of the regions' shares of total national demand (as measured by aggregate expenditure) and the vector of the regions' shares of total national production (as measured by either aggregate fixed cost payments or, equivalently, free entry, aggregate operating profits) in the differentiated good sector. The equilibrium condition (5) reveals that the relation between λ* and θ is linear at any interior solution and is parameterized by the trade freeness matrix, Φ. By developing such a linear relation, Behrens et al. (2009) formulated a simple linear filter to distill the pure effect of market sizes on firms' spatial distribution (i.e., the "pure HME") from other effects (such as the "third-country effect") that blended within the "observable HME." The linear filter is based on the linear decomposition of λ* in equation (5), represented by

$$\lambda^* = (\eta W)\lambda^{SA} + (1-\eta)\lambda^{CC} \quad (6)$$

Where $W \equiv (diag(\Phi^{-1}\,\mathbf{1})\Phi\Gamma^{\sigma})^{-1}$ and $\eta \equiv (1-\overline{\phi})/((1+(M-1)\overline{\phi}) \in (0,1)$ where $\overline{\phi}$ is the mean value of ϕ_{ij}. Equation (6) also shows that the vector of regions′ shares of total national production (λ^*) is the linear combination of

$$\lambda^{SA} \equiv \frac{1+(M-1)\overline{\phi}}{1-\overline{\phi}}\theta - \frac{\overline{\phi}}{1-\overline{\phi}}$$ [5]

and

$$\lambda^{CC} \equiv {}^{1}\!/_{M}\, W\mathbf{1}$$ [6]

Inverting this equation gives:

$$\lambda^{SA} = (\eta W)^{-1}(\lambda^* - (1-\eta)\lambda^{CC}\ ) \quad (7)$$

Equation (7) is the simple linear filter proposed by Behrens et al. (2009), who provided the following general prediction based on the model: a more than proportional relationship between a region's share of total national demand and its share of total production only occurs after the influence of centrality (i.e., the "third-country effect") is filtered out through equation (7). Using this simple linear filter, we test for a "pure HME" in inter-regional trade data of manufacturing industries across Korean regions. To do so, we first convert the theoretical simple linear filter into an empirical framework.

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5 λ^{SA} is the production shares that would prevail without centrality advantage ($\phi_{ij} = \overline{\phi}$ for all $i \neq j$). In this case, size and absolute advantage alone determine the cross-region variation of production shares.

6 λ^{CC} is the production shares after removing the absolute advantage ($z_i = z$ for all i′s) so that $\theta_i = 1/M$ for all $i = 1, \ldots, M$. In this case centrality alone determine the cross-region variation of production shares.

3.2. An empirical framework for testing for the HME

Strictly speaking, NTT/NEG general equilibrium models such as that of Behrens *et al*. (2009) are merely sets of mathematical tools for performing thought experiments. In addition, these tools tend to be based on somewhat unrealistic assumptions, just for the sake of mathematical convenience. When evaluating empirically testable hypotheses derived from these theoretical frameworks, we need to relax these unrealistic assumptions and substitute them with more manipulable devices. Hence, here we describe how we applied a theoretical tool such as a linear filter to actual data prior to testing for the HME.

3.2.1. Data sources

The NTT considers the HME in relation to patterns of trade, while NEG perceives the HME as an implicit alternative way of indicating agglomeration, particularly in interacting with trade (or more specifically, trade cost). As a result, most HME hypothesis tests have utilized trade data. Using international trade data is especially prevalent among these studies since the vast majority of them share the same theoretical basis of NTT. However, few studies have tested the HME between regions within a country, which potentially would have interested NEG researchers or regional economists. One reason for this is that intra-regional trade data tend to be less available than international trade data. Collecting raw data and generating statistical data on international trade is easier than doing the same for inter-regional trade within a country. This is because the former, which has to go through the customs of the country, tends to be more controllable than the latter, which can happen rather more sporadically and ubiquitously within the borders of the country.

Fortunately, the Korean central bank (i.e., the Bank of Korea) has published "regional input-output tables" twice (in 2005 and 2008)[7] following the policy schemes for national development called *the strategy for a balanced development of the nation*. These regional input-output tables contain information on the volumes of trade flows among spatial units. The spatial units comprised five integrated economic regions in 2005 and 16 regions (seven metropolitan cities and nine provinces) in 2008. The tables also contain information on production (value-added and total revenues) and expenditure by spatial unit. The data are all expressed in terms of the value at producers' prices (or mill prices), which are common to 168 sectors (including the 100 manufacturing sectors). In our actual tests for the HME, we only include the data from the regional input-output table published in 2008 (representing economy in 2005), since it provides richer information covering more regions.

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[7] Tables were published in 2005 and 2008. The table published in 2005 represented the economic situation in 2003, while the table published in 2008 reflected the situation in 2005.

3.2.2. Parameter estimation issues

Since the linear filter is parameterized from a theoretical model, as shown in equation (7), I need to specify the value of the parameters constructing it. The main set of parameters, in matrix form, is merely the matrices of trade freeness (Φ), which make up matrix W in equation (5).

In order to estimate the second set of main parameters, namely the trade freeness matrix (Φ), we use the method proposed by Head and Mayer (2003, 2004):

$$\frac{\widehat{\phi_{IJ}}}{\widehat{\phi_{II}}} = \sqrt{\frac{m_{ij}m_{ji}}{m_{ii}m_{jj}}}$$

where m_{ij} $(= n_i c_{ij}(p_i \tau_{ij}) = n_i c_{ij} p_{ij})$ represents the value of imports from region *i* into region *j*, at a purchase price inclusive of transportation costs, and m_{ii} and m_{jj} denote the value of commodities produced and consumed[8] within region *i* or region *j*, respectively. Following Head and Mayer (2003, 2004), we assume trade freeness within a region ($\widehat{\phi_{II}}$ or $\widehat{\phi_{JJ}}$) takes a unit value over all regions (i.e., $\widehat{\phi_{II}} = \widehat{\phi_{JJ}} = \hat{\phi} = 1$). By applying this assumption to the data obtained from the regional input-output table, we calculate the values $\hat{\phi}$ for the 100 manufacturing sectors. Table 1 shows the geometric mean of $\hat{\phi}$ for every pair of regions, by sector. The mean values of inter-regional trade freeness for the Korean manufacturing sectors fall within the relatively wide range of 0.59 to 1, but are very skewed toward 1. As seen in Fig. 1, 87% of the sectors are more than 0.9. These results imply that inter-regional trade takes place very freely, particularly in comparison with international trade.[9] This would seem to be quite reasonable, and is consistent with the finding of Monroe *et al*. (2003) on the representative attributes of inter-regional trade within a country, as mentioned earlier.

[8] Head and Mayer (2003) named these "imports from self" (or, equivalently, "exports to self").

[9] For example, Head and Mayer (2003) reported estimates of trade freeness between the U.S. and Canada and between France and Germany in two sectors (textiles, apparel, and leather and motor vehicles and parts). For textiles, apparel, and leather, the U.S.–Canada trade freeness is 0.111, while the value for Germany–France is 0.130. In the case of motor vehicles and parts, the U.S.–Canada trade freeness is 0.717 and that of Germany–France is 0.114. The estimates of Head and Mayer (2003) reflecting international trade are significantly lower than our results.

Table 1 Estimated geometric mean values of ϕ_{ij} by upper tier sector

	Sectors (No.)	Geometric mean values of $\widehat{\phi_{ij}}$ of sectors (Mean values by upper tier sector)			
		Mean	S.D.	Min	Max
Food, beverages & tobacco products	16	0.93439	0.06496	0.76540	0.99620
Textile & apparel	11	0.94233	0.04895	0.84820	1.00000
Wood & paper products	5	0.86758	0.16053	0.58170	0.94950
Printing & Reproduction of recorded media	1	0.98500		0.98500	0.98500
Petroleum & coal products	4	0.89608	0.09176	0.77230	0.98220
Chemicals, drugs & medicines	14	0.95080	0.03310	0.89780	0.98630
Non-metallic mineral products	6	0.93325	0.05126	0.83320	0.96740
Basic metal products	8	0.94539	0.03297	0.89830	0.97620
Fabricated metal products*	4	0.98933	0.00417	0.98430	0.99450
General machinery & equipment	8	0.97580	0.00672	0.96390	0.98510
Electronic & electrical equipment	10	0.96898	0.02671	0.91110	0.99160
Precision instruments	3	0.96373	0.00618	0.95820	0.97040
Transportation equipment	7	0.93914	0.09677	0.72040	0.98760
Furniture & other manufactured products	3	0.95913	0.00325	0.95580	0.96230
Total	100	0.94493	0.06204	0.58170	1.00000

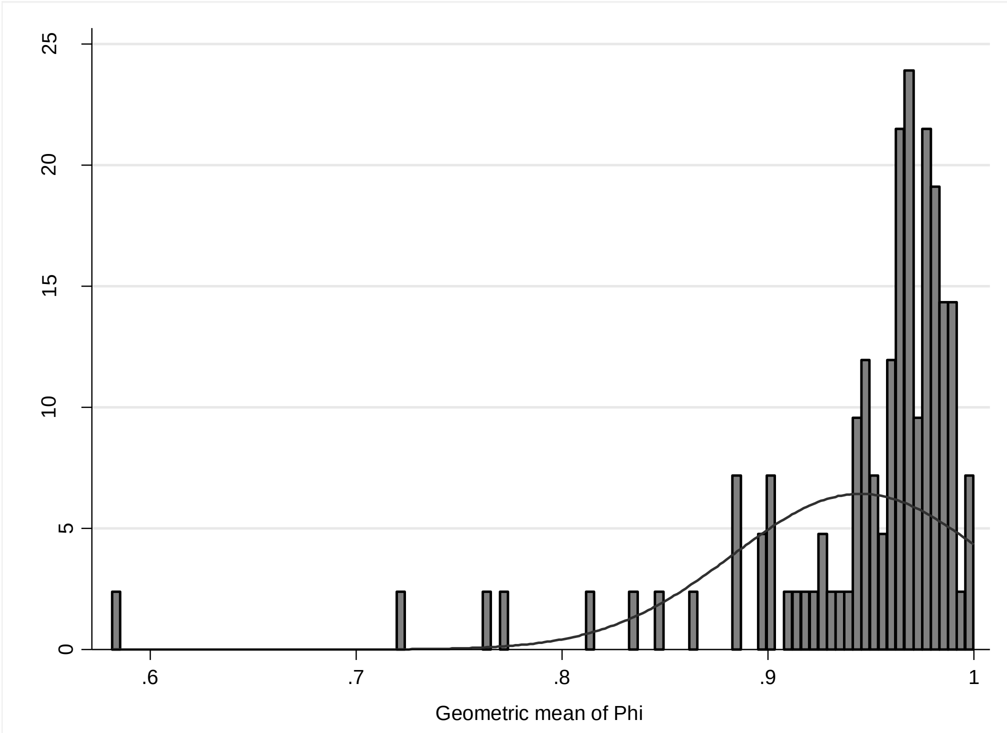

Figure 1. Distribution of $\hat{\phi}$ over sectors

4. Testing for the HME

4.1. An operational definition of the HME

Empirically testing the HME requires a testable operational definition of the HME. The HME can be defined *as the disproportionate positive causation from demand to supply* (Head *et al.*, 2002). Indeed, this has already become the standard definition of the HME in both theory and applications since the HME was introduced in NTT and NEG literature, which emphasized the importance of market size in explaining the pattern of trade and industry location, respectively. However, as pointed out by Behrens *et al*. (2005, 2009), such a definition is "*neatly implied*" by a two-country (or region) framework, but it cannot be symmetrically and easily extended to a multi-country (or region) context. Hence, particularly in a multi-country (or region) world, the definition of the HME was a source of debate among researchers prior to the proposal by Behrens *et al*. (2005, 2009), which reads as follows. To start with, we assume that regions *i* and *j* host a sector production share that is proportional to their expenditure (or demand) share, which can be expressed as follows:

$$\lambda_i^* = k_i\theta_i, \quad \lambda_j^* = k_j\theta_j$$

where k_i and k_j are positive coefficients. Since the disproportionate positive causation from demand to supply requires $k_i \geq k_j$ (i.e., $\lambda_i^*/\theta_i \geq \lambda_j^*/\theta_j$) whenever $\theta_i \geq \theta_j$, in the presence of the HME, the following condition holds:

$$\theta_i \geq \theta_j \quad \Rightarrow \quad \frac{\lambda_i^*}{\theta_i} \geq \frac{\lambda_j^*}{\theta_j} \quad , \forall j = 1, 2, \cdots, M \tag{8}$$

Consequently, we can assert that the HME exists in region *i* for a certain manufacturing sector when the condition in equation (8) holds for that region towards all regions ($\forall j$ =1, 2, …, *M*). In addition, on the condition that the HME exists in all regions for a sector, we can also argue the presence of the HME in that sector. Therefore, specifically assuming that region labels are ordered such that $\theta_1 \geq \theta_2 \geq \cdots \geq \theta_M$, we can, without loss of generality, state that the HME exists in a sector when

$$\frac{\lambda_1^*}{\theta_1} \geq \frac{\lambda_2^*}{\theta_2} \geq \cdots \geq \frac{\lambda_M^*}{\theta_M} \tag{9}$$

which implies that the ordering in terms of production shares reflects the "natural" ordering in terms of the market size of each region. Though the two variables $\frac{\lambda^*}{\theta}$ and θ have to be discrete in the real world, if we assume that they can be defined on a continuous space of positive real numbers, we can transform this expression into the following continuous version:

$$\frac{d\left(\lambda^*/_\theta\right)}{d\theta} = \upsilon \geq 0 \tag{10}$$

If this condition holds for the given continuous domain of θ, the presence of the HME can be confirmed. Considering only discrete data can be available, we can approximate expression (10) as

$$\frac{\Delta\left(\lambda^*/_\theta\right)}{\Delta\theta} = \frac{\left(\lambda_i^*/_{\theta_i} - \lambda_j^*/_{\theta_j}\right)}{\theta_i - \theta_j} = \upsilon_{ij} \geq 0 \tag{11}$$

where, if the signs of $\upsilon_{ij}s$ are nonnegative for all i (*i* = 1, 2, …, M) and *j* (*j* = 1, 2, …, *M*), the presence of the HME in that sector can be verified. However, from a more practical point of view, because $M \times M$ nonnegative $\upsilon_{ij}s$ are required, this verification needs a weaker condition, for instance, $E(\upsilon_{ij}) \geq 0$. In other words, the mean value, υ_{ij}, is not statistically significantly greater than zero. This weaker condition would seem to be feasible for testing the HME, particularly when considering statistical aspects such as measurement errors, and so on.

4.2. The method of testing for the HME

To test for the HME in the Korean manufacturing sectors using the aforementioned data, especially the inter-regional trade data, we employ two alternative testing methods.

The first is the rank correlation test based on expression (9). This test evaluates the consistency or correlation between the ordering of production shares and that of regional market size shares after filtering out the influence of positional and comparative advantage using the simple linear filter. Here, we use two nonparametric test statistics: the Spearman rank-correlation coefficient (ρ) and the Kendall rank-correlation coefficient (τ). In this test, the null hypothesis is that $\rho = 1$ (or $\tau = 1$), which implies that both orderings (i.e., production shares and region market sizes) match each other exactly within a certain sector. If the null hypothesis cannot be rejected by a *Z*-test, we can confirm the presence of the HME, at least in that sector.[10,11] we carry out the tests twice, by sector. The first test uses all the data. The second test uses the data after filtering out the effects described above using the simple linear filter.

The second testing method is the network OLS regression method, based on equation (11). To begin with, multiplying both sides of equation (11) by the denominator ($\theta_i - \theta_j$) yields:

$$\lambda_i^* / \theta_i - \lambda_j^* / \theta_j = \upsilon_{ij}(\theta_i - \theta_j) \tag{12}$$

Both sides of this equation represent dyadic relations (or more precisely, differences of variables) between the two regions. Such dyadic relations can easily be transformed into $M \times M$ dimensional matrices, which are given by

$$\Lambda \equiv \begin{pmatrix} 0 & \lambda_1^*/\theta_1 - \lambda_2^*/\theta_2 & \dots & \lambda_1^*/\theta_1 - \lambda_M^*/\theta_M \\ \lambda_2^*/\theta_2 - \lambda_1^*/\theta_1 & 0 & & \lambda_2^*/\theta_2 - \lambda_M^*/\theta_M \\ \vdots & & \ddots & \vdots \\ \lambda_M^*/\theta_M - \lambda_1^*/\theta_1 & \lambda_M^*/\theta_M - \lambda_2^*/\theta_2 & \cdots & 0 \end{pmatrix},$$

$$\Theta \equiv \begin{pmatrix} 0 & \theta_1 - \theta_2 & \dots & \theta_1 - \theta_M \\ \theta_2 - \theta_1 & 0 & & \theta_2 - \theta_M \\ \vdots & & \ddots & \vdots \\ \theta_M - \theta_1 & \theta_M - \theta_2 & \cdots & 0 \end{pmatrix} \tag{13}$$

Then, adding the $M \times M$ dimensional matrix of white noise (E) to the matrix version of equation (12), we formulate the following regression model(is the network OLS regression model):

$$\Lambda = \upsilon\Theta + E \tag{14}$$

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[10] In order to obtain bias-corrected estimates of both rank-correlation coefficients and confidence intervals for the *Z*-tests, we performed bootstrapping with 2000 replications.

[11] The results of the *Z*-test for the null hypothesis at the sector level are reported in Table 1 in the Appendix.

The mean value of υ is utilized to construct a *t*-test, using the quadratic assignment procedure, to test for the presence of the HME, particularly in expression (11) (Kranckhardt, 1987, 1988). Once again, we conduct the estimations twice, by sector, as in the rank correlation test. [12]

4.3. Test results

Tables 2 and 3 summarize the results of the two rank correlation tests shown in Table 1 in the Appendix and the network OLS regression test shown in Table 2 in the Appendix, respectively. In the third row in Table 2, the labels "99%," "95%," and "90%" refer to the confidence levels (or tolerance levels) used to determine whether to accept or reject the null hypothesis. Note that the confidence levels in this row appear in reverse order to the third row of Table 3 owing to the different judgment rules in each. In Table 2, we are determining whether to accept the null hypothesis ($E(\rho) = 1$ or $E(\tau) = 1$). In Table 3, we are determining whether to reject null hypothesis ($E(\upsilon) = 0$). From a conservative perspective, we hereafter use the strictest criterion (i.e., confidence level) in each test to describe the implications of our results.

To begin with, through overview of the results, the test with Kendall rank-correlation coefficient (τ) turns arguably out to be the strictest testing technique among these three ones due to the fact that Just only 17 sectors could pass the test (in other words, accept null hypothesis) after filtering as well as no sectors before filtering, while the weakest testing technique appears to be the Network OLS regression test which 8 sectors before filtering and even 75 sectors after filtering passed. Considering such the variation in testing power across testing techniques, we synthesize three results by counting the number of overlapping ones among sectors that passed each test and, in turn, report it in Table 4 with identifying those sectors.

Table 4 shows that the simple linear filter proposed by Behrens *et al.* (2009), modified for our empirical test, can be highly effective in confirming the presence of the HME from observable data. The first two columns of Table 4 reveal no sectors passed the three tests before filtering. The other two columns show that 46 sectors passed more than two tests after filtering. This result indicates we might not be able to observe the HME in any of the 100 manufacturing sectors in Korea, at least in terms of inter-regional trade, unless we filter out the other effects, particularly considering the stark contrast before and after filtering. we argue that is empirical evidence in favor of the conjecture made by Behrens *et al.* (2009), stating that "the HME does not generally arise in the extended model because …(*omitted)*… the countries' equilibrium production shares λ are affected not only by their demand shares θ but also by relative centrality and comparative advantage in the differentiated good sector" (Behrens *et. al*., 2009, p.263).

[12] The estimation results at the sector level are reported in Table 2 in the Appendix.

Table 2 Results of Rank Correlation Tests

	Sectors (No.)	Spearman ρ (No. of sectors accepted the hypothesis: $\rho = 1$)						Kendall τ (No. of sectors accepted the hypothesis: $\tau = 1$)					
		Before filtering			After filtering			Before filtering			After filtering		
		99%	95%	90%	99%	95%	90%	99%	95%	90%	99%	95%	90%
Food, beverages & tobacco products	16	2	0	0	13	10	9	0	0	0	8	5	3
Textile & apparel	11	7	0	0	6	3	1	0	0	0	2	1	1
Wood & paper products	5	1	0	0	4	4	3	0	0	0	4	1	0
Printing & Reproduction of recorded media	1	1	0	0	1	1	1	0	0	0	1	1	1
Petroleum & coal products	4	1	0	0	1	1	1	0	0	0	1	0	0
Chemicals, drugs & medicines	14	4	1	0	8	8	6	0	0	0	6	5	3
Non-metallic mineral products	6	2	0	0	4	3	2	0	0	0	3	1	1
Basic metal products	8	4	0	0	6	4	4	0	0	0	5	2	0
Fabricated metal products*	4	2	0	0	4	4	4	0	0	0	4	3	3
General machinery & equipment	8	0	0	0	8	7	5	0	0	0	7	4	2
Electronic & electrical equipment	10	4	0	0	10	7	6	0	0	0	6	4	3
Precision instruments	3	1	0	0	3	2	1	0	0	0	1	0	0
Transportation equipment	7	3	0	0	2	1	1	0	0	0	1	0	0
Furniture & other manufactured products	3	0	0	0	3	3	2	0	0	0	2	0	0
Total	100	32	1	0	73	58	46	0	0	0	51	27	17

* Machinery and furniture were excluded from Fabricated metal products

Table 3 Results of Network OLS regression test

	Sectors (No.)	t- test for the hypothesis: $\upsilon \geq 0$ (No. of Sectors passed t-test)					
		Before filtering			After filtering		
		90%	95%	99%	90%	95%	99%
Food, beverages & tobacco products	16	0	0	0	14	14	14
Textile & apparel	11	5	4	2	9	9	8
Wood & paper products	5	1	1	0	5	4	4
Printing & Reproduction of recorded media	1	1	1	1	1	1	1
Petroleum & coal products	4	3	2	2	3	2	2
Chemicals, drugs & medicines	14	2	2	1	11	10	9
Non-metallic mineral products	6	0	0	0	5	5	4
Basic metal products	8	2	1	1	6	6	6
Fabricated metal products*	4	2	2	0	4	4	4
General machinery & equipment	8	2	1	0	8	8	7
Electronic & electrical equipment	10	3	2	0	10	10	9
Precision instruments	3	2	1	1	2	2	2
Transportation equipment	7	1	1	0	5	3	2
Furniture & other manufactured products	3	0	0	0	3	3	3
Total	100	24	18	8	86	81	75

* Machinery and furniture were excluded from Fabricated metal products

Table 4 Sectors exhibiting HME

Before filtering		After filtering	
Sectors Passed 3 tests	Sectors Passed 2 tests	Sectors Passed 3 tests	Sectors Passed 2 tests
		Starches & other sugars	Dairy products
		Bakery & confectionery products, noodles	Seasonings
		Alcoholic beverages	Canned or cured fruits & vegetables
		Textile wearing apparels & accessories	Misc. food preparations
		Printing & reproduction of recorded media	Soft drinks & ice
		Cosmetics, soap, & other toilet preparations	Prepared livestock feeds
		Plastic products	Wood
		Other rubber products	Wooden products
		Glass products	Paper products
		Metal products for construction	Other petroleum products
		Hand tools & wire products	Inorganic basic chemical products
		Other fabricated metal products	Fertilizers & pesticides
		Engines & turbines	Medicaments
		Other machinery & equipment of special purpose	Concrete products
		Other electrical equipment & supplies	Steel ingots & semi-finished products
		Electronic signal equipment	Hot rolled steel products
		Other electric components & accessories	Other primary iron and steel products
			Primary nonferrous metal products
			Metal containers
			Parts of general-purposed machinery & equipment
			Other machinery & equipment of general purpose
			Agricultural implements & machinery & construction machinery
			Motors, generators, capacitors & rectifiers
			Semiconductors & related devices
			Household electrical appliances
			Medical, measuring, analyzing, & controlling instruments
			Motor vehicle engines & parts
			Toys & sporting goods
			Misc. manufactured products
0	0	17	29

However, note that the effectiveness of the filter might also imply that other, exogenous factors, such as position, have a similar or greater influence than market size in accounting for the spatial distribution of production. It might be that not being able to identify any sectors with the HME before filtering points to the influence of other effects being strong enough to offset the "pure HME" caused by the market size effect. Further research is necessary to separate these effects from the HME, but also to measure the effects and, in turn, compare them.

Lastly, note that although the HME is likely to be generally unobservable (or even never observable) owing to other effects being blended into the relation between spatial production, distribution, and market size, the problem is one of observability, not of the presence of the HME itself. As mentioned earlier, Table 4 shows almost half the sectors (46 sectors) successfully passed more than two tests. This implies that the NEG theoretical predictions may be valid for the spatial units at the regional level within a country, quite apart from the national or international level. In order to confirm such HME predictions more universally, we feel it is necessary to extend the range of applications to all spatial units, such as regions at the si, gun, and gu levels. This task is reserved for future studies.

5. Summary and conclusions

The HME, indicating a disproportionate positive causation from demand to supply, is a crucial testable prediction in accounting for the pattern of trade in NTT theories and agglomeration in NEG theories. Several empirical works have tested for the HME since it was introduced, but only from the perspective of international trade within NTT theory. In addition, these tests have only investigated a simple two-country framework. Empirical HME tests in a multi-country framework, within an economy, or in inter-regional trade have received limited attention.

In this study, we tested the HME hypothesis within inter-regional trade in Korea. For this purpose, we modified the simple linear filter proposed by Behrens *et al*. (2009), which allowed us to separate the "pure HME" from other effects blended within the data. After converting the theoretical simple linear filter into an empirical framework for testing, we applied the empirical linear filter to inter-regional trade data for 100 manufacturing sectors in 16 Korean regions.

Our tests identified the presence of the HME in inter-regional trade in almost half the manufacturing sectors, but only after filtering out the influence of centrality. we argue this is empirical evidence in favor of the conjecture made by Behrens *et al*. (2009).

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Appendix

Appendix Table1. Results of Rank Correlation Tests(sectors)

	Spearman ρ						Kendall τ					
	Before filtering			After filtering			Before filtering			After filtering		
	$\hat{\rho}$	z*	P_value	$\hat{\rho}$	z*	P_value	$\hat{\tau}$	z*	P_value	$\hat{\tau}$	z*	P_value
Meat and processed meat products	-0.17	4.44	0.0000	0.38	2.75	0.0030	-0.12	5.43	0.0000	0.23	4.46	0.0000
Dairy products	0.14	3.28	0.0005	0.85	1.25	0.1052 ***	0.12	4.39	0.0000	0.70	2.42	0.0077
Processed seafood products	0.15	2.89	0.0019	0.83	1.46	0.0725 **	0.14	3.62	0.0001	0.68	2.76	0.0029
Polished grains	-0.03	3.27	0.0005	0.40	2.31	0.0104 *	0.00	4.01	0.0000	0.28	3.57	0.0002
Flour and cereal preparations	0.23	2.90	0.0019	0.44	2.30	0.0108 *	0.20	3.83	0.0001	0.30	3.48	0.0003
Sugar	-0.34	7.54	0.0000	0.21	3.33	0.0004	-0.30	8.23	0.0000	0.15	4.85	0.0000
Starches and other sugars	0.34	2.34	0.0096	0.86	0.92	0.1782 ***	0.26	3.49	0.0002	0.84	1.12	0.1320 ***
Bakery and confectionery products, noodles	0.50	1.98	0.0241 *	0.97	0.55	0.2914 ***	0.37	3.10	0.0010	0.92	1.20	0.1158 ***
Seasonings	0.42	2.18	0.0145 *	0.96	0.71	0.2376 ***	0.31	3.27	0.0005	0.88	1.62	0.0523 **
Fats and oils	0.18	2.64	0.0041	0.54	2.18	0.0147 *	0.18	3.48	0.0002	0.42	3.39	0.0004
Canned or cured fruits and vegetables	-0.12	3.76	0.0001	0.90	1.01	0.1560 ***	-0.06	4.50	0.0000	0.80	1.73	0.0422 *
Misc. food preparations	-0.02	3.48	0.0002	0.88	1.20	0.1142 ***	-0.02	4.45	0.0000	0.77	2.17	0.0149 *
Alcoholic beverages	-0.14	4.53	0.0000	0.99	0.38	0.3538 ***	-0.14	6.08	0.0000	0.97	0.96	0.1685 ***
Soft drinks and ice	-0.23	4.16	0.0000	0.94	0.91	0.1809 ***	-0.21	4.94	0.0000	0.85	1.88	0.0299 *
Prepared livestock feeds	-0.38	5.91	0.0000	0.94	0.80	0.2113 ***	-0.24	6.44	0.0000	0.87	1.54	0.0618 **
Tobacco products	-0.13	4.21	0.0000	0.06	3.90	0.0000	-0.12	4.87	0.0000	0.04	5.47	0.0000
Fiber yarn	-0.20	3.97	0.0000	0.24	2.38	0.0086	-0.19	5.38	0.0000	0.27	2.86	0.0021
Fiber fabrics	0.10	3.07	0.0011	-0.03	3.94	0.0000	0.05	4.32	0.0000	0.03	4.84	0.0000
Fiber bleaching and dyeing	0.42	2.14	0.0162 *	0.09	3.29	0.0005	0.32	3.16	0.0008	0.02	4.87	0.0000
Knitted wearing apparels and accessories	0.42	2.28	0.0112 *	0.54	2.02	0.0218 *	0.35	3.53	0.0002	0.42	2.93	0.0017
Textile wearing apparels and accessories	0.70	1.80	0.0359 *	0.98	0.47	0.3191 ***	0.53	3.21	0.0007	0.95	1.11	0.1326 ***
Leather and fur wearing apparels	0.45	2.46	0.0069	0.35	2.46	0.0070	0.36	3.26	0.0006	0.27	3.81	0.0001
Other fabricated textile products	0.51	1.91	0.0280 *	0.78	1.63	0.0518 **	0.41	2.98	0.0014	0.63	2.76	0.0029
Leather and fur	-0.02	3.45	0.0003	0.67	1.73	0.0415 *	-0.02	4.26	0.0000	0.57	2.57	0.0051
Luggage and handbags	0.74	1.69	0.0455 *	0.30	2.41	0.0081	0.57	2.85	0.0022	0.24	3.61	0.0002
Footwear	0.50	2.27	0.0116 *	0.71	1.43	0.0762 **	0.35	3.75	0.0001	0.64	1.92	0.0273 *
Other leather products	0.50	2.16	0.0153 *	0.53	1.97	0.0246 *	0.40	3.38	0.0004	0.43	3.29	0.0005
Wood	0.12	3.08	0.0010	0.89	0.93	0.1768 ***	0.09	4.02	0.0000	0.80	1.70	0.0449 *
Wooden products	0.23	2.78	0.0028	0.87	1.04	0.1495 ***	0.17	3.92	0.0000	0.78	1.62	0.0527 **

(continued)

	Spearman ρ						Kendall τ					
	Before filtering			After filtering			Before filtering			After filtering		
	$\hat{\rho}$	z*	P_value	$\hat{\rho}$	z*	P_value	$\hat{\tau}$	z*	P_value	$\hat{\tau}$	z*	P_value
Pulp	-0.31	4.58	0.0000	0.37	2.78	0.0027	-0.26	5.44	0.0000	0.29	4.09	0.0000
Paper	-0.10	4.42	0.0000	0.66	1.54	0.0619 **	-0.10	6.43	0.0000	0.58	2.18	0.0145 *
Paper products	0.56	1.74	0.0410 *	0.88	1.11	0.1336 ***	0.43	3.01	0.0013	0.77	2.12	0.0170 *
Printing and reproduction of recorded media	0.53	1.98	0.0240 *	0.98	0.47	0.3175 ***	0.42	2.99	0.0014	0.95	1.16	0.1236 ***
Coke and hard-coal	0.19	2.68	0.0037	0.30	2.33	0.0099	0.17	3.39	0.0003	0.34	2.77	0.0028
Naphtha	0.74	1.99	0.0234 *	-0.28	5.02	0.0000	0.66	2.78	0.0027	-0.21	6.25	0.0000
Fuel oils	0.08	4.17	0.0000	0.22	2.94	0.0016	0.03	5.17	0.0000	0.13	4.38	0.0000
Other petroleum products	0.46	2.38	0.0087	0.90	0.98	0.1630 ***	0.36	3.82	0.0001	0.80	1.96	0.0247 *
Petrochemical basic products	0.83	1.60	0.0550 **	-0.17	4.49	0.0000	0.71	2.92	0.0018	-0.11	5.65	0.0000
Other industrial organic basic chemical products	0.74	1.71	0.0432 *	0.09	3.02	0.0013	0.60	2.96	0.0016	0.09	3.82	0.0001
Inorganic basic chemical products	0.14	2.93	0.0017	0.93	1.01	0.1565 ***	0.12	4.03	0.0000	0.85	1.88	0.0297 *
Synthetic resins	0.00	3.68	0.0001	0.21	2.84	0.0022	0.02	4.86	0.0000	0.20	3.80	0.0001
Synthetic rubber	0.12	3.59	0.0002	0.07	2.87	0.0020	0.08	5.02	0.0000	0.05	4.03	0.0000
Chemical fibers	0.21	2.63	0.0042	0.08	3.29	0.0005	0.16	3.90	0.0000	0.07	4.24	0.0000
Fertilizers and pesticides	0.12	3.15	0.0008	0.97	0.65	0.2573 ***	0.08	4.83	0.0000	0.90	1.64	0.0510 **
Medicaments	0.16	2.81	0.0025	0.82	1.15	0.1247 ***	0.08	3.98	0.0000	0.75	1.58	0.0575 **
Cosmetics, soap, and other toilet preparations	0.03	2.93	0.0017	0.98	0.54	0.2952 ***	0.01	4.10	0.0000	0.93	1.28	0.1003 ***
Dyes, pigments, and paints	0.37	2.19	0.0143 *	0.82	1.47	0.0713 **	0.32	2.99	0.0014	0.70	2.44	0.0074
Misc. chemical products	0.30	2.46	0.0069	0.86	1.30	0.0964 **	0.21	3.36	0.0004	0.74	2.41	0.0081
Plastic products	0.44	2.06	0.0197 *	0.99	0.37	0.3541 ***	0.35	3.03	0.0012	0.97	0.90	0.1829 ***
Tires and tubes	0.04	3.64	0.0001	0.61	2.43	0.0075	-0.01	5.01	0.0000	0.46	3.93	0.0000
Other rubber products	0.31	2.62	0.0044	0.98	0.48	0.3147 ***	0.21	3.85	0.0001	0.95	0.90	0.1828 ***
Glass products	0.25	2.90	0.0019	0.99	0.38	0.3502 ***	0.18	4.07	0.0000	0.97	0.91	0.1802 ***
Pottery	0.41	2.35	0.0095	0.80	1.73	0.0421 *	0.32	3.49	0.0002	0.66	2.92	0.0018
Clay products	0.41	2.30	0.0107 *	0.38	2.56	0.0052	0.31	3.51	0.0002	0.26	3.85	0.0001
Cement	0.47	2.21	0.0135 *	-0.22	4.82	0.0000	0.32	3.51	0.0002	-0.13	5.62	0.0000
Concrete products	0.09	2.99	0.0014	0.90	0.95	0.1710 ***	0.11	3.42	0.0003	0.81	1.70	0.0449 *
Other nonmetallic mineral products	0.32	2.48	0.0065	0.83	1.34	0.0904 **	0.24	3.47	0.0003	0.72	2.30	0.0108 *
Pig iron and ferroalloys	-0.25	3.76	0.0001	-0.06	3.62	0.0001	-0.23	4.32	0.0000	-0.04	4.42	0.0000
Steel ingots and semifinished products	0.21	2.60	0.0047	0.72	1.21	0.1123 ***	0.20	3.47	0.0003	0.69	1.54	0.0622 **
Hot rolled steel products	0.61	1.87	0.0304 *	0.78	1.26	0.1038 ***	0.47	3.26	0.0006	0.68	1.99	0.0235 *

(continued)

	Spearman ρ						Kendall τ					
	Before filtering			After filtering			Before filtering			After filtering		
	$\hat{\rho}$	z*	P_value	$\hat{\rho}$	z*	P_value	$\hat{\tau}$	z*	P_value	$\hat{\tau}$	z*	P_value
Cold rolled steel sheet, strip, and bars	0.82	1.90	0.0286 *	0.06	2.86	0.0021	0.68	3.04	0.0012	-0.01	3.84	0.0001
Iron and steel foundries and forgings	0.37	2.43	0.0076	0.59	1.73	0.0422 *	0.30	3.46	0.0003	0.56	2.09	0.0182 *
Other primary iron and steel products	0.26	2.58	0.0050	0.79	1.12	0.1309 ***	0.21	3.57	0.0002	0.72	1.87	0.0311 *
Nonferrous metal ingots	0.68	1.79	0.0365 *	0.41	2.04	0.0206 *	0.54	2.96	0.0015	0.37	2.68	0.0036
Primary nonferrous metal products	0.50	2.16	0.0152 *	0.90	0.96	0.1698 ***	0.37	3.43	0.0003	0.83	1.56	0.0597 **
Metal products for construction	0.23	2.82	0.0024	0.96	0.57	0.2841 ***	0.18	3.98	0.0000	0.90	1.24	0.1067 ***
Metal containers	0.56	2.03	0.0214 *	0.78	1.20	0.1149 ***	0.41	3.23	0.0006	0.70	1.90	0.0290 *
Handtools and wire products	0.43	2.78	0.0027	0.99	0.38	0.3515 ***	0.30	5.21	0.0000	0.97	0.85	0.1979 ***
Other fabricated metal products	0.62	1.90	0.0286 *	0.99	0.38	0.3514 ***	0.48	3.25	0.0006	0.97	0.93	0.1751 ***
Engines and turbines	0.18	2.95	0.0016	0.99	0.26	0.3960 ***	0.14	4.14	0.0000	0.98	0.60	0.2734 ***
Parts of general-purposed machinery and equipment	0.11	3.07	0.0011	0.84	1.01	0.1571 ***	0.05	4.20	0.0000	0.77	1.61	0.0539 **
Conveyors and conveying equipment	0.24	2.88	0.0020	0.79	1.31	0.0959 **	0.15	4.15	0.0000	0.68	2.07	0.0192 *
Air-conditioning, refrigeration and heating machines	0.19	2.89	0.0019	0.59	1.87	0.0309 *	0.15	4.07	0.0000	0.41	3.18	0.0007
Other machinery and equipment of general purpose	0.19	3.19	0.0007	0.95	0.73	0.2339 ***	0.15	4.47	0.0000	0.89	1.42	0.0774 **
Metalworking machinery and equipment	0.37	2.49	0.0064	0.80	1.29	0.0991 **	0.27	3.86	0.0001	0.70	2.14	0.0160 *
Agricultural implements & machinery & construction machinery	-0.06	4.08	0.0000	0.93	0.89	0.1856 ***	-0.06	5.30	0.0000	0.85	1.73	0.0416 *
Other machinery and equipment of special purpose	0.41	2.43	0.0076	0.99	0.38	0.3525 ***	0.30	3.77	0.0001	0.97	0.88	0.1883 ***
Motors, generators, capacitors and rectifiers	0.51	2.24	0.0125 *	0.94	0.81	0.2101 ***	0.35	3.70	0.0001	0.85	1.70	0.0445 *
Other electrical equipment and supplies	0.46	2.21	0.0135 *	0.99	0.37	0.3550 ***	0.34	3.19	0.0007	0.97	0.77	0.2213 ***
Electronic signal equipment	0.25	2.55	0.0054	0.77	1.04	0.1481 ***	0.18	3.82	0.0001	0.78	1.12	0.1317 ***
Semiconductors and related devices	0.41	2.14	0.0161 *	0.95	0.79	0.2152 ***	0.26	3.69	0.0001	0.88	1.52	0.0644 **
Other electric components and accessories	0.36	2.67	0.0038	0.78	1.06	0.1449 ***	0.23	4.20	0.0000	0.79	1.15	0.1249 ***
Audio and video equipment	0.39	2.54	0.0056	0.68	1.87	0.0309 *	0.34	3.47	0.0003	0.52	3.03	0.0012
Communications and broadcasting equipment	0.22	2.71	0.0033	0.74	1.48	0.0689 **	0.16	3.80	0.0001	0.63	2.34	0.0097
Computer and peripheral equipment	0.52	2.08	0.0187 *	0.50	1.75	0.0401 *	0.42	2.97	0.0015	0.41	2.71	0.0034
Office machines and devices	0.32	2.66	0.0039	0.40	2.27	0.0117 *	0.22	3.73	0.0001	0.29	3.28	0.0005
Household electrical appliances	0.30	2.55	0.0053	0.74	1.21	0.1122 ***	0.24	3.75	0.0001	0.68	1.78	0.0371 *
Medical, measuring, analyzing, and controlling instruments	0.39	2.39	0.0085	0.95	1.01	0.1555 ***	0.30	3.26	0.0006	0.85	2.28	0.0113 *
Photographic and optical instruments	0.36	2.48	0.0066	0.72	1.64	0.0510 **	0.29	3.81	0.0001	0.60	2.40	0.0081
Watches and clocks	0.67	1.96	0.0251 *	0.60	1.76	0.0395 *	0.55	3.08	0.0010	0.47	2.76	0.0029
Motor vehicles and motor vehicle equipment	-0.27	5.39	0.0000	0.57	1.78	0.0379 *	-0.19	7.02	0.0000	0.47	2.60	0.0047

(continued)

	Spearman ρ								Kendall τ							
	Before filtering				After filtering				Before filtering			After filtering				
	$\hat{\rho}$	z*	P_value		$\hat{\rho}$	z*	P_value		$\hat{\tau}$	z*	P_value	$\hat{\tau}$	z*	P_value		
Motor vehicle engines and parts	0.05	3.46	0.0003		0.71	1.23	0.1099	***	0.08	4.72	0.0000	0.63	1.82	0.0341	*	
Trailers and containers	0.28	2.89	0.0019		0.08	3.54	0.0002		0.24	3.96	0.0000	0.12	4.23	0.0000		
Ship building and repairing	0.57	2.14	0.0163	*	0.21	2.39	0.0085		0.42	3.56	0.0002	0.17	3.19	0.0007		
Railroad vehicles and parts	0.03	3.27	0.0005		0.39	2.39	0.0084		0.03	4.38	0.0000	0.37	3.35	0.0004		
Aircraft and parts	0.49	2.03	0.0213	*	0.11	3.41	0.0003		0.29	3.46	0.0003	0.09	4.79	0.0000		
Motorcycles, bicycles, and misc. transportation equipment	0.57	2.12	0.0170	*	0.25	3.43	0.0003		0.45	3.33	0.0004	0.15	5.66	0.0000		
Furniture	0.19	2.60	0.0046		0.89	1.29	0.0988	**	0.18	3.36	0.0004	0.76	2.43	0.0077		
Toys and sporting goods	0.46	2.85	0.0022		0.92	0.99	0.1603	***	0.30	5.04	0.0000	0.82	2.01	0.0223	*	
Misc. manufactured products	0.14	3.11	0.0009		0.90	0.95	0.1704	***	0.10	4.48	0.0000	0.80	1.77	0.0381	*	

Appendix Table2. Results of Network OLS regression tests (sectors)

	Before filtering				After filtering			
	Cof.	t	P_value		Cof.	t	P_value	
Meat and processed meat products	-4.11	-3.56	0.3870		966.69	12.33	0.0400	
Dairy products	0.30	0.22	0.9650		4794.13	12.21	0.0420	
Processed seafood products	-4.34	-2.87	0.5260		3531.22	13.99	0.0250	
Polished grains	-6.43	-3.63	0.3910		736.39	14.08	0.0250	
Flour and cereal preparations	-4.83	-2.31	0.4560		7991.43	5.40	0.0920	
Sugar	-27.17	-3.88	0.3300		12426.39	2.57	0.4470	
Starches and other sugars	1.52	1.36	0.7670		7142.35	7.58	0.0660	***
Bakery and confectionery products, noodles	2.73	3.15	0.4100		14679.86	12.56	0.0470	***
Seasonings	1.97	1.71	0.6900		6614.27	13.29	0.0210	**
Fats and oils	5.20	2.34	0.4410		1853.23	10.57	0.0490	
Canned or cured fruits and vegetables	-4.48	-4.24	0.3530		4288.73	12.84	0.0160	*
Misc. food preparations	-1.81	-1.21	0.7810		7223.20	12.73	0.0420	*
Alcoholic beverages	-4.91	-2.89	0.5020		52716.97	14.74	0.0180	***
Soft drinks and ice	-3.69	-2.68	0.5540		6670.69	12.94	0.0270	*
Prepared livestock feeds	-36.81	-6.07	0.1430		29106.68	11.67	0.0060	**
Tobacco products	-9.23	-3.37	0.4600		10132.81	0.77	0.7980	
Fiber yarn	-12.44	-4.43	0.2010		4692.52	5.60	0.1480	
Fiber fabrics	-1.88	-2.58	0.5540		2935.43	1.47	0.4130	
Fiber bleaching and dyeing	1.21	1.23	0.7870		3.51E+50	5.93	0.1120	
Knitted wearing apparels and accessories	16.88	14.10	0.0190	**	3414.22	9.10	0.0680	
Textile wearing apparels and accessories	11.67	26.77	0.0100	***	18202.29	11.58	0.0450	***
Leather and fur wearing apparels	13.26	20.09	0.0210	**	3418.83	6.05	0.1260	
Other fabricated textile products	7.09	6.51	0.1500	*	5086.90	14.54	0.0030	
Leather and fur	-5.77	-2.77	0.3970		4968.77	4.50	0.1080	
Luggage and handbags	11.15	31.69	0.0010	***	9481.47	3.58	0.2720	
Footwear	5.33	3.92	0.3460		7860.02	16.63	0.0010	*
Other leather products	-1.27	-0.51	0.9210		5001.26	7.49	0.0670	
Wood	3.20	4.20	0.2400		3624.66	7.74	0.0790	*
Wooden products	1.46	1.00	0.7940		4964.16	16.52	0.0050	**

(continued)

	Before filtering			After filtering		
	Cof.	t	P_value	Cof.	t	P_value
Pulp	-187.94	-5.19	0.1500	10638.23	4.10	0.2380 *
Paper	-6.76	-4.70	0.2780	4528.71	6.38	0.1040 ***
Paper products	4.01	8.66	0.0460 **	4112.24	11.35	0.0480 ***
Printing and reproduction of recorded media	2.33	12.03	0.0030 ***	10727.11	8.58	0.0810 ***
Coke and hard-coal	8.68	8.46	0.0340 ***	2074.25	7.61	0.0580 ***
Naphtha	2.59	43.20	0.0000 ***	102.26	2.41	0.2150 *
Fuel oils	-9.30	-2.20	0.5700	1556.49	1.45	0.5990
Other petroleum products	7.49	6.47	0.1260 *	8242.25	12.47	0.0130 ***
Petrochemical basic products	3.80	16.45	0.0050 ***	-20345.60	-1.73	0.5740
Other industrial organic basic chemical products	7.61	6.36	0.1190	2281.93	6.74	0.1150 ***
Inorganic basic chemical products	-1.00	-0.88	0.8660	27413.90	7.29	0.0880 ***
Synthetic resins	56.27	1.26	0.5750	-4264.65	-0.62	0.7870
Synthetic rubber	-9.53	-3.11	0.4880	845.01	5.51	0.2010 *
Chemical fibers	-12.60	-2.61	0.5190	-15525.05	-1.71	0.6450
Fertilizers and pesticides	-12.24	-5.42	0.2060	16165.89	23.55	0.0000 ***
Medicaments	5.26	3.97	0.3900	7370.53	14.67	0.0010 ***
Cosmetics, soap, and other toilet preparations	-5.19	-2.71	0.5510	13500.58	12.41	0.0320 ***
Dyes, pigments, and paints	4.05	4.94	0.2460	6751.02	12.05	0.0120 ***
Misc. chemical products	2.62	3.75	0.4110	7430.79	6.18	0.0660 ***
Plastic products	3.62	9.13	0.0350 **	14127.78	8.64	0.0740 ***
Tires and tubes	-16.05	-4.16	0.2810	15898.53	6.63	0.1250 **
Other rubber products	3.44	4.87	0.2300	52280.43	6.66	0.0710 ***
Glass products	2.52	3.11	0.4800	18131.15	7.10	0.1480 ***
Pottery	-0.10	-0.07	0.9880	4647.43	12.00	0.0580 ***
Clay products	0.51	0.42	0.9220	5138.65	6.67	0.1170 **
Cement	-2.68	-0.96	0.7530	155.06	3.02	0.4270
Concrete products	-0.09	-0.17	0.9790	8245.59	13.34	0.0190 ***
Other nonmetallic mineral products	3.55	4.33	0.3220	4462.37	12.47	0.0350 ***
Pig iron and ferroalloys	-45.03	-2.43	0.3840	-237079.56	-1.66	0.6050
Steel ingots and semifinished products	-3.40	-1.36	0.7590	1437274.54	2.23	0.1310 ***
Hot rolled steel products	8.06	6.30	0.1350 *	11774.91	13.85	0.0040 ***

(continued)

	Before filtering				After filtering			
	Cof.	t	P_value		Cof.	t	P_value	
Cold rolled steel sheet, strip, and bars	9.01	14.42	0.0020	***	432.33	2.46	0.5680	
Iron and steel foundries and forgings	1.89	2.66	0.5500		10724.73	9.37	0.0380	***
Other primary iron and steel products	0.33	0.30	0.9410		12514.13	9.79	0.0640	***
Nonferrous metal ingots	3.18	4.62	0.1840		3597.19	6.27	0.1170	***
Primary nonferrous metal products	1.52	1.89	0.5370		13918.91	4.92	0.0610	***
Metal products for construction	0.66	0.76	0.8740		23977.77	11.87	0.0410	***
Metal containers	7.73	9.99	0.0410	**	13654.06	11.86	0.0260	***
Handtools and wire products	2.62	3.41	0.4090		55120.51	7.18	0.0740	***
Other fabricated metal products	4.05	7.86	0.0650	**	108607.24	6.54	0.0910	***
Engines and turbines	1.86	6.90	0.0880	*	10732.52	5.65	0.0870	***
Parts of general-purposed machinery and equipment	2.26	3.19	0.4480		13013.22	11.20	0.0220	***
Conveyors and conveying equipment	2.85	1.77	0.6620		9903.25	15.04	0.0020	***
Air-conditioning, refrigeration and heating machines	1.63	1.08	0.8140		9318.22	9.84	0.0350	**
Other machinery and equipment of general purpose	3.25	3.75	0.3930		21536.68	8.42	0.0540	***
Metalworking machinery and equipment	3.54	2.50	0.5400		15071.42	15.83	0.0030	***
Agricultural implements & machinery & construction machinery	-18.90	-0.39	0.9180		15160.40	15.15	0.0000	***
Other machinery and equipment of special purpose	3.28	7.07	0.1210	**	44172.57	5.32	0.0550	***
Motors, generators, capacitors and rectifiers	2.23	2.53	0.4670		25148.59	7.35	0.0860	***
Other electrical equipment and supplies	3.47	5.48	0.1860		32803.22	7.95	0.0570	***
Electronic signal equipment	-0.17	-0.24	0.9490		176032.79	4.97	0.1370	***
Semiconductors and related devices	5.83	12.64	0.0420	**	23732.65	4.78	0.1170	***
Other electric components and accessories	0.97	1.65	0.7240		42586.94	7.64	0.0890	***
Audio and video equipment	7.88	6.60	0.1100	*	18030.41	8.82	0.0490	**
Communications and broadcasting equipment	12.88	10.03	0.0460	**	9485.98	14.63	0.0040	***
Computer and peripheral equipment	1.81	1.33	0.7270		1390.47	12.20	0.0080	***
Office machines and devices	5.89	3.41	0.4560		7935.82	7.10	0.0870	***
Household electrical appliances	3.16	1.92	0.6680		13022.70	12.80	0.0060	***
Medical, measuring, analyzing, and controlling instruments	5.84	6.91	0.1020	*	17333.20	9.14	0.0540	***
Photographic and optical instruments	0.21	0.16	0.9710		4693.00	10.78	0.0380	***
Watches and clocks	13.24	13.75	0.0050	***	4823.92	4.33	0.2590	
Motor vehicles and motor vehicle equipment	-17.35	-3.54	0.3440		7434.81	10.42	0.0460	***

(continued)

	Before filtering			After filtering		
	Cof.	t	P_value	Cof.	t	P_value
Motor vehicle engines and parts	-0.94	-1.30	0.7720	7312.15	10.38	0.0230 ***
Trailers and containers	2.67	1.56	0.7140	649.89	6.60	0.1420 *
Ship building and repairing	8.99	11.03	0.0190 **	32421.37	5.17	0.2040 *
Railroad vehicles and parts	-3.32	-1.22	0.7790	15904.81	5.80	0.1380 **
Aircraft and parts	-7.52	-1.46	0.7040	15810.03	0.68	0.8510
Motorcycles, bicycles, and misc. transportation equipment	6.67	4.52	0.2030	30083.52	1.92	0.5800
Furniture	5.53	4.53	0.2530	8802.92	9.67	0.0760 ***
Toys and sporting goods	4.01	3.58	0.4070	5385.20	14.09	0.0180 ***
Misc. manufactured products	0.88	2.30	0.6260	4770.60	8.68	0.0570 ***