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The Effects of Network on Exports of Petroleum Refinery Goods in Korea*

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This paper uses the 1980-2003 data to estimate the effects of the network structure on the exports of Korean petroleum refineries. This paper reports three gravity and H-O models with or without a network of petroleum refineries to demonstrate the effects of the network structure on the export of petroleum refineries. The network structure of the petroleum refinery increases the importance of the H-O model, but the effects of the network structure decrease over time. This means that when the network structure of most energy products is more concentrated (higher level) than all other manufacturing products, the different endowment ratios play a more important role in exporting most energy products than other manufacturing products in South Korea.

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1. INTRODUCTION

Traditional international trade models generally explain that countries gain economic benefits from trade. The sources of the international trade and its economic gains are productivity differences between trading countries as expressed in the Ricardian model or the endowment differences between the countries as noted in the Heckscher-Ohlin (H-O) model. The H-O model explains that international trade is heavily dependent on the ratio of national resources. As seen in Leontief (1953) and Bowen *et al*. (1987), however, the H-O model showed many drawbacks. Baskaran and Brück (2005) also showed that the difference in endowment is less important in concentrated networks. For example, some countries export crude oil to most other countries, but most countries are connected to well-known crude oil producing countries, regardless of the proportion of their resources. Likewise, due to the fact that in the petroleum refineries there are a few well-known exporters and many more importers, the network in the petroleum refineries may be one of the important factors deciding the interactive trade.

For some concentrated products like petroleum refinery, it is important to add bi-directional network theory to the H-O model. This paper accommodates the H-O model in conjunction with network theory and examines the network structure of the petroleum refinery for South Korea's exports. Most of the studies in the petroleum refineries of South Korea have focused on the market structure (Lee, 2013; Shim and Jung, 2012) and thus this paper's focus on the network structure will provide new insights on the petroleum refineries in South Korea.

The network structure has different degrees of trade exposure for each product. In addition to the positive link of networks to productivity (Atrostic and Nguyen, 2005), the trade patterns of each product may differ in terms of network architecture. In other words, the more concentrated the network of the products, the fewer exporters to a large number of countries there are and, thus, the higher exposure to trade there will be. Rauch (1999) argued that the trade of heterogeneous products is in a network structure while a trade in homogeneous products is in the market. Baskaran and Brück (2005), Blöchl *et al*. (2010), Schweitzer *et al*. (2009), Baskaran *et al*. (2011), Cho *et al*. (2015) applied the network theory of physical sciences to the international trade field by presenting a formal mathematical model. However, the network structure of individual products has not been largely explained. The paper examines how petroleum refineries are exposed to exports and then tests whether the network structure can better explain exports than the H-O model.

This paper applies the network structures to estimate the exports of petroleum refineries in South Korea, which complements to Cho *et al*. (2015). Petroleum is an important natural resource. Petroleum is used to maintain most industries in modernized nations. Petroleum is often mined in places that are far away from the countries with petroleum refineries. Petroleum is processed and refined into useful products such as gasoline, heating oil, petroleum naphtha, and so on. A large percentage of the world's energy consumption is produced by petroleum refineries, ranging from 51% for Organisation of Economic Co-operation and Development (OECD) countries in Europe, America and Asia, to 43% for developing countries (see "World Oil Outlook 2012"). The top oil consumers mostly consist of OECD countries in the Americas. This paper analyzes the exports of petroleum refineries in South Korea by using the network theory with the H-O model. Specifically, this paper examines the time trends of the network index derived by the mathematical model and the effects of the network variable on the exports and the H-O model.

The remainder of this paper is organized as follows. Section 2 briefly introduces the theoretical network model for the empirical analysis. Section 3 reviews and discuss the empirical results with the network variable. Conclusions are in section 4.

2. METHODS

The random network concept developed by Erdös and Rényi (1959) describes some real world networks because a set of nodes in random networks tends to be homogeneous and to have similar connectivity. Amaral *et al*. (2000) showed that the small-world networks proposed by Watts and Strogatz (1998) comprise a more appropriate model in describing real world networks and that the connectivity distribution of scale-free networks follows a power law. The power law describes why a few popular search websites such as Google and Naver or a few famous actors tend to be well connected (Albert and Barabási, 2002; Newman, 2003; Vega-Redondo, 2007). We consider the power law's distribution as follows:

$$p(y) = \frac{y^{-g}}{\sum_{y=1}^{\infty} y^{-g}}, \tag{1}$$

where *p, y* and *g* denote a power law, the number of the connections per node, and the number of networks, respectively. $\varsigma(y) = \sum_{y=1}^{\infty} y^{-g}$ is called the Riemann zeta function. Assume that every product is traded in network structures where the countries are considered as nodes and trade follows the power laws. Then, the value *g* is the network structure. The larger *g* is, the lower the number of countries exporting the particular products, and vice versa. Now consider the probability, $L = \prod_{i=1}^{n} \frac{y_i^{-g}}{\varsigma(g)}$, called the likelihood of the data. To maximize this function, we consider the logarithmic function of the likelihood with respect to *g*:

$$\log L = \sum_{i=1}^{n} [-g \log(y_i) - \log(\varsigma(g)] = -g \sum_{i=1}^{n} [\log(y_i)] - n \log(\varsigma(g)). \tag{2}$$

To maximize the log-likelihood function, the corresponding derivative is taken with respect to *g* and set at zero.

$$\frac{d\log L}{dg} = 0 => -\sum_{i=1}^{n}[\log(y_i)] = n\frac{1}{\varsigma(g)}\frac{d\varsigma(g)}{dg}. \quad (3)$$

Rearranging equation (3), we obtain the following equation:

$$\frac{1}{\varsigma(g)}\frac{d\varsigma(g)}{dg} = \frac{1}{n}\sum_{i=1}^{n}\ln(y_i). \quad (4)$$

When the number of the connections per country is considered, equation (4) must correspond to the network variable *g*. The network variable *g* for each year is obtained by solving equation (4) using mathematical software in which a numerical algorithm such as the Newton iteration method is implemented. The mean and standard deviation of the network variable *g* is 1.35 and 0.02 and the values of the variable have a declining trend with fluctuations during the period under consideration. As more countries are open to trade over time, trade between countries increases and, thus, the network index decreases over time. This phenomenon also applies to petroleum refineries.

3. RESULTS

The panel trade data for petroleum refineries are taken from the Trade and Production Database of the Centre d'Etudes Prospectives et d'Informations Internationales (CEPII).[1] The distance comes from http://www.mapcrow.info. The data set used in this study cover 110 countries and Korea for the period from 1980 to 2003.

Two of the most popular classic trade theories are the gravity model and the H-O model. The gravity model predicts that the closer the distance

[1] http://www.cepii.fr/anglaisgraph/bdd/TradeProd.htm.

between two countries and the higher the national incomes, the more trade there will be between countries. The H-O model says that the bigger the difference between two cross-country capital-labor ratios, the greater the trade will be. The two classical models are extended by incorporating network theory. The network index varies across each year but not across countries. By including the network index as a variable, we can investigate the effects of network index on exports in the gravity and H-O models. We predict that the network index accelerates the effects of distance, national income, and capital-labor ratio on the exports of petroleum refineries from South Korea. That is, with the introduction of the network index, exports from South Korea to other countries would increase further with GDP and with differences of capital-labor ratios, and would further decrease with increasing distance between South Korea and other countries. This is because the network values of petroleum refineries are larger than those of popular and homogeneous products, and differentiated goods from petroleum refineries confirm the gravity and H-O model. The empirical model including the gravity and the H-O model is:

$$\ln X_{it} = \beta_1 \ln(GDP_{it}) + \beta_2 \ln(PGDP_{it}) + \beta_3 \ln(D_i) + \beta_4 \ln(R_{it}) + \beta_5 (g_t) + \beta_6 (g_t \times \ln(R_{it})) + \varepsilon_{jt}. \quad (5)$$

In this model, X_{it} is the exports of petroleum refineries from South Korea to country i at time t (unit: \$1,000), GDP_{it} is the product of GDP (unit: \$1,000) of South Korea and GDP of country i at time t, $PGDP$ is the product of per capita GDP in two countries, D is the distance (unit: 1km), R is the absolute value of the difference of capital-labor ratios between South Korea and country i, g represents the network structure, and ε is the error term.

We estimate three models: the gravity model, the H-O model in a gravity model specification, and network structures with gravity and H-O models. All models are estimated with panel random effects. The Hausman test for the fixed-effect and random effect model shows that we cannot reject the null hypothesis of randomness, implying that the random effects model is an

Table 1 Results of Three Models

Variables	(1)	(2)	(3)
D	–4.2046*** (0.860)	–4.4762*** (0.827)	–4.3871*** (0.787)
GDP	0.0265*** (0.005)	0.0223*** (0.005)	0.0232*** (0.004)
PGDP	0.0060 (0.019)	0.0126 (0.018)	0.0134 (0.019)
R		0.0013*** (0.000)	–0.0548** (0.024)
g			–10.8839 (8.294)
*g*R*			0.0421** (0.018)
Constant	2.2397 (4.354)	5.0405 (4.265)	18.5547 (12.899)
Observations	1,089	1,087	1,087
Number of Countries	110	110	110
R^2	0.36	0.35	0.37
Hausman Test			Chi2(3)=5.79
(H_0: Random)			Prob>chi2=0.22

Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.09.

appropriate specification.

The results of the three models are presented in table 1. The first is estimated with the gravity model without the H-O and network variables. The *D* is negatively associated with the exports while the GDP is significantly positively associated with the exports. The coefficient of *PGDP* is not statistically significant. This result confirms the prediction of the gravity model. The second is estimated with the inclusion of the difference of capital-labor ratios to test the H-O prediction. The *R* is significantly positively associated with the exports, confirming the H-O prediction. The third model investigates how the network variable interacts with the difference of endowment ratio. The inclusion of the network variable does not qualitatively change the first and the second results. It allows for the change in the slope of the relationship. It lowers the effect of

D and increases the effect of GDP. The partial derivative of the expected exports with respect to the difference of capital labor ratios is confirmed to be positive and statistically significant, but it is negative with respect to the network variable.

The results of this paper suggest two important findings. First, the difference of the endowment ratio increases the exports in the network interaction model more than in the first two models. This result is much more favorable for the H-O model. When fewer countries participate in exports with higher *g*, the difference in the endowment ratio increases exports. Because the petroleum refineries produce highly capital-intensive products and could not be produced in most countries, the difference of capital-labor ratios is more important in deciding the exports in the interaction model. Second, the network values of petroleum refineries are declining over time. The decreasing network values over time mean that petroleum refineries have become more popular and are easier to produce. So the difference in the endowment ratio becomes less important over time.

4. CONCLUSIONS AND POLICY IMPLICATIONS

This report uses data from 1980 to 2003 to analyze the effects of the network structure on the export of petroleum refineries. We have found that the distance is negatively associated with exports while the GDP and the differences of resource ratios are positively related to exports. Therefore, it could be said that the network structures of the petroleum refineries support the gravity model and the H-O model. Important findings are that the inclusion of the network variable can change the slope of the gravity model and the H-O model. This result is much more favorable for the H-O model. When fewer countries participate in exports with higher *g*, the difference in the endowment ratio increases exports produced by petroleum refineries. However, the decline in network values over time means that petroleum refineries have become more popular and, thus, the difference in the endowment ratio becomes less important over time.

REFERENCES

Albert, R. and A. L. Barabási, “Statistical Mechanics of Complex Networks,” *Reviews of Modern Physics*, 74(1), 2002, pp. 47-97.

Amaral, L. A. N., A. Scala, M. Barthélémy, and H. E. Stanley, “Classes of Small-world Networks,” *Proceedings of the National Academy of Sciences of the United States of America*, 97(21), 2000, pp. 11149-11152.

Atrostic, B. K. and Sang V. Nguyen, “It and Productivity in U.S. Manufacturing: Do Computer Networks Matter?,” *Economic Inquiry*, 43(3), 2005, pp. 493-506.

Barabási, A. L. and Reka Albert, “Emergence of Scaling in Random Networks,” *Science*, Vol. 286, 1999, pp. 509-512.

Baskaran, T., F. Blöchl, T. Brück, and F. J. Theis, “The Heckscher-Ohlin Model and the Network Structure of International Trade,” *International Review of Economics & Finance*, 20(2), 2011, pp. 135-145.

Baskaran, T. and T. Brück, “Scale-free Networks in International Trade,” DIW Discussion Papers, 493, 2005.

Blöchl, F., F. J. Theis, F. Vega-Redondo, and E. O. Fisher, “Which Sectors of a Modern Economy Are Most Central?,” CESifo Working Paper Series, 3175, 2010.

Bowen, H., E. Leamer, and L. Sveikauskas, “Multicountry, Multifactor Tests of the Factor Abundance Theory,” *The American Economic Review*, 77, 1987, pp. 791-809.

Cho, T., S. Lee, and Y. Goo, “Determinants of Imports of Petroleum-based Refinery Goods in South Korea: Network Structure and the Heckscher-Ohlin Theory,” *Korea and the World Economy*, 16, 2015, pp. 253-267.

Erdös, P. and A. Rényi, “On Random Graphs I,” *Publications Mathematicae Debrecen*, 6, 1959, pp. 290-297.

Lee, M., “The Effects of an Increase in Power Rate on Energy Demand and Output Price in Korean Manufacturing Sectors,” *Energy Policy*, 63, 2013, pp. 1217-1223.

Leontief, W., “Domestic Production and Foreign Trade: The American Capital Position Re-examined,” *American Philosophical Society*, 97, 1953, pp. 332-349.

Newman, M. E. J., “The Structure and Function of Complex Networks,” *SIAM Review*, 45(2), 2003, pp. 167-256.

Schweitzer, F., G. Fagiolo, D. Sornette, F. Vega-Redondo, A. Vespignani, and D. R. White, “Economic Networks: The New Challenges,” *Science*, 325(5939), 2009, pp. 422-425.

Shim, K. and Yonghun Jung, “Trade Liberalization and Tax Reform Strategies: The Case of the Korean Oil Industry,” *Energy Policy*, 41, 2012, pp. 686-691.

Steven H. Strogatz, “Exploring Complex Networks,” *Nature*, Vol. 410, 2001, pp. 268-276.

Vega-Redondo, F., *Complex Social Networks*, Cambridge University Press, 2007.

Watts, D. J. and S. H. Strogatz, “Collective Dynamics of ‘small-world’ Networks,” *Nature*, 393, 1998, pp. 440-442.

World oil outlook 2012, Organization of the Petroleum Exporting Countries 2012 (available at: http://www.opec.org/opec_web/static_files_project/media/downloads/publications/WOO2012.pdf).

MapCrow Info, 2015 (available at: http://www.mapcrow.info).