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Fragmented Production in East Asia: The Impact of Economic Integration and Network Quality

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FRAGMENTED PRODUCTION IN EAST ASIA:
THE IMPACT OF ECONOMIC INTEGRATION AND NETWORK QUALITY

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Abstract:

This paper investigates the impact of improving quality of production network on international fragmented production in East Asia. To analyze the extent of fragmentation, this paper employs the O-ring theory of production, which emphasizes the quality of product itself and production network is more important than the quantities. Then, this paper applies the gravity equation approach with the trade facilitation index as a proxy of network quality to estimate the fragmented production of machinery industries. This paper presents that regional integration with policy cooperation to facilitate trade would have an important impact on reducing the service link costs and improving quality of the fragmented production network in East Asia.

Keywords: O-ring theory of production, fragmentation, trade facilitation.

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1. Introduction

The formation of international production networks was noticeable phenomena in East Asia in the recent decade. Such phenomenon is resulted in rapid growth in trade of parts and components for international fragmented production. We can observe this rapid development of international fragmented production particularly in machinery sectors.

Despite the realized importance of rapid development of fragmented production networks, the formal economic analysis of fragmentation has not yet been thoroughly conducted both in theoretical and empirical fields. In particular, what is the important factors promoting the fragmented production networks and how significant service link costs are important questions to be investigated.

This paper tries to investigate that to explain the extent of fragmentation using the O-ring theory of production to investigate the importance of network quality for the fragmented production. Then we apply the gravity equation approach to international trade flows of machinery parts and components. The estimated coefficients for trade facilitation index are carefully examined as a proxy of the network quality. Finally, we try to analyze the possible impact of regional integration on the fragmented production network in East Asia.

The rest of the paper is organized as follows: section 2 briefly review the existing literature of fragmentation. Section 3 presents the so-called O-ring theory of production to explain the extent of fragmented production. Section 4 reports the empirical analysis on machinery parts and components trade in the gravity equation approach. Section 5 concludes.

2. Literature Review: Theoretical and Empirical Works on Fragmentation

The production of a final product usually consists of many processes that are vertically integrated. The “fragmentation” means to divide such vertically integrated production processes into separate production blocks and to shift them to various locations that are most suitable for each activity. A number of literatures have investigated fragmentation. Jones and Kierzkowski (1990) present an initial framework for analyzing fragmentation. They formulate an analytical framework in which an increase in the number of production blocks to produce a final product lowers marginal costs but raise service link costs and hence the optimal number of fragmented production blocks rises as output level increases. On the other hand, Arndt (1997, 1998) defines “offshore sourcing” as production of components in foreign countries. Then, Grossman and Helpman (2002a, b) theoretically explain how industry characteristics affect the extent of outsourcing. Yi (2003) constructs a theoretical model to demonstrate that vertical specialization of production can explain the non-linear relation between tariff reduction and the growth of world trade in recent 50 years.

Hummels, Ishii, and Yi (2001) focus on trade in intermediate goods which are used as inputs to produce a country's export goods. they empirically analyze how each country is involved in the fragmented production network using the Input-Output Table. On the other hand, Hanson, Mataloni, and Slaughter (2003) analyze production chains from the viewpoint of individual firms. They focus on trade in intermediate goods within firm groups, using firm-level micro data. In any case, firms optimize their activities by the location choice of fragmented production network.

Basically fragmentation is observed throughout the world recently. However, Ando and Kimura (2003) claim that “the international production networks in East Asia are distinctive in their significance in the regional economy, their geographical extensiveness, and their sophistication of both intra-firm and arm’s-length relationships across different firm nationalities.”

3. The Model

In this section, we develop a new theoretical framework for the fragmented production in order to introduce the network quality as an important key for fragmentation. We adapt Kremer's (1993) O-ring theory to determine the market equilibrium for intermediate inputs in a fragmented production network. The production consists of a number of production blocks, and the value of the resulting output depends on the successful performance at all production blocks. The O-ring production function reads:

$$Y = nB\left(\prod_{i=1}^{n} q_i\right)^{\alpha} \qquad (1)$$

Y is final output, n is the exogenous number of production blocks needed to complete the production process, q is the quality of intermediate goods i*;* $q \in (0, 1)$ and can be interpreted as the probability that the intermediate good i will have the required quality and arrive at the next production block at the right time. B is a scalar that represents the output volume if all production blocks are performed to perfection. The parameter $\alpha \in (0, 1)$ represents returns to quality. The profit maximizing firm chooses quality according to the following maximization problem:

$$\underset{q}{Max}\, nB\left(\prod_{i}^{n} q_i\right)^{\alpha} - \sum_{i=1}^{n} p(q_i) \qquad p'(q) > 0; p''(q) < 0\,.$$

The first-order condition is

$$\alpha nB\left(\prod_{i=1}^{n} q_i\right)^{\alpha-1} \prod_{j\neq i}^{n} q_j - p'(q_i) = 0$$

Kremer (1993) has shown that a firm will choose the same quality of all its inputs such that the first-order condition can be written as $p'(q) = nq^{\alpha n-1}$. Assuming that the price of each intermediate goods is a continuous function of its quality, we can find the relation between price and quality by integrating both sides of the first-order condition, which yields:

$$p(q) = \int nq^{\alpha n-1} dq = Bq^{\alpha n} + c \qquad (2)$$

The constant term, c, in the integration must be zero if the firm operates in a competitive environment, which is assumed. We notice that the price increases in q. The suppliers' cost of producing quality q is given by:

$$c(q) = e^{\beta q} - 1 \qquad (3)$$

The parameter β represents the impact of exogenous variables on the cost function such as the network quality or trade facilitation. A high β represents low quality of production network or low level of trade facilitation. A decline in β or increase in network quality would move the cost function and shift the break-even quality to be higher.

The supplier will provide a quality level that maximizes his profits as follows:

$\underset{q}{Max}\left[Bq^{\alpha n} - e^{\beta q} + 1\right]$, which yields the first-order condition:

$$\alpha nBq^{\alpha n-1} - \beta e^{\beta q} = 0 \qquad (4)$$

The optimal level of quality for the supplier is the level where the difference between price and cost is the largest. A decline in β will shifts the second term in first order condition and the new equilibrium yields a higher quality at a lower cost and would have an incentive to improve the quality of product itself.

4. Empirical Analysis: Effect of Trade Facilitation on fragmentation

Now we empirically investigate the effect of increasing quality of production network arising from trade facilitation on the fragmented production network in East Asia by using a gravity regression analysis. The trade facilitation is measured by the trade facilitation index derived by Kim and Park (2004)'s four indicators of trade facilitation: customs procedures (CP), standards and conformity (SC), business mobility (BM), and information and communication technology (ICT). We divided fifteen APEC countries into three groups by the stage of development. The trade facilitation indexes for those three APEC economic groups are figured in Table 2. Higher index values indicate better trade facilitation, which means higher network quality and incur lower service link costs.

The empirical model is specified as

$$\ln EX_{ij}^{t} = \ln\alpha + \beta_1 \ln GDP_i^t + \beta_2 \ln GDP_j^t + \beta_3 \ln GDPPC_i^t + \beta_4 \ln GDPPC_j^t$$
$$+ \beta_5 \ln DIST_{ij} + \beta_6 \ln TF_{ij} + \mathrm{B} * DUMMY + \ln\varepsilon_{ij}$$

where i and j stand for the exporter and importer respectively, and t denotes trading years (t=1996-2003). The value of machinery parts and components exports from country i to j is denoted as EXij. GDPi, GDPPCi, GDPj, and GDPPCj are GDP and per capita GDP of i and j, respectively. DISTij stands for the distance between i and j. The term TFj denotes importing country j's trade facilitation index. ε_{ij} represents the error term that follows lognormal distribution. β s are estimated coefficients. DUMMY denotes a matrix of dummy variables and B is a vector of coefficients for them. we introduce the regional dummies, the adjacency dummy and the common language dummy, which are often used in the usual gravity equation approach. The definition and data source of these variables are summarized in Table 1. We apply the generalized least squares (GLS) estimation technique for random effects estimation.

The panel data covers 15 APEC economies from 1996 to 2003 including Australia, Canada, Chile, China, Hong Kong, Japan, Korea, Malaysia, Mexico, New Zealand, Peru, Philippines, Singapore, Thailand, and the USA. The estimations use annual data consisting of 1,680 country pairs in total. The regional dummies include the ASEAN FTA (AFTA including Malaysia, Philippines, Singapore, and Thailand) and the North American FTA (NAFTA).

Table 3 presents the results of estimations. The dependent variables of Models 1 to 3 are exports of total manufactured goods, machinery final goods, and machinery parts and components, respectively. In every equation, the estimated coefficients for economic size and distance have expected signs and are statistically significant. The coefficients for the trade facilitation index are also positive. Regional dummies (NAFTA and AFTA) are mostly statistically significant, meaning each region has some distinctive characteristics.

The elasticity of trade facilitation varies greatly across the equations. In the estimate with total manufacture trade, the elasticity is 0.04, which means the 1% increase in trade facilitation index between trading countries increases trade by 0.04%. With machinery final goods, the corresponding figure is 0.10. Trade in machinery final goods are more sensitive to trade facilitation or network quality in comparison with total manufacture trade. Parts and components of machinery goods have the largest elasticity, meaning that trade facilitation encourages trade in parts and components the most.

Two possible explanations are considerable for these differences in the elasticity of trade facilitation. First, the elasticity of substitution can be different across commodity groups. The commodity with high elasticity of substitution is more sensitive to change in price. Since the level of trade facilitation can affects total trade costs, the elasticity of trade facilitation index is likely to be larger for the equation of trade in machinery parts and components if the elasticity of substitution for parts and components are higher than final products. Second, the network quality can be so important in production process that the trade facilitation for parts and components is more effective than for final products, and the elasticity for trade facilitation index for machinery parts and components becomes larger. It means that improvement of trade facilitation can make the machinery parts and components pass through country borders more times within the production networks for the particular machinery final goods and hence the international fragmentation can be motivated to develop by the trade facilitation as we stated in theoretical section.

Another interesting finding is that East Asia has a completely different characteristic from other regions. The coefficients for AFTA dummy in Table 3 changes in the opposite order to NAFTA. The coefficient for AFTA dummy in the equation for machinery parts and components is much higher than in the equations for total manufactures and machinery final goods. AFTA countries intensively trade machinery parts and components with each other. Fragmentation of production blocks is happened by flows of parts and components among each block. This observation implies the formation of international fragmented production networks in East Asia.

5. Conclusions

The formation of international fragmented production networks in East Asia is an important experience in the recent years. This paper tries to investigate the extent of fragmentation using the O-ring theory of production, and the importance of network quality for fragmented production in East Asia using gravity equations for trade in machinery parts and components.

In the theoretical section, we found that the O-ring theory of production predicts that the better trade facilitation the production process, the more lead firms are willing to pay for high quality inputs. It suggests that the regional Integration with policy cooperation to facilitate trade would make the incentive to improve the quality of product itself for the developing member country firms.

In the empirical analysis, we found that the trade flows of machinery parts and components have the large elasticity on the Trade facilitation index. It means that improvement of network quality encourage trade in machinery parts and components and develop the fragmentation in the region. Moreover, the regional Integration with policy cooperation to facilitate trade would have an important role in improving quality of the production network and enhancing the fragmentation in East Asia.

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Table 1. Definition and Source of Data

	Definition	Source
EX	Export value in US$	Authors' calculation based on UN Comtrade
EXGDP	GDP of exporter	World Development Indicators 2004
IMGDP	GDP of importer	World Development Indicators 2004
EXGDPPC	per capita GDP of exporter	World Development Indicators 2004
IMGDPPC	per capita GDP of importer	World Development Indicators 2004
DIST	Distance between capital cities	Fitzpatrick and Modlin (1986)
TF	Trade facilitation index	Authors' calculation based on Kim and Park (2004)
ADJ	Adjacency dummy	1 if both countries have a common national border, 0 otherwise.
LAN	Common language dummy	1 if both countries use at least one common language, 0 otherwi
NAFTA	Intra NAFTA dummy	1 if both countries are members of NAFTA, 0 otherwise.
AFTA	Intra AFTA dummy	1 if both countries are members of AFTA, 0 otherwise.
EASIA	Intra East Asia dummy	1 if both countries are members of EA, 0 otherwise.

Note: EX, EXGDP, IMGDP, EXGDPPC, IMGDPPC, DIST, and TF are log form.

Table 2. Trade Facilitation Index

	Customs Procedures	Standards and Conformity	Business Mobility	Information and Communication	Trade Facilitation Index
Industrialized APEC Economies*	1.686	0.912	1.029	1.506	**1.283**
Newly Industrialized APEC Economies**	1.268	0.827	0.910	1.413	**1.105**
Industrializing APEC Economies***	0.618	1.441	1.076	0.256	**0.848**
APEC Economies	1.000	1.000	1.000	1.000	**1.000**

* Industrialized APEC Economies include Australia, Canada, Japan, New Zealand, and the USA.

** Newly Industrialized APEC Economies include Chile, Hong Kong, Korea, Mexico, and Singapore.

*** Industrializing APEC Economies include China, Malaysia, Peru, Philippines, and Thailand.

Sorce: Kim and Park (2004)

Table 3. Estimate Results of Gravity Equations

	1	2	3
dependent variable	**total manufactures**	**machinary final goods**	**machinary parts and**
Constant	-3.54***	-13.22***	-12.73***
	(0.51)	(0.78)	(0.73)
EXGDP	1.18***	1.78***	1.66***
	(0.03)	(0.03)	(0.04)
IMGDP	1.06***	1.08***	1.18***
	(0.03)	(0.04)	(0.03)
EXGDPPC	0.28***	0.68***	0.57***
	(0.03)	(0.04)	(0.04)
IMGDPPC	0.10**	0.24***	0.20***
	(0.03)	(0.04)	(0.05)
DIST	-1.29***	-1.52***	-1.74***
	(0.05)	(0.06)	(0.07)
TF	0.04***	0.10***	0.17***
	(0.01)	(0.03)	(0.22)
ADJ	0.28	0.12	-0.01
	(0.24)	(0.25)	(0.28)
LAN	1.08***	1.83***	1.65***
	(0.12)	(0.20)	(0.19)
NAFTA	-1.38**	-1.95*	-2.11**
	(0.57)	(0.92)	(0.87)
AFTA	2.86***	3.73***	4.97***
	(0.17)	(0.24)	(0.23)
Adjusted R-squared	0.577	0.525	0.548
No. of Observations	1,680	1,680	1,680

Note: Figures in parentheses are standard errors.
***: significant at 1% **: 5% *: 10% levels