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Executive Summary

This paper derives a consolidated regression equation to estimate the sources of comparative advantage; integrating the Heckscher-Ohlin model, the Ricardian model, and the gravity model. It also aims to test which of the three competing models better explains the bilateral trade flows. For the empirical estimation, it sets up a consistent dataset for 65-countries and 42-industries in 1997, 2001, and 2004.

The estimation results generally confirm the three competing models, but relative strength of the Heckscher-Ohlin model turns out to be the most potent, followed by the gravity model, and the Ricardian model. The results reveal that the signs of the estimates such as production factors and total factor productivity are positive in all significant results. In addition, the gravity variables including the distance variable and dummies such as borders, languages, colony, and FTA explain the changes in trade share very well.

The explanatory power of the three competing models turned out to be different depending on sectoral and regional groups. A sign for the capital turned out to be negative in case of regressions for the natural resource intensive sector, but they are not statistically significant. In case of the Ricardian model, this paper does not indicate that technological difference is statistically significant for the sectoral groups. It is interesting to see that the sign of the colony dummy for developed countries, other European countries, and Central America turned out to be different from the prediction.

Keywords: Factor Proportions, Technology, Geography
JEL Classification: F11, F12, F14

국문요약

본 논문은 헥셔–오린모형, 리카도모형, 중력모형 등 국제비교우위를 설명하는 기존의 무역모형을 통합하는 회귀방정식을 도출하고, 어느 무역모형의 설명력이 높은지를 분석하였다. 이를 위해 본 논문은 GTAP 데이터와 세계은행, UN의 거시·무역 데이터를 통합한 분석 데이터베이스를 구축하였다.

본 연구의 분석결과에 따르면 기존의 세 가지 무역모형 중에서 헥셔–오린모형의 설명력이 가장 높으며, 그 다음으로 중력모형과 리카도모형의 설명력이 높은 것으로 나타났다. 또한 모든 유의한 결과에서 부존자원 및 기술격차의 부호가 모형의 예측과 일치하는 것으로 나타났다. 아울러 거리, 국경, 언어, 식민지, FTA 등 중력모형의 변수들이 무역의 흐름을 잘 설명하는 것으로 나타났다.

무역모형의 설명력은 산업 및 지역별로 크게 다른 것으로 나타났다. 즉, 자본요소의 파라메터 추정 부호는 자원집약적 부문의 경우 예상과 다르게 마이너스 부호를 가지지만 통계적 유의성은 없었다. 또한 기술격차도 산업별 분석에서는 예상과 다르게 유의한 결과를 보이지 않았다. 아울러 선진국, 유럽 국가, 중미 국가에서 식민지 더미변수의 부호도 예상과 다르게 나타났다.

핵심용어: 요소비율, 기술, 지리

Nakgyoon Choi is a Senior Research Fellow at the Korea Institute for International Economic Policy (KIEP) and a Commissioner of Korea Trade Commission. He was also a former Vice President of KIEP. He received his Ph.D. in International Trade in 1991 from the University of Texas at Austin. Since then, he has been actively involved in formulating Korea's trade policy. Before joining KIEP, he served as an advisor to the Minister of Trade, Industry, and Energy and as a Senior Research Fellow at the Korea Institute for Industrial Economics and Trade. He has published extensively on the topic of trade policy, including "Impacts of Free Trade Agreements on Structural Adjustment in the OECD: Panel Data Analysis" (KIEP Working Paper 09-05, 2009), "General Equilibrium Analysis of DDA Trade Liberalization: Assessment of Alternative Scenarios" (KIEP Working Paper 10-01, 2010), "Determinants of Staging Categories for Tariff Elimination in Chinese, Japanese and Korean Negotiations of Free Trade Agreements" (*Asian Economic Papers*, 2011).

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저서 및 논문

"General Equilibrium Analysis of DDA Trade Liberalization: Assessment of Alternative Scenarios" (KIEP Working Paper 10-01, 2010)
"Determinants of Staging Categories for Tariff Elimination in Chinese, Japanese and Korean Negotiations of Free Trade Agreements" (*Asian Economic Papers*, 2011) 외

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Empirical Tests of Comparative Advantage: Factor Proportions, Technology, and Geography

Nakgyoon Choi*

I. Introduction

There have been competing theories on factors that determine the comparative advantage of each country. David Ricardo is well known as the originator of the doctrine of comparative advantage. He proposes that each country specializes in the commodity in which it has a comparative advantage and selected only by relative labor costs or level of technology. The Ricardian model emphasizes that technological levels can differ across countries because labor, the only production factor, cannot cross national borders.

Basically, however, the Heckscher-Ohlin model assumes that each country is identical, except for the difference in factor endowments. It endogenizes the factors price, output, and consumption; treating the factor supply and international production price as exogenous variables. The Heckscher-Ohlin theorem proposes that a capital-abundant country would export capital intensive commodities while a labor-abundant country exports labor intensive commodities.

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Besides the technology and factor proportions, a role of geography has been incorporated in the recent literature on trade patterns. The gravity model relates each country's bilateral trade to the economic size and distance between the two countries. The advantage of this approach is that it captures a wide range of comparative advantage components including product differentiation and institutional framework, among others.

Most of the previous literature tests the Ricardian model, the Heckscher-Ohlin model, and the gravity model, individually. For Example, Baldwin (1971, 1978) regresses total exports as well as net exports of the US and other major countries, and found that human capital turned out to be important in explaining comparative advantage. Leamer (1980, 1984), and Bowen, Leamer and Sveikauskas (1987) initiate empirical tests on the Heckscher-Ohlin model by regressing factor intensity, factor supplies, and factor endowment on net exports. Their empirical results reveal that the explanatory power of Heckscher-Ohlin-Vanek theory is less than satisfactory.

Davis and Weinstein (2001) use the input-output table of 10 advanced countries and reveal that each country exports abundant production factors consistent with the Heckscher-Ohlin-Vanek theory. Eaton and Kortum (2002) develop a Ricardian model that incorporates geographic elements into the general equilibrium. They regress the technology and geographic barriers on bilateral trade using the data from 19 OECD countries in 1990, and reveal that geographic barriers as well as technology determine specialization.

Romalis (2004) integrates the multi-country Heckscher-Ohlin model with the Krugman (1980) model of monopolistic competition and transport costs and regresses the trade share on factor intensities with the 1998 US data. It demonstrates that each country produces and exports the commodity which makes intensive use of the abundant production factors.

Morrow (2008) incorporates the Ricardian differences in the total factor productivity with the Romalis (2004) model. It regresses the relative revenue on factor proportion and relative productivity, using the data on 24 industries, 11 years (1985-1995), and 20 countries. It indicates that both factor abundance and relative productivity are important in explaining the comparative advantage, and productivity differences across industries are uncorrelated with the factor intensities of these industries.

Chor (2010) considers the geographic elements, production factors, and institutional characteristics as sources of comparative advantage, using the data on 83 countries and 20 manufacturing industries in 1990. The empirical results turn out to be consistent with theoretical predictions with some variation, depending on the estimation methodologies.

This paper investigates the sources of comparative advantage, integrating the Ricardian model, the Heckscher-Ohlin, and the gravity model in the multi-country and multi-goods set-up. It also aims to test which of the three competing models better explains the bilateral trade flows. It integrates the differences in total factor productivity and geographic barriers to the Romalis (2004) model. This paper tests the representative elements from the three competing models using a consolidated database.

Specifically, it uses a consistent data on factor intensity created from the input-output table and estimates the differences in total factor productivity. The data for estimation consists of 65 countries and the 42 industries in 1997, 2001, and 2004 which were selected according to the GTAP (Global Trade Analysis Project) classification. It reconciles the trade and input-output data using the GTAP concordance table.

This paper is organized as follows. In Section 2, we extend the Romalis (2004) model to incorporate the Ricardian and gravity models, while discussing how to obtain the consistent database. In Section 3, we provide a discussion about the estimation results and the relative strength of competing models. Section 4 concludes.

Ⅱ. Basic Model and Database

1. Basic Model

This paper extends the Romalis (2004) model, which is a multi-country Heckscher-Ohlin model with the Krugman (1980) model of monopolistic competition and transport costs. Romalis (2004) incorporates the Ricardian and gravity models in the basic set up, assuming that each country is different in levels of technology and relative factor abundance. It also introduces iceberg transport costs which are implicitly assumed to be identical in all countries, and they are cancelled out in the price function after profit maximization.

In this paper, we introduce the iceberg transport costs to explain the geographical distance emphasized by the gravity model.[1] But, we assume that the iceberg transport costs between the countries are different and placed them directly in the total cost function.

In this paper, every consumer is assumed to have identical Cobb-Douglas preferences and consumes the fraction $b(z)$ on industry z. Therefore the utility function, U, can be represented as follows.

$$U = \int b(z) \ln Q(z)\, dz \tag{1}$$

[1] Anderson (1979), Deardorff (1989), and Krugman (1980) show that a product is differentiated by geographical location which means that a gravity factor can be a source of the comparative advantage.

Q(z) is a sub-utility function that depends on the quantity of each variety of *z* consumed.[2]

Total cost (*TC*) is assumed to be determined by the three elements. First, factor cost is Cobb-Douglas in skilled labor and unskilled labor whose factor rewards are *s* and *w*, respectively. Commodities are produced with a fixed cost and a constant marginal cost. The quantity produced in industry *z* is denoted by *Q(z)*. We assume that higher *z* implies an industry that is much more skilled-labor intensive, because index *z* represents both industry and skilled labor's share of income in that industry. Second, Hicks neutral TFP (Total Factor Productivity) is represented by *A(z)*, and it is assumed to upgrade the efficiency of both skilled labor and unskilled labor. Third, this paper assumes that international trade is accompanied by transportation costs. It introduces the iceberg assumption such that τ unit of commodities need to be transported to deliver 1 unit of commodity to a foreign country.

$$TC[Q(z)] = \frac{[\alpha + Q(z)]\, s^{z} w^{1-z}}{A(z)} \times \tau \qquad (2)$$

In the general equilibrium, a consumer optimizes his/her utility while a firm maximizes its profits. All production factors are utilized completely and international trade is balanced. The price level is determined as follows.

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2 Romalis (2004) represents *Q(z)* as the symmetric CES function, assuming that firms produce the variety of commodities which are imperfect substitutes for each other. Refer to Romalis (2004), p. 71.

$$\mathrm{P(z)} = \frac{\sigma}{\sigma - 1}\frac{s^{z} w^{1-z}}{A(z)} \times \tau \qquad (3)$$

Where $\sigma = 1/(1 - \theta)$, θ is elasticity of substitution among commodities. The relative price, $(\tilde{p} = p / p^{*})$ is represented by the relative wage rate $(\tilde{w} = w / w^{*})$, relative productivity, $\tilde{a}(z) = A(z) / A(z)^{*}$, and the transport cost, $(\tilde{\tau})$.[3]

$$\tilde{p}(z) = \prod_{f=1}^{F} \tilde{w}^{\theta_{z,f}} \times \frac{\tilde{\tau}}{\tilde{a}(z)};\ \sum_{f=1}^{F} \theta_{z,f} = 1;\ \theta_{z,f} \rangle 0\ \forall f \qquad (4)$$

We will introduce the trade equation of each country to see what exactly determines comparative advantage in international trade. The share of trade in each country's total import value of foreign country, x, is assumed to be a function of relative price $(\tilde{p} = p / p^{*})$.[4]

When we log-linearize the trade share, x at z_0 to let $\tilde{p}(z_0) = 1$ and rearrange equation (4), we get the following.[5]

$$\begin{aligned} x(z) &= x(z_0) + \frac{\partial x(z_0)}{\partial \ln(\tilde{p}(z_0))} \mathrm{I}n(\tilde{p}(z)) \\ &= x(z_0) + \frac{\partial x(z_0)}{\partial \ln(\tilde{p}(z_0))} \left[\sum_{f=1}^{F} \theta_{z,f} \ln \tilde{w} - \ln \tilde{a}(z) + \ln \tilde{\tau}\right] \end{aligned} \qquad (5)$$

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3 This paper assumes that the elasticity of substitution is the same for all countries in the theoretical setup. Thus, θ is not represented by the relative term.

4 Romalis (2004) reveals that the share of trade declines in the relative price of output.

5 Morrow (2008) derives the "unrestricted expression" by log-linearizing the relative revenue function, in order to assess the role of Ricardian productivity that is not correlated with the factor intensity.

Equation (5) implies that the trade share is determined by factor intensity *(θ)*, relative factor price $(\tilde{w})$, transport cost $(\tilde{\tau})$, and technological difference $(\tilde{a})$. This paper does not regard the relative factor price $(\tilde{w})$ as an independent variable in the empirical test because it is not observable in the industry levels. As a result, the coefficient estimates on factor intensity *(θ)* are functions of relative factor price $(\tilde{w})$.[6]

2. Estimation Equation and Database

From equation (5), we arrive at the estimation equation.

$$X_{jt}^{kl} = \beta_{0t} + \sum_{f=1}^{F} \beta_{jft}\theta_{jft}^{k} + \beta_{mt}\ln a_{t}^{kl} + \beta_{nt}\ln \tau_{t}^{kl} + D^{k} + D_{j} + D_{t} + \varepsilon_{jt}^{kl} \qquad (6)$$

where X_{jt}^{kl} denotes the trade share of country *k* with respect to country *l* in industry j in year t; θ_{jft}^{k} denotes factor intensity of factor *f* in industry j of country *k* in year t; a_{t}^{kl} represents relative total factor productivity of country *k* with respect to country *l* in year t; τ_{t}^{kl} denotes the transport cost from country *k* to country *l* in year t; $D^{k}, D_{j}, D_{t}, \varepsilon_{jt}^{kl}$ denotes country dummy, industry dummy, time dummy, and error term, respectively.

The coefficient (β_{jft}) sign of factor intensity tests the predictability of the Heckscher-Ohlin model that each country exports the commodity which intensively uses its relatively abundant factor. The coefficient

6 Romalis (2004) does not estimate the coefficient on relative factor price $(\tilde{w})$ but factor intensity *(θ)*.

(β_{mt}) sign of the total factor productivity will test the Ricardian model that posits that technological difference as a source of comparative advantage. Finally, the coefficient (β_{nt}) sign of the transport costs can indicate the validity of the gravity model.

We expect positive signs for β_{jft} and β_{mt} because they represent the Heckscher-Ohlin and Ricardian models, respectively. The coefficient (β_{nt}) sign of the transport costs including contiguity (*contig*), colonial link (*colony*), and common language (*comlang*) are expected to be negative, while the coefficient sign on the distance (*LDIST*) is expected to be positive.

Table A1 of the Annex shows that the country list includes the 7 developed countries including the US and Japan, the 27 EU member countries, 3 other European countries including Russia, 11 Asian countries including China, 8 Latin American countries, and 9 African countries/LDCs. Industry list in Table A2 includes 19 agricultural industries; 16 manufacturing industries; 6 natural resource intensive industries including fishery, forestry, and mining, and 1 service industry.[7]

The HS 6 digit data on bilateral trade was obtained from the UN Comtrade database and it was reconciled to the GTAP classification.[8] Trade share is calculated by dividing the industry export by the total export value.[9]

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[7] Refer to Table A1 and A2 for the detailed country and industry lists. The raw milk industry (RMK) is excluded from the dataset for this paper.

[8] The GTAP classification is built from a correspondence table supplied by the U.N. Statistical Division for HS96 - ISIC REV3. - CPC version 1.0 - SITC Rev 3.

[9] Romalis (2004) rescales the trade share by dividing average value in order to ensure that the result is not driven by a few large trading partners. Refer to Romalis (2004), pp. 81-83. The trade share in this paper does not have a problem of large country bias.

This paper extracts the data on factor intensity from the GTAP database, because it is based on the input-output data of major economies and provides a consistent industry classification. It uses the cost share data on capital (*CAPITAL*), unskilled labor (*UNSKLAB*), and skilled labor (*SKLAB*).[10]

This paper estimates the total factor productivity, extracting the data on capital from the GTAP database,[11] and labor as well as GDP from the database of WBDI (World Bank Development Indicator).[12] It applies the methodology proposed by Caves *et al.* (1982) and Harrigan (1997) to estimate the total factor productivity of countries b and c as follows.

$$TFP_{bc} = \frac{y_b}{y_c}\left(\frac{\bar{l}}{l_b}\right)^{\sigma_b}\left(\frac{\bar{\kappa}}{\kappa_b}\right)^{1-\sigma_b} \times \left(\frac{l_c}{\bar{l}}\right)^{\sigma_c}\left(\frac{\kappa_c}{\bar{\kappa}}\right)^{1-\sigma_c} \tag{7}$$

where y, *k*, and *l* denotes the value added, capital, and labor, respectively. $\bar{l}$ and $\bar{\kappa}$ represent the geometric averages of all observations in the sample, $\sigma_c = (s_c + \bar{s})/2$ when s_c is the share of labor to total cost of country *c*. This paper estimates the productivity level by setting the

10 The data on endowments - firms' purchases at agents' prices (EVFA) in the GTAP database are used for the cost shares. This paper uses the data on unskilled labor, skilled labor, and capital, excluding data on land and natural resources.

11 The data on capital stock value at beginning of period (VKB) in the GTAP database is used for the capital.

12 This paper estimates the total factor productivity of each country, but does not report the total factor productivity for each industry according to the sectoral classification in this paper. It is because the GTAP database does not provide the sectoral data on the labor for each country.

US productivity at 100, and uses the results of setting 2001 as the base year for the estimations of Section 3.

Table 1. Total Factor Productivity

Country	1997		2001	2004	
	Base Yr: 1997	Base Yr: 2001		Base Yr: 2004	Base Yr: 2001
United States	100.0	98.7	100.0	100.0	103.8
Japan	87.1	86.0	88.4	84.8	88.0
England	80.1	79.0	86.2	74.6	77.5
Germany	62.6	61.8	71.2	59.4	61.6
France	67.2	66.3	76.6	65.3	67.8
Italy	64.9	64.0	71.0	56.0	58.1
Spain	57.2	56.4	62.2	48.0	49.8
Sweden	77.5	76.5	88.6	74.0	76.8
Belgium	75.4	74.4	85.1	70.2	72.9
Luxemburg	134.9	133.1	131.5	107.5	111.6
Poland	32.3	31.8	31.6	30.4	31.6
Austria	60.3	59.5	68.8	59.6	61.9
Bulgaria	15.4	15.2	16.0	14.2	14.7
Cyprus	52.0	51.3	53.7	43.0	44.6
Czech Republic	28.0	27.6	31.4	24.7	25.7
Denmark	79.1	78.0	87.6	71.5	74.2
Estonia	24.5	24.2	32.3	30.6	31.8
Finland	62.3	61.5	70.1	60.5	62.8
Greece	49.2	48.5	55.7	46.1	47.8
Hungary	30.8	30.3	33.1	26.4	27.4
Ireland	84.6	83.4	92.5	74.0	76.8
Latvia	24.6	24.3	29.8	27.3	28.3
Lithuania	24.4	24.0	29.3	27.5	28.5
Malta	51.1	50.5	51.8	42.7	44.3
Netherland	68.5	67.5	72.9	59.7	61.9
Portugal	46.5	45.8	49.2	39.8	41.3
Romania	15.9	15.7	14.8	12.4	12.9
Slovakia	37.4	36.9	39.2	36.6	38.0
Slovenia	39.9	39.3	48.4	40.4	41.9

Source: Author’s calculation.

Table 1. Total Factor Productivity- Continued

Country	1997		2001	2004	
	Base Yr: 1997	Base Yr: 2001		Base Yr: 2004	Base Yr: 2001
Korea	50.1	49.5	57.3	50.6	52.5
China	12.7	12.5	14.5	16.4	17.0
Hong Kong	73.1	72.1	75.9	83.6	86.7
India	14.3	14.1	14.1	14.0	14.5
Indonesia	19.5	19.3	22.0	15.9	16.5
Malaysia	31.2	30.7	32.6	32.3	33.5
Philippines	18.5	18.3	20.6	20.0	20.8
Singapore	61.6	60.7	69.8	71.0	73.7
Thailand	19.7	19.5	22.4	14.6	15.2
Vietnam	11.5	11.4	11.1	8.9	9.2
Canada	73.2	72.3	77.4	68.4	71.0
Australia	64.7	63.9	77.4	63.1	65.5
New Zealand	47.3	46.7	57.8	45.1	46.8
Russia	12.2	12.0	16.8	27.9	29.0
Switzerland	80.7	79.7	85.6	72.3	75.1
Turkey	43.9	43.3	44.2	38.0	39.5
Croatia	29.1	28.7	33.0	29.4	30.5
Argentina	47.3	46.6	45.3	58.7	60.9
Brazil	25.9	25.6	30.8	28.9	30.0
Chile	45.0	44.4	51.1	45.3	47.0
Colombia	36.0	35.5	33.1	32.7	34.0
Mexico	46.6	46.0	40.3	37.7	39.2
Peru	24.9	24.6	26.2	20.0	20.7
Uruguay	60.6	59.7	58.1	61.8	64.2
Venezuela	46.7	46.1	35.3	36.4	37.8
Albania	16.8	16.5	18.2	13.5	14.0
Bangladesh	9.2	9.0	9.9	10.0	10.3
Botswana	31.1	30.7	33.7	31.1	32.3
Malawi	4.7	4.7	5.0	5.2	5.4
Morocco	18.8	18.6	21.0	18.2	18.9
Mozambique	6.2	6.1	9.4	8.5	8.8
Sri Lanka	14.2	14.0	14.7	16.6	17.2
Tanzania	11.2	11.1	10.7	10.5	10.9
Uganda	8.1	7.9	9.4	9.8	10.2
Zambia	8.9	8.8	9.5	8.2	8.5
Zimbabwe	11.9	11.7	9.8	12.4	12.8

Source: Author’s calculation.

Table 1 indicates that the productivity of Luxemburg turned out to be the highest, surpassing the US, but the difference has been decreasing over the period from 1997 to 2004. The US is followed by Japan, Ireland, Switzerland, England, Denmark, Sweden, Belgium, Canada, and Hong Kong.

This paper uses the CEPII gravity dataset (dist_cepii.xls) for transport costs including the distance measure *(dist)*, which uses latitudes and longitudes of the most important cities/agglomerations and takes the log transformation (*LDIST*). It includes the dummy variables indicating whether the two countries are contiguous (*contig*), have ever had a colonial link (*colony*), and a language spoken by at least 9% of the population in both countries (*comlang*). It also considers the dummy indicating whether the two countries are the members of the same FTAs (Free Trade Agreements) including the EU, EFTA, ASEAN, ANCOM (Andean Community), CARICOM (Caribbean Community and Common Market), CACM (Central America Common Market), ECO (Economic Cooperation Organization), ECOWAS (Economic Community of West African States), UEMOA (West African Economic and Monetary Union), and CEMAC (Economic and Monetary Community of Central Africa), and so on.

Ⅲ. Estimation Results

This paper tests the statistical significance of the three competing trade models at once, which is different from previous literature that estimates them individually. We apply the OLS method to the pooled dataset of 65 countries and 42 industries in 1997, 2001, and 2004; considering country dummies, industry dummies, and time dummies. We also regress the trade shares for the regional as well as sectoral groups.

1. Estimation for the Pooled Data

Table 2 reveals that the parameters of production factors such as unskilled labor (UNSKLAB), skilled labor (SKLAB), and capital (CAPITAL) turned out to be positive, as expected, and significant in the level of 0.1%. The total factor productivity (TFP) turned out to be positive and statistically significant.

The gravity variables such as distance, common borders, colony, common language, and FTA turned out to be consistent with the predictions and significant in the level of 0.1~5 %. The distance variable has a negative effect on the trade share, but other dummies have a positive effect.

When we regress the trade shares on unskilled labor (UNSKLAB), skilled labor (SKLAB), capital (CAPITAL), and total factor productivity (TFP) separately, all variables in Model 2, 3, and 5 turned out to be significant and consistent with the predictions of the competing theories.

Table 2. Estimation Results for the Pooled Data

	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**
UNSKLAB	1.99*** (6.71)	0.47*** (3.07)	-	-	-
SKLAB	9.86*** (15.29)	-	5.02*** (10.96)	-	-
CAPITAL	3.09*** (11.11)	-	-	-0.10 (-0.83)	-
TFP	0.006 (1.26)	0.01** (2.03)	0.008* (1.76)	0.01** (2.06)	0.01** (2.06)
LDIST	-0.51*** (-21.04)	-0.44*** (-18.50)	-0.45*** (19.05)	-0.43*** (-18.33)	-0.43*** (-18.41)
contig	8.73*** (113.15)	8.84*** (115.12)	8.81*** (114.79)	8.84*** (115.13)	8.84*** (115.15)
colony	0.65*** (7.43)	0.65*** (7.51)	0.65*** (7.50)	0.65*** (7.51)	0.65*** (7.51)
comlang	2.34*** (40.39)	2.36*** (40.78)	2.36*** (40.73)	2.36*** (40.81)	2.36*** (40.81)
FTA	1.12*** (19.48)	1.24*** (21.74)	1.22*** (21.38)	1.24*** (21.82)	1.24*** (21.81)
Country Dummy	Yes.	Yes.	Yes.	Yes.	Yes.
Industry Dummy	Yes.	Yes.	Yes.	Yes.	Yes.
Time Dummy	Yes.	Yes.	Yes.	Yes.	Yes.
Sample	220,092	220,092	220,092	220,092	220,092
F Value	613.46***	621.38***	622.67***	621.28***	626.78***
$\overline{R}^2$	0.24	0.24	0.24	0.24	0.24

Note: The numbers in the parenthesis denote the t-statistics. ***, **, and * represent the levels of 1%, 5%, 10%, respectively.

The TFP in Model 1 turned out to be insignificant but its sign was consistent with the predictions. The estimates on the CAPITAL in Model 4 seemed to be inconsistent with the predictions partly because the capital endowments are embodied in the skilled labor.

2. Estimation by Regional Groups

Table 3 indicates that the signs of the parameter estimates turned out to be consistent with the predictions except the gravity parameters, when we regress the trade shares for seven regions including the developed countries (the US, Japan, and Canada and so on), the EU, other European countries, Asia, Central American countries, Africa, and LDCs (Least Developed Countries).

Specifically, the parameters of production factors are all positive and statistically significant, except the *UNSKLAB* in Africa and LDCs. It is partly because the agricultural sector is dominant in Africa and LDCs, and production factors such as land, and other resources have greater effect on their trade shares than unskilled labor.

The signs of factor productivity (*TFP*) turned out to be significant and consistent with the predictions for the developed countries, EU, other European countries, and Asia; but insignificant for Central America, Africa, and LDCs. It is because the level of technology of these regions has been relatively low and there are seldom products with technological advantage.

The distance variable turned out to have a negative effect on trade share, but common border and common language have positive effects on all regional groups. The colony dummy has a positive effect on trade shares of the EU, Asia, Africa and the LDC, but negative effect for the developed countries, other European countries, and Central America.

Table 3. Estimation Results for Individual Regions

Variables	Developed countries	EU	Other Europe	Asia	Central America	Africa	LDCs
UNSKLAB	14.18*** (15.90)	2.34*** (5.40)	12.54*** (3.83)	13.46*** (14.14)	9.19*** (3.63)	6.09 (0.84)	3.80 (1.20)
SKLAB	10.77*** (8.85)	17.58*** (17.22)	32.05*** (4.40)	6.76*** (3.89)	10.22** (2.44)	256.15*** (9.20)	41.81*** (3.41)
CAPITAL	14.19*** (16.29)	5.20*** (12.29)	16.34*** (5.39)	12.54*** (14.66)	8.06*** (3.83)	45.00*** (8.51)	10.7*** (3.26)
TFP	0.04*** (3.75)	0.06*** (7.23)	0.14*** (4.83)	0.07*** (5.50)	0.02 (1.42)	-0.19 (-0.74)	0.42 (1.24)
LDIST	-1.58*** (-28.52)	-0.37*** (-12.37)	-1.18*** (-8.98)	-1.33*** (-21.61)	2.06*** (13.60)	-1.84*** (-4.77)	-0.73** (-2.02)
contig	13.05*** (45.50)	9.02*** (95.72)	3.40*** (7.71)	9.77*** (42.93)	10.85*** (32.89)	2.27** (2.27)	2.75*** (3.35)
colony	-2.12*** (-11.27)	1.73*** (15.64)	-3.60*** (-6.65)	5.20*** (19.26)	-4.55*** (-10.92)	11.73*** (10.69)	5.42*** (7.54)
comlang	1.41*** (13.87)	0.15 (1.50)	-	1.93*** (17.56)	6.34*** (27.28)	1.39** (2.51)	1.88*** (4.19)
FTA	3.43*** (12.10)	1.01*** (15.68)	0.04 (0.10)	0.16 (0.85)	10.13*** (25.84)	-2.68** (-2.23)	-0.80 (-0.83)
Country Dummy	Yes.	Yes.	Yes.	Yes.	Yes.	Yes.	Yes.
Industry Dummy	Yes.	Yes.	Yes.	Yes.	Yes.	Yes.	Yes.
Time Dummy	Yes.	Yes.	Yes.	Yes.	Yes.	Yes.	Yes.
Observations	33,716	106,543	7,337	41,526	22,981	2,229	5,760
F value	245.76***	543.68***	43.68***	210.41***	160.61***	26.59***	38.49***
$\overline{R}^2$	0.29	0.28	0.23	0.23	0.29	0.36	0.27

Note: The numbers in the parenthesis denote the t-statistics. ***, **, and * represent the levels of 1%, 5%, 10%, respectively.

The FTA dummy turned out to have a positive effect on all regional groups except Africa, which implies that the trade diversion effect is bigger than the trade creation effect in case of African FTAs.

3. Estimation by Sectoral Groups

Table 4 shows that the results are consistent with the predictions in case of the statistically significant parameters, when we classify the sectoral groups into agriculture, natural resource intensive (fishery, forestry, and mining), and manufacturing industries.

In case of agriculture, all variables turned out to be significant and consistent with the predictions except skilled labor (*SKLAB*) and total factor productivity (*TFP*). The estimates for the production factors including unskilled labor (*UNSKLAB*), skilled labor (*SKLAB*), and capital (*CAPITAL)* as well as total factor productivity (*TFP*) turned out to be insignificant for the natural resource intensive sector. It is partly because this sector is more dependent on resources such as land. In case of the manufacturing sector, all parameters except total factor productivity turned out to be significant.

Estimation results for the three sectors indicate the individual characteristics of each sector. If we disaggregate the sectoral groups into more than three sectors, it can reveal the more detailed information on the industrial characteristics. It is notable that the *TFP* parameter turns out to be statistically insignificant, partly because this paper does not use the sectoral *TFP* data due to the data constraints.

Table 4. Estimation Results for Individual Sectors

Variables	Agriculture	Natural Resource Intensive Sector	Manufacturing
UNSKLAB	1.56*** (2.83)	-0.29 (-0.24)	8.08*** (23.11)
SKLAB	2.69 (1.31)	1.43 (0.39)	8.27*** (13.00)
CAPITAL	2.27*** (4.76)	-1.39 (-1.33)	7.99*** (23.75)
TFP	-0.007 (-0.67)	0.03 (1.42)	-0.003 (-0.84)
LDIST	-0.47*** (-10.04)	-0.63*** (-6.00)	-0.85*** (-35.28)
contig	9.71*** (65.32)	10.53*** (30.54)	6.39*** (80.39)
colony	0.48*** (2.82)	0.70* (1.77)	0.75*** (8.57)
comlang	2.07*** (17.48)	1.56*** (5.60)	2.38*** (42.99)
FTA	1.40*** (12.01)	1.12*** (4.05)	0.42*** (7.70)
Country Dummy	Yes.	Yes.	Yes.
Industry Dummy	Yes.	Yes.	Yes.
Time Dummy	Yes.	Yes.	Yes.
Observations	71,872	18,077	129,836
F value	270.90***	87.67***	430.96***
$\bar{R}^2$	0.25	0.27	0.22

Note: The numbers in the parenthesis denote the t-statistics. ***, **, and * represent the levels of 1%, 5%, 10%, respectively.

4. Relative Strength of Competing Models

This paper aims to test which of the three competing models explains the trade shares better. However, the magnitude of a parameter estimate as such is not a meaningful criterion to compare the relative strength of the competing models. It is because the independent variables related to each model are measured in the different units. Thus, this paper calculates the standardized coefficients which can be obtained by dividing a parameter estimate by the ratio of the sample standard deviation of the dependent variable to the sample standard deviation of the independent variable.

Table 5 reveals the standardized coefficients and relative strength compared to total factor productivity (*TFP*). The relative strength of the Heckscher-Ohlin model turns out to be the most potent, followed by the gravity model, and the Ricardian model. The sum of one standard deviation change in the three Heckscher-Ohlin variables turned out to be about 9.69 times more potent than the Ricardian variable, total factor productivity (*TFP*). On the other hand, the sum of one standard deviation change in the gravity parameters turned out to be about 5.06 times more potent than the Ricardian variable, total factor productivity (*TFP*).

Table 5. Relative Strength of Competing Models Compared to the Ricardian Model

Variable	Standardized Coefficient	Relative Strength compared to *TFP*
UNSKLAB	0.29106	3.66
SKLAB	0.14204	1.79
CAPITAL	0.33700	4.24
TFP	0.07945	1.00
LDIST	0.32565	4.10
contig	0.02989	0.38
colony	0.00719	0.09
comlang	0.01013	0.13
FTA	0.02898	0.36

Ⅳ. Conclusions

This paper tests which of the three competing trade models better explains the bilateral trade flows. For the empirical study, it derives a consolidated regression equation to estimate the sources of comparative advantage, setting up a consistent dataset on factor intensity, total factor productivity, and gravity variables.

The estimation results generally confirm the three models, but relative strength of the Heckscher-Ohlin model turns out to be the most potent, followed by the gravity model, and the Ricardian model. The estimation results also reveal that signs of the production factor parameters are positive in all significant results. That signifies that each country exports the commodity which intensively utilizes the relatively abundant production factor. The Ricardian model was also confirmed by the estimation results that signs of the total factor productivity turned out to be positive in all significant results. The gravity variables including the distance variable and dummies such as border, language, colony, and FTA explain the changes in trade share very well. They turned out to be significant in the level of 0.1~5% and have signs consistent with the predictions.

It is very interesting to see that an explanatory power of each competing model is different depending on the regional and sectoral groups. A sign of the capital turned out to be negative in case of regressions for the natural resource intensive sector, but they are not statistically significant. In case of the Ricardian model, this paper does not indicate that technological difference is statistically significant for sectoral groups. If we can estimate the industrial rather than the national total factor productivity in a future research, it will produce a more consistent result with respect to differences in the level of technology. Notably, the sign of the colony dummy for developed countries, other European countries, and Central America turned out to be different from the prediction. Interestingly, the sign of the FTA dummy for Africa turned out to be negative due to the trade diversion effect.

The empirical results provide some policy implications for the Korean economy. First, Korea should strengthen the various sources of comparative advantage because the competing trade models were confirmed by the estimation results. Specifically, Korea needs to set up an institutional framework to support the accumulation of human capital as well as physical capital, because skilled labor and capital turned out to be more important than unskilled labor.

Second, Korea needs to adjust itself to the changing world trade structure and homogenizing consumer demands. Furthermore, Korea needs to set up global FTA networks to make the best of its sources of comparative advantage. It is because the regional and sectoral results reveal that each source of comparative advantage has different relative strength depending on the regional and sectoral groups.

References

Anderson, James E. and Eric Van Baldwin. 2003. "Gravity with Gravitas: A Solution to the Border Puzzle." *American Economic Review*, Vo. 93, No. 1, pp. 170-205.

Baldwin, Robert E. 1971. "Determinants of the Commodity Structure of U.S. Trade." *American Economic Review*, Vol. 61, No. 1, pp. 126-146.

Bowen, Harry P., Edward E. Leamer, and Leo Sveikauskas. 1987. "Multicountry, Multifactor Tests of the Factor Abundance Theory." *American Economic Review*, Vol. 77, No. 5, pp. 791-809.

Caves, Douglas W, C. L. Christensen, and W. E. Diewert. 1982. "Multilateral Comparisons of Output, Input, and Productivity Using Superlative Index Numbers." *Economic Journal,* 92(365), pp. 73-86. (March)

Choi, Nakgyoon and Hongshik Lee. 2010. *Analysis of Comparative Advantage Patterns and Its Policy Implication*. Policy Analysis 10-01. Korea Institute for International Economic Policy.

Chor, D. 2010. "Unpacking Sources of Comparative Advantage: A Quantitative Approach." Singapore Management University.

Davis, D. and D. Weinstein. 2001. "An Account of Global Factor Trade." *American Economic Review*, Vol. 91, No. 5, pp. 1423-1453.

Dornbusch, R., S. Fischer and P. Samuelson. 1980. "Heckscher-Ohlin Trade Theory with a Continuum of Goods." *QJE*, Vol. 95, No. 2, pp. 203-224.

Eaton, Jonathan and Samuel Kortum. 2002. "Technology, Geography, and Trade." *Econometrica*, Vol. 70, No. 5, pp. 1741-1779.

Harrigan, James. 1997. "Technology, Factor Supplies, and International

Specialization: Estimating the Neoclassical Model." *American Economic Review*, pp. 475-493.

Krugman, P. 1980. "Scale Economies, Product Differentiation, and the Pattern of Trade." *American Economic Review*, Vol. 70(5), pp. 950-959.

Leamer, Edward E. 1980. "The Leontief Paradox, Reconsidered." *The Journal of Political Economy*, Vol. 88, No. 3, pp. 495-503.

______. 1984. *Sources of International Comparative Advantage - Theory and Evidence*. Cambridge, Massachusetts, London, England: The MIT Press.

MacDougal, G.D.A. 1951. "British and American Export: A Study Suggested by the Theory of Comparative Costs." *Economic Journal,* Vol. 61, pp. 697-724.

Morrow, Peter M. 2008. "East is East and West is West: A Ricardian-Heckscher-Ohlin Model of Comparative Advantage." Gerald R. Ford School of Public Policy, The University of Michigan, Discussion Paper No. 575.

Romalis, John. 2004. "Factor Proportion and the Commodity Structure of Trade." *American Economic Review*, Vol. 94(1), pp. 67-97.

Appendix

Table A1. Country List

Region	Country
Developed Countries (7)	Australia (AUS); Canada (CAN); Japan (JPN); New Zealand (NZL); Switzerland (CHE); Turkey (TUR); USA (USA)
EU (27)	Austria (AUT); Belgium (BEL); Bulgaria (BGR); Cyprus (CYP); Czech Rep. (CZE); Denmark (DNK); Estonia (EST); Finland (FIN); France (FRA); Germany (DEU); Greece (GRC); Hungary (HUN); Ireland (IRL); Italy (ITA); Latvia (LVA); Lithuania (LTU); Luxembourg (LUX); Malta (MLT); Netherlands (NLD); Poland (POL); Portugal (PRT); Romania (ROM); Slovakia (SVK); Slovenia (SVN); Spain (ESP); Sweden (SWE); United Kingdom (GBR)
Other Europe (3)	Albania (ALB); Croatia (HRV); Russian Federation (RUS)
Asia (11)	Rep. of Korea (KOR); China (CHN); China, Hong Kong SAR (HKG); India (IND); Indonesia (IDN); Malaysia (MYS); Philippines (PHL); Singapore (SGP); Sri Lanka (LKA); Thailand (THA); Viet Nam (VNM)
Central America (8)	Argentina (ARG); Brazil (BRA); Chile (CHL); Colombia (COL); Mexico (MEX); Peru (PER); Uruguay (URY); Venezuela (VEN)
Africa (3)	Botswana (BWA); Morocco (MAR); Zimbabwe (ZWE)
LDCs (6)	Bangladesh (BGD); Malawi (MWI); Mozambique (MOZ); United Rep. of Tanzania (TZA); Uganda (UGA); Zambia (ZMB)

Note: Country names followed by ISO codes in parentheses.

Table A2. Industry List

Sector	Industry
Agriculture (19)	paddy rice (PDR); wheat (WHT); cereal grains nec (GRO); vegetables, fruit, nuts (V_F); oil seeds (OSD); sugar cane, sugar beet (C_B); plant-based fibers (PFB); crops nec (OCR); bovine cattle, sheep and goats, horses(CTL); animal products nec (OAP); wool, silk-worm cocoons (WOL); bovine meat products (CMT); meat products nec (OMT); vegetable oils and fats (VOL); dairy products (MIL); processed rice (PCR); sugar (SGR); food products nec (OFD); beverages and tobacco products (B_T)
Manufacturing Sector (16)	textiles (TEX); wearing apparel (WAP); leather products (LEA); wood products (LUM); paper products, publishing (PPP); petroleum, coal products (P_C); chemical, rubber, plastic products (CRP); mineral products nec (NMM); ferrous metals (I_S); metals nec (NFM); metal products (FMP); motor vehicles and parts (MVH); transport equipment nec (OTN); electronic equipment (ELE); machinery and equipment nec (OME); manufactures nec (OMF)
Natural Resource Intensive Sector (6)	forestry (FRS); fishing (FSH); coal (COA); oil (OIL); gas (GAS); minerals (OMN)
Service Sector (1)	services (Svces)

Note: Industry names followed by GTAP sectoral codes in parentheses.

Table A3. Summary Statistics of Variables

VARIABLE	MEAN	STANDARD DEVIATION
UNSKLAB	0.432	0.155
SKLAB	0.099	0.073
CAPITAL	0.408	0.196
TFP	49.409	25.958
LDIST	8.330	1.124
contig	0.067	0.250
colony	0.043	0.203
Comlang	0.122	0.327
FTA	0.272	0.445

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Empirical Tests of Comparative Advantage: Factor Proportions, Technology, and Geography

Nakgyoon Choi

This paper derives a consolidated regression equation to estimate the sources of comparative advantage; integrating the Heckscher-Ohlin model, the Ricardian model, and the gravity model. It also aims to test which of the three competing models better explains the bilateral trade flows. For the empirical estimation, it sets up a consistent dataset for 65-countries and 42-industries in 1997, 2001, and 2004. The estimation results generally confirm the three competing models, but relative strength of the Heckscher-Ohlin model turns out to be the most potent, followed by the gravity model, and the Ricardian model. The results reveal that the signs of the estimates such as production factors and total factor productivity are positive in all significant results. In addition, the gravity variables including the distance variable and dummies such as borders, languages, colony, and FTA explain the changes in trade share very well. The explanatory power of the three competing models turned out to be different depending on sectoral and regional groups. A sign for the capital turned out to be negative in case of regressions for the natural resource intensive sector, but they are not statistically significant. In case of the Ricardian model, this paper does not indicate that technological difference is statistically significant for the sectoral groups. It is interesting to see that the sign of the colony dummy for developed countries, other European countries, and Central America turned out to be different from the prediction.

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