Evolution of Export Product Space:

A case of Korea

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Abstract

This paper analyzes the relationship between topology of export products and export competitiveness by country. It is used the product space which defined as the linkage structure between export products and industrial structure in the form of non-dimensional topological structure. The effect of changes in network on the trade and its impact on export competitiveness are examined. Proximity is used as the key concept to quantify the relatedness or similarity of all products that exist in the product space. In this study, a UN COMTRADE dataset is used for the analysis of RRI intensity and the estimation the gravity model. The results of the analysis implies the importance of connectivity and complexity in selecting a new growth industry.

Key words

Product Space, Revealed Comparative Advantage, Revealed Relatedness Index, Export Similarity Index

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1. Introduction

International trade plays a crucial role in economies since it naturally combines the markets of countries. East Asian countries have experienced rapid economic growth driven by export. Korea is a good exemplar of those countries. In there, import substitution accelerated its industrialization. Westphal (1978) evaluates its outward-looking policies lead fast industrialization with a substantial level of efficiency. Thanks to Advanced technologies and relatively cheap labor market, Korea possess a number of leading sectors in the world market by now.

However, as the growth of key industries has been slowing even declining after the great fall, it is not certain that they could continue the same role as the past. Thus, contemporary industrial strategies for Korea should be more kind of organic. In other words, considerations of internal and external conditions-which we will call “network” is needed when it comes to industrial strategy.

In the past, export-oriented strategy in the region also had been based on internal and external conditions. Those conditions includes free-trade, external market, stable supply of raw materials, logistics, and national consensus on the strategy. But situations are changing fast. Unexpected reprise of protectionism, fragmentation of industries and blurred boundaries by 4IR can be risks but also can be opportunities.

Reflecting this situation, this paper analyzes the relationship between topology of export products and export competitiveness of Korea. For this purpose, the effect of changes in the structure of product space network on the level of trade and its impact on export competitiveness will be examined. The examinations in this study are based on the proximity between export commodities and the proximity is referred to as the "Revealed Relatedness Index" matrix. Also the similarity of export structure and export fitness as variables that reflect trade characteristics of product space is used.

2. Concept of product space and Development of RRI

The concept of product space is a network that formalizes the idea of relatedness between products traded in the global economy. The product space quantifies the relatedness of products with a measure called proximity which formalizes the intuitive idea that a country's ability to produce a product depends on its ability to produce other products. For examples, a country which exports apples most probably has conditions suitable for exporting pears, and the country would already have the soil, climate, packing equipment, refrigerated trucks, agronomists, phytosanitary laws, and working trade agreements. All of these could be easily redeployed to the pear business.

These inputs would be futile, however, if the country instead chose to start producing a dissimilar product such as copper wire or home appliances. While quantifying such overlap between the set of markets associated with each product would be difficult, the measure of proximity uses an outcome-based method founded on the idea that similar products (apples and pears) are more likely to be produced in tandem than dissimilar products (apples and copper wire).

The product space proposed by Hidalgo et al. (2007) is mainly based on proximity and density measured by Revealed Comparative Advantage (hereafter *RCA*). It suggests the linkage structure between export products and industrial structure in the form of non-dimensional topological structure. The product space is a map that visualizes the similarity of the knowledge required for the production of goods through location and distance. In particular, the proximity between goods is expressed as a 'conditional probability' as follows:

$$\varphi_{i,j} = \min\{P(x_{i,c} = 1 | x_{j,c} = 1), P(x_{j,c} = 1 | x_{i,c} = 1)\} \text{ for all countries c.} \quad (1)$$

In this case, $x_{i,c}$ has a value of 1 when the *RCA* value is greater than 1 and otherwise zero. In the product space model, the location of each product is determined by the proximity between the products. Therefore, the core technology or knowledge having a high complexity or the product requiring the much resources tend to be located at the core of the product space.

However, goods requiring limited knowledge and resources for production are located in the periphery. Thus, the product space provides information on the product network of a country. Also, by displaying the country's comparative advantage products on the network connection node where each product is located, it can observe how the export product structure is changing by the stage of industrial development.

Hausmann & Klinger (2006) defines the process of moving from a simple, low-level, low-cost product oriented structure located in the periphery of a product space to a highly developed, advanced country-type structure located in the central part as an industrial structure enhancement.

Freitas et al. (2015) complements the weaknesses in the original model of Hidalgo et al. (2007). Freitas et al. (2015) model is also based on the concept of proximity between export commodities and the proximity is referred to as the "Revealed Relatedness Index (hereafter *RRI*)" matrix. The index is different for its calculation process. Unlike the existing method that directly calculates the linkage on the product space, the new process estimates the following equation using probit model and then uses only statistically significant results for *RRI* matrix.

$$x_{i,c} = 1 \text{ if } RCA_{i,c} > 1, \ 0 \text{ otherwise.} \quad (2)$$

$$\mathrm{P}(\mathrm{x}_{\mathrm{j,c}} = 1 | x_{i,c}) = G(\alpha_0 + \alpha_1 x_{i,c}) \quad (3)$$

$$RR\mathrm{I}_{ij} = G(\widehat{\alpha_0} + \widehat{\alpha_1}) - G(\widehat{\alpha_0}) \quad (4)$$

α_0 represents the average probability of having a comparative advantage in j. That is the percentage of countries that have a comparative advantage in item j of the total countries.

If α_1 is 0, the probability of having a comparative advantage in item j is not affected by having a comparative advantage in item i. RRI matrix is obtained through the marginal effect. However, if there is no statistical significance, it means that the probability of having the comparative advantage in the product j is not affected by having the comparative advantage in the product i, and the corresponding relevance index value is set to zero.

RRI matrix is an increment of the probability that a country has comparative advantage on product j when that country has a comparative advantage over product i. RRI determines the position of each product within the product space through the comparative advantage between the products.

Since the RRI matrix is a non-symmetric matrix, the results for products on the basis of row and column are different. First, the sum of the row-total in the RRI matrix is termed the “out-path index”.

$$outpath_i = \sum_j RRI_{ij} \quad (5)$$

Out-path index measures the degree to which the overall product experience helps to generate competitive advantage for other products. This index is not an indicator of the industrial structure of individual countries because it is defined for each product in the global market. The index provides a criterion for determining whether the product is located in the center or in the periphery of the product space.

A value based on the column will determine how the country's overall specialization pattern will help to produce a particular product. Freitas et al. (2015) label this as the "pure density" index between commodities.

$$\mathrm{w}_{j,c} = \sum_i RRI_{ij} x_{k,c} \quad (6)$$

The pure density between products provides information on how much experience the country c needs to produce products that are currently specialized can help in the production of a 'new product' that considers future production.

Freitas et al. (2015) uses significant results derived from the estimation of the probit model, unlike the existing method, which directly calculates the linkage on the product space through the nonparametric conditional probability. The method of Freitas et al. (2015) has three advantages over the existing product space model.

First, the correlation between products can be confirmed based on statistical significance. Second, the linkage index can have positive (+) and also negative (-) values, so it is possible to consider the linkages between negative products. In case of the original method, the linkage value is always set to positive so that the technology or knowledge used in the production of a particular product does not reflect the possibility of producing a negative effect on the production of another product. For example, countries rich in skilled labor are specialized in producing high value-added products that require high technology, but they are not likely to have comparative advantage in producing products that require low-skilled skills. Third, the construction of a non-symmetric product-related matrix is allowed. In the case of the original product space model, it is assumed that the production capacity of a particular product necessarily contributes to the production of another product with high connectivity by imposing a symmetric constraint on the matrix of conditional probability.

In reality, however, there is no guarantee that the production capacity of a product will necessarily contribute to the production of another product. For example, a country with a comparative advantage in automobile production may have the capacity to produce automotive carpets to improve its economic performance, but in the opposite case, it does not need to have that capability.

3. Methods[1]

Density of RRI matrix within a particular industry gives an implication of export synergy of the industry. To see those kind of synergy, each product in RRI matrix reclassified into more broad level of product group. For the analytical simplicity, each element of RRI matrix is dichotomized by its relevance so that the matrix can be transformed into a Boolean matrix. A Boolean matrix is a matrix with entries from a Boolean algebra in mathematics. When the Boolean algebra has just two elements {0, 1} the Boolean matrix is called a logical matrix. Theoretically, if a product group is technically and economically connected, RRI submatrix for that product group should not have element zero. This situation can be understood as a complete network with directions. Thus, the ratio of actual number of significant links over the number of links in the complete network reflects relatedness of a product group (or an industry).

The upgrading of the export structure of a country can be achieved through the expansion of exports by improving the quality of existing export products. This paper focuses on the fact that the exports structure also can be upgraded by expanding the export of commodities with high interconnectivity between export commodities. Therefore, we adopt a modified gravity model that adds a parameter representing the characteristics of the inter-commodity network reflected in RRI matrix to a traditional gravity model to determine the effect of the inter-commodity linkage change on the trade level. In this study, we considered 'similarity of export structure' and 'export fitness' as variables that reflect trade characteristics of product space in addition to the standard model. The modified gravity model using this is as follows.

$$\ln X_{ij} = \beta_0 + \beta_1 lnM_i + \beta_2 lnM_j + \beta_3 Distance_{ij} + \beta_4 Closeness_{ij} + \beta_5 ESI_{ij} + \beta_6 ExportFitness_{ij} + e_{ij} \qquad (7)$$

[1] We refer to the modeling part of ″Park et al. (2018) A Study on the Dynamics and Competitiveness of the Export Structure in South Korea, KIET research paper (in Korean)″ written by the author Kim.

Export Similarity is set to reflect the Linder hypothesis which states that trade between countries with similar demand is more likely to be active than otherwise. That hypothesis is an economics conjecture about international trade patterns: The more similar the demand structures of countries, the more they will trade with one another. Further, international trade will still occur between two countries having identical preferences and factor endowments (relying on specialization to create a comparative advantage in the production of differentiated goods between the two nations). This structural similarity is measured for each country pair through the Export Similarity Index (ESI) proposed by Finger and Kreinin (1979).

Export fitness, which is the key concept of this paper, reflects the linkage of the export structure of the country in product space. This index is defined as the weighted average of the pure densities which can be directly derived from RRI matrix.

$$ExportFitness_{ij} = \frac{\sum_{k \in K}\{PureDensity_{ik} \times x_{ijk}\}}{X_{ij}} \tag{8}$$

The reason for naming the weighted average pure density as 'export fitness' is that the higher the index is, the closer the items exported to a particular country are. That is, there is no country-specific maximum of pure density that can be taken for each item, but when the export structure is linked well, the value of pure density for each item increases. Therefore, the higher the dependence on exports for items with high pure densities, the greater the export fitness.

4. Data and Results

Practically, UN COMTRADE dataset classified in SITC rev.3 (Standard International Trade Classification, Revision 3) is used for the analysis. To make a comparison, major East Asian countries, Germany and the U.S. are illuminated during 1992 to 2016. Statistics other than trade mainly come from World Bank’s database, World Development Indicators (WDI). In case of gravity model estimation, variables related to geographic distance, language, and socio-cultural characteristics were from CEPII which the leading French center for research and expertise on the world economy.

The results of an analysis of *RRI* intensity and estimation the gravity model using the data mentioned above are shown in Table 1, Table 2 and Table 3. First of all, as shown in table 1, during the period from 1990 to 2015, the relative intensity of linkage in the industry of Food and live animals chiefly for food increased from 0.042 to 0.731.Also the relative intensity of linkage in the industry of Machinery and transport equipment increased from 0.586 to 0.668. However, excluding these two industries , in the remaining industries, the relative density of linkage in 2015 declined compared to 1990, indicating that even if one country has export competitiveness to a particular product, the likelihood of having similar export competitiveness has declined. This is attributable to the expansion of geopolitical scope of synergies in the industry due to the rise of global value chains. However, in the case of machinery and transportation equipment, it is analyzed that the structure of comparative advantage between countries is maintained due to high entry barriers.

Table 1 Changes in RRI Density by Product Group

Product Group	SITC	1990	1995	2000	2005	2010	2015
Food and live animals chiefly for food	0	0.042	0.074	0.655	0.644	0.659	0.731
Beverages and tobacco	1	0.469	0.700	0.052	0.117	0.155	0.152
Crude materials, inedible, except fuels	2	0.277	0.319	0.166	0.207	0.174	0.206
Mineral fuels, lubricants and related materials	3	0.590	0.643	0.115	0.215	0.198	0.244
Animal and vegetable oils, fats and waxes	4	0.403	0.557	0.024	0.141	0.139	0.136
Chemicals and related products, nes.	5	0.634	0.630	0.307	0.436	0.406	0.454
Manufactured goods classified chiefly by materials	6	0.620	0.672	0.547	0.543	0.558	0.529
Machinery and transport equipment	7	0.586	0.610	0.627	0.667	0.675	0.668
Miscellaneous manufactured articles	8	0.519	0.523	0.374	0.407	0.478	0.364
Commodities and transactions not classified elsewhere in the SITC	9	0.599	0.528	0.045	0.011	0.000	0.000

Table 2 Gravity model estimation results (whole sample)

	1995		2015	
	Model 1	Model 2	Model 1	Model 2
GDP of Exporter	0.893***	0.896***	0.936***	0.908***
	-0.019	-0.019	-0.018	-0.018
GDP of Importer	1.165***	1.087***	1.330***	1.296***
	-0.02	-0.021	-0.017	-0.017
Neighbor dummy	0.296	0.405**	0.460**	0.499**
	-0.203	-0.2	-0.198	-0.195
Common language	0.903***	1.054***	1.059***	1.179***
	-0.099	-0.097	-0.091	-0.089
Colonial experience	1.055***	0.934***	0.471**	0.393*
	-0.213	-0.21	-0.213	-0.21
Distance	-1.083***	-1.068***	-1.159***	-1.170***
	-0.044	-0.043	-0.04	-0.04
ESI	3.656***	3.033***	4.288***	4.141***
	-0.382	-0.378	-0.318	-0.311
Export Fitness	0.025***		0.042***	
	-0.008		-0.006	
Adjusted		2.879***		3.474***
Export Fitness		-0.249		-0.214
Obs.	4,227	4,227	6,143	6,143
R-squared	0.649	0.659	0.666	0.677

Cross sectional regression analyses are performed from 1995 to 2015 for every five years to estimate the modified gravity models on the whole sample and Korea. As a result shown in table 2 for the whole sample and 3 for Korea, the signs were consistent with those expected of. But when it comes to the case of Korea, some different results were observed. In the case of the whole sample, exports increased by 2.5% in 1995 when export fitness increased by one. However, in case of Korea, export fitness has no significant effect on export growth. In sum, it is estimated that the increase in export suitability has a significant effect on the increase of exports in the whole sample. When the exporting country is limited to Korea, only the export adjustment that has undergone the further adjustment process has a significant positive effect.

Table 3 Gravity model estimation results (Korea)

	1995		2015	
	Model 1	Model 2	Model 1	Model 2
GDP of Importer	0.957***	0.899***	1.060***	1.106***
	-0.125	-0.125	-0.117	-0.12
Distance	-0.791**	-0.777**	-0.4	-0.234
	-0.367	-0.361	-0.305	-0.314
ESI	2.968	2.771	3.723**	1.536
	-2.213	-2.179	-1.573	-1.876
Export Fitness	-0.415		-0.183***	
	-0.251		-0.0581	
Adjusted Export Fitness		9.212**		17.39***
		-4.536		-5.954
Obs.	59	59	63	63
R-squared	0.698	0.705	0.798	0.794

The export similarity index (ESI), which takes a value between 0 and 1, has a positive effect on exports as a result of estimating the total sample in 1995. Numerically, 1p% increase in export similarity is estimated to increase exports by 3 ~ 3.6%. However, in Korea, the export similarity index does not show statistical significance with exports, which is attributed to export heterogeneity with Korea's major exporting countries. In other words, Korea has the highest export structural similarity with Japan, but it is analyzed that the export similarity index has little impact on exports to countries with heterogeneous characteristics such as China, the US, and ASEAN.

5. Conclusion

The effect of export fitness on bilateral trade under the gravity model had statistically significant influence although the extent was varying over time. ESI between the importing and exporting countries also had a significant positive impact on exports. The exclusion of primary commodities from the overall sample has increased the impact of export fidelity and export similarity, and its impact has increased even more by limiting its scope to high-technology products. This is due to the fact that the trade of high technology products is more affected by the environment of exporting countries.

The results of the analysis show that policies for enhancing export structure and improving competitiveness are needed from two perspectives. First, it implies the importance of connectivity and complexity in selecting a new growth industry. Here, linkage means linkage with existing industries, and complexity means the degree of core technology, knowledge, or resources required to produce a product. Second, it im1plies the necessity of verifying whether the designated industry possesses the ability to drive the efficiency and productivity of the entire ecosystem and to jump the growth of the entire economy.

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