한국경제학보 제19권 제2호
The Korean Journal of Economics Vol. 19, No. 2(Autumn 2012)

A Research on the Modifications of the Factor Content of Trade Model with Data Reconstruction*

Yeon Joon Kim**

Abstracts

Some trade economists use the factor content of trade model to prove the Heckscher-Ohlin-Vanek (HOV) model. The current empirical methodology known as the factor content of trade model is amain stream especially for the supply-side determinants of trade. A research by Davis and Weinstein (2001) is a forerunner regarding the factor content of trade model with twisting and turning the original HOV model. This paper studies the modified factor content of trade model by using new and amended methodologies. This paper modifies the original HOV model and the pair-wise HOV model by using different methodologies. And, when we construct our database, we use the data from the OECD IO, the OECD STAN, and the ISDB. By overcoming previous errors when we construct data, we can get solid database. These are contributions of this paper. The Sign test, using the pair-wise HOV model and assuming that all countries have the same technology as Germany's technology, has the best result. And, we have the best Slope test's result when we use the original HOV model assuming that technologies are the same as the US' technology with data of the US and European countries. We get the best result of the Variance ratio test when we use the pair-wise HOV model with the US' technology. By twisting and turning the original HOV model and the pair-wise HOV model with data reconstruction, we get better results than previous researches regarding the factor content of trade model.

KRF Classification : B030800
Keywords : The Factor Content of Trade model, The HOV model, Supply Side, The pair-wise HOV model, Technology

---

* This paper is supported by Kyungsung University Research Grants in 2012. All errors are mine. I appreciate two anonymous referees on their helpful comments.

** Department of International Trade & Commerce, Kyungsung University, 309, Suyeong-ro (Daeyeon-dong), Nam-gu, Busan 608-736, Rep. of Korea, Office: +82-51-663-4425, e-mail: yeonjoonkim@ ks.ac.kr

Ⅰ. Introduction

After Leontieff's (1953) seminal study about the US' international trade, trade economists have been interested in testing the factor content of trade. Many trade economists use the "factor content" methodology with modifications of the model to test the factor content of trade.

The factor content methodology needs to calculate the amounts of capital and labor with two factors' model. And, the factor content methodology needs to calculate the amounts of other factors with multi-factor model. These factors are embodied in a country's trade. And then, they need to compare them to the theoretical predictions of the Heckscher-Ohlin (HO) model. This theoretical prediction is generalized by Vanek (1968). In the decades since Leontieff's work, this line of research has threaded through many twists and turns of the original HO model. It starts from Leontieff's spectacular failure in demonstrating that the US is a net exporter of capital services. And, it continues with a number of advances followed by more setbacks. Ultimately, it culminates in no less spectacular success. Within the "Ricardian" versus "the Heckhser-Ohlin" dichotomy in explaining trade, these previous findings add explanatory power to the former and foreshadowed what is to come. Finally, by amending the Heckscher-Ohlin-Vanek (HOV) model in various ways, Davis and Weinstein (2001) find that the amended model can largely account for the observed factor content of trade. The Ricardian model takes technological differences to be the main driving force of trade, while the Heckscher-Ohlin (HO) model explains trade with differences in the proportions of factor endowments across countries.

In this paper, we begin by deriving a theory of the factor content of trade. Then, we test the theory along the way that estimates the importance of the factor content of trade's methodology. We do this test by calculating a predicted factor content of trade based on the theory. And then, we compare it to the actual factor content of trade. When we derive the factor content of trade's methodology, this paper explains methodologies in calculating data from the raw data of the OECD. Actually, this process of calculating database is a very sensitive one. And it is also a very important work to prepare actual empirical test. Both in the theoretical and in the empirical sections, we follow a step-by-step procedure that helps us uncover the successive layers of the importance of supply in the factor content of trade model. In the empirical section, we begin by reproducing Davis and Weinstein's (2001) first set of results. And, this paper twists and turns the Davis and Weinstein's (2001) original test.

One of the contributions of this paper is that we construct our own database from the various sources such as the OECD, the WDI, and so on. Actually, it is not only an important to construct new equation in explaining the factor content of trade, but also it is important to calculate and construct a high quality database that this paper uses to test the model. This paper is valuable in comparing Davis and Weinstein's (2001) database with our newly constructed database. With this, we explain which database explains the factor content of trade better. Another contribution of this paper is that this paper makes an effort to construct the best model in explaining the factor content of trade model. Here, the best model means that we construct diversified and developed factor content of trade models that are different from the previous researches.

With our various factor content of trade's model, we explain which model explains better the factor content of trade's theory. Chapter II explains the methodologies and models. Chapter III explains test results. Chapter IV explains concluding remarks. Additionally, we add data appendix and this explains how this paper constructs a new and a modified data.

Ⅱ. Methodologies and Models

This paper derives the most basic version of the factor content of international trade in the Heckscher-Ohlin-Vanek (HOV) model. This derivation has an advantage that it retreads the first model in Davis and Weinstein (2001). Therefore, as the first step, we should be able to reproduce Davis and Weinstein's (2001) results. Further steps relax successive layers of hypothesis on some models' basic hypotheses. In order to control for the supply side, we stay within the most simplistic version of the factor proportions' theory. We use the standard Heckscher-Ohlin-Vanek (HOV) model in proving the factor content of trade's model. Consider the case in which there are N countries, n goods and m factors of production. Suppose that preferences are homo thetic and identical across countries. Different countries share identical technologies. The market structure is perfectly competitive and there are no trade costs. Furthermore, for the moment, we assume that there is only one cone of production and that countries' factor endowments are sufficiently close to each other to ensure factor price equalization.

It then follows that one country's consumption is proportional to the world's consumption. With the constancy of proportionality given by the country's share of the world's GDP, we denote it here by $s^c = I^c/I^W$, where I^c is country c's GDP and I^W is the GDP of the world. And, I^W can be calculated by $I^W = \sum I^c$. Writing the demand vectors of country c and of the world as D^{c} and D^{W}, respectively, it follows that $\mathrm{D}^{\mathrm{c}} = s^c \mathrm{D}^{\mathrm{W}}$. Because world's demand must be equal to world's supply in equilibrium, we also have that

$$\mathrm{D}^{c} = s^{c}\mathrm{Y}^{W}, \tag{1}$$

where Y^{W} is the vector of the world's output. Next let us write country c's net export vector as $\mathrm{T}^{c} = \mathrm{Y}^{c} - \mathrm{D}^{c}$. Note that row i of T^{C} is positive if the country is net exporter of good i and negative if it is a net importer of good i.

We pre-multiply this expression by the total factor input matrix of a "reference" country c', denoted by $\mathrm{B}^{c'}$. Most researches on the factor content of trade use a reference country, typically the US, due to data limitations until Davis and Weinstein's (2001) research. In our test, we use the US as a reference country to do the factor content of trade's test with hypothesis 1, 2, 5, and 8. Additionally, we use Germany as a reference country to do the test with hypothesis 6. Davis and Weinstein (2001) are the first trade economists who use each country's input-output tables to construct the matrix B^{c} for each country c. With the above procedures, we obtain the following expression: $\mathrm{B}^{c'}\mathrm{T}^{c} = \mathrm{B}^{c'}(\mathrm{Y}^{c} - \mathrm{D}^{c}) = \mathrm{B}^{c'}(\mathrm{Y}^{c} - s^{c}\mathrm{Y}^{W})$, which finally leads to our testing hypothesis,

$$\mathrm{B}^{c'}\mathrm{T}^{c} = \mathrm{V}^{c} - s^{c}\mathrm{V}^{W}. \tag{2}$$

Here, V^{c} is country c's vector of endowment and V^{W} is the world's vector of endowment. Endowment's vector of the world can be calculated as $\mathrm{V}^{W} = \sum_{c=1}^{n}\mathrm{V}^{c}$. Note that $\mathrm{B}^{c'}$ is an $m \times n$ matrix, while goods vectors (such as Y^{c}) are n-dimensional and endowment vectors (such as V^{c}) are m-dimensional. In equation (2), we make use of the fact that identical technologies and factor price equalization across countries imply $\mathrm{B}^{c'} = \mathrm{B}^{c}$ for any c, thus $\mathrm{B}^{c'}\mathrm{Y}^{c} = \mathrm{B}^{c}\mathrm{Y}^{c} = \mathrm{V}^{c}$.

Equation (2) is Davis and Weinstein's first trade specification.

Davis and Weinstein (2001)call this equation (2) as T1. It is their starting hypothesis, before they introduce series of modifications on the supply side. And it plays the same role here, except that our modifications happen in differentiating data calculation and different modification in the model. The left-hand side of equation (2) is the actual factor content of trade (namely, the measured factor content of trade), while the right-hand side is the factor content of trade that is the predicted (namely, the predicted factor content of trade) by the theory. It is based on the mismatch between a country's factor endowments and the world's factor endowments. For example, if country c is capital-abundant relative to the rest of the world, this is reflected on the right-hand side with a plus sign on the row for capital. Plus sign on the left-hand side (the country would need, according to the theory) means a net exporter of goods that utilize capital in a relatively intensive way. Those goods would produce plus signs in vector T^c. Because $B^{c'}$ would have relatively large numbers on the capital row for such goods, the end result is the desired one. Of course, that theory performs horribly and Davis and Weinstein (2001) need their series of modifications before they get the tests' results to perform according to the theory.

This paper does the Sign test, the Slope test, and the Variance ratio test to prove if this equation (2) explains the factor content of trade model well. These three tests are the tests that previous trade economists who study the factor content of trade model use. Davis and Weinstein (2001) also do these three tests in their paper.

Here, the Sign test means that we compare the sign of the left-hand side of the factor content of trade with the sign of the right-hand side of the factor content of trade. We call the left-hand side of the factor content of trade as the measured factor content of trade. We call the right-hand side of the factor content of trade as the predicted factor content of trade. If we find that both signs are the same, we count it one. If both signs are different with each other, then we do not count it. We also do this for the rest of the model to check the same sign of the factor content of trade model. When we find the perfect matching case that both the left-hand side of the factor content of trade and the right-hand side of the factor content of trade model have the same sign, then it is an ideal result of the Sign test. But, actually it is very hard to get ideal result that is unity for this Sign test.

The Slope test means that we run a regression with the measured factor content of trade and the predicted factor content of trade model. We put measured factor content of trade in the regression as a dependent variable and we put predicted factor content of trade in the regression as an independent variable. We run an ordinary least square (OLS) and find the coefficient of the regression. When we get one for this coefficient, the unity, we get a perfect derivation in the factor content of trade's model. So, the ideal result for this Slope test is one.

The Variance ratio test means that we construct the following equation (3). When we get one, the unity, for this calculation, we can say that we get an ideal model of the factor content of trade.

$$\frac{VAR^{predicted\ factor\ content\ of\ trade}}{VAR^{measured\ factor\ content\ of\ trade}} \tag{3}$$

In addition to use Davis and Weinstein's (2001) data, this paper uses a newly constructed data.

Additionally, this paper uses a modified pair-wise HOV model. Hakura (2001) uses the pair-wise HOV model in her paper. We derive a modified pair-wise HOV model like following equation (4).[1] Difference between the original pair-wise HOV model and the

1) $B^cT^c - B^mT^m = B^c(Y^c - D^c) - B^m(Y^m - D^m) = V^c - B^cD^c - V^m + B^mD^m = V^c$

modified pair-wise HOV model is the use of s^m in the equation.

$$B^c T^c - B^m T^m = V^c - V^m + (s^m - s^c) V^w \tag{4}$$

The original pair-wise HOV model can be derived like the following way.

$$\begin{aligned} & B^c T^c - s^{cm} B^m T^m = B^c(Y^c - D^c) - s^{cm} B^m (Y^m - D^m) \\ & = V^c - B^c D^c - s^{cm} V^m + s^{cm} B^m D^m = V^c - s^{cm} V^m - s^c V^w \\ & + s^m V^w = V^c - s^{cm} V^m + (s^m - s^c) V^w \end{aligned} \tag{5}$$

And, here s^{cm} can be calculated like following equation (6).

$$s^{cm} = s^c / s^m = \frac{\frac{GDP^c}{GDP^w}}{\frac{GDP^m}{GDP^w}} = \frac{GDP^c}{GDP^m} \tag{6}$$

This paper uses the original HOV model and the pair-wise HOV model. This paper uses different technical method and the same technical method inside of the HOV model.

In case of the same technology case, we use the US' technology or Germany's technology on behalf of the other countries' technology. This paper uses the data from Davis and Weinstein (2001). Also, this paper uses a newly constructed data that has more industries and more countries than Davis and Weinstein's (2001) data. This paper uses scientifically better methodologies than Davis and Weinstein's (2001) paper in constructing data with the OECD database. The reason why we use a new and a modified data and methodology is because Davis and Weinstein's (2001) research does not explains the

---

$- V^m - s^c V^m + s^m V^w = V^c - V^m + (s^m - s^c) V^w$

factor content of trade well. This paper also uses the Hicks neutral efficiency adjustment in the model. This paper also changes number of country's group such as eighteen countries, ten selected countries, and seven selected developed countries. With the above various and modified testing models, this paper does three tests (the Sign test, the Slope test, and the Variance ratio test) to show which modified models show the best results. Table 1 shows the summary of methodology and data that this paper uses.

【Table 1】 Summary of methodologies and data

Hypothesis	H1	H2	H3	H4	H5	H6	H7	H8
Basic model	The Original HOV model	The Pair-Wise HOV model	The Pair-Wise HOV model	The Pair-Wise HOV model	The Original HOV model	The Pair-Wise HOV model	The Original HOV model	The Original HOV model
Technology	Same (The US' tech. 'B')	Same (The US' tech. 'B')	Different	Same (The US' tech. 'B')	Different	Same (Germany's tech. 'B')	Different, The Hicks neutral efficiency adjustment	Same (The US' tech. 'B')
Data	D&W (2001), ten countries	New (WDI 2007), seven countries	D&W (2001), seven countries	D&W (2001), seven countries	New (WDI (2007)), eighteen countries	D&W (2001), seven countries	D&W (2001), eleven countries	New (WDI (2007)), eighteen countries
Other				Without s^{cm}				

Notes: 'H' means hypothesis. 'D&W (2001)' means Davis and Weinstein (2001). 'WDI (2007)' means World Development Indicators. 'tech.' means technology. 'Same' means same technology. 'Different' means different technology. 'B' means technology matrix.

Ⅲ. Test Results

This paper does the Sigh test, the Slope test, and the Variance ratio test under the eight hypotheses to find out the best model that explains the factor content of trade. With these tests, this research compares our results with Davis and Weinstein's (2001) results.

Hypothesis 1: First, we test the factor content of trade model with the US' and European data of 1985. We use the original HOV model. We present the test result of the factor content of trade in table 2. Under this hypothesis 1, we use Davis and Weinstein's (2001) data. This hypothesis uses the US' B. Again, B means technology matrix. We run a regression of the basic factor content of trade's model and see the result of the Slope test. If the Slope is close to one, that is unity, it is a better result that explains the factor content of trade. The result of this test shows that the slope is positive 0.089, which is the best result among eight hypotheses. And, their result is also better than Davis and Weinstein's (2001) result. This paper does a Sign test, counting the number of the same sign between the measured factor content of trade (MFCT) and the predicted factor content of trade (PFCT). The result of the Sign test (0.45) is less than one half, which suggests that the HOV theory fails. This hypothesis 1 does the Variance ratio test, $\frac{Var(MFCT)}{Var(PFCT)}$. The result of the Variance ratio test is 0.03, which is far from one.

Hypothesis 2: Hypothesis 2 uses the pair-wise HOV model. This hypothesis 2 assumes that all countries have the same technology. This paper uses seven countries: France, Germany, Italy, the Netherlands, the UK, Denmark, and the US. These countries are developed countries in the world. And, we interpret this as the North-North trade. The US'technology is used for all the other six countries. This means that all seven countries have the same technologies. To get equation (7), we use GDP data for the seven countries from the World Development Indicators (2007). We then test the following equation (7).

$$B^{USA}T^{c} - s^{cm}B^{USA}T^{m} = V^{c} - s^{cm}V^{m} \tag{7}$$

The results show like followings. The slope is positive 0.012, which is not a good result. If the slope is close to one, it is a better result. We also perform the Sign test, counting the number of the same sign between the measured relative factor content of trade (MRFCT) and the predicted relative factor content of trade (PRFCT).[2] The result of the Sign test (0.66) is more than one half which is a satisfactory result for the HOV theory. Result of the Variance ratio test is 0.099, the best result among eight hypotheses. And also this test's result of the Variance ratio test is better than Davis and Weinstein's (2001) result.

Hypothesis 3: Hypothesis 3 uses the pair-wise HOV model with different technology's hypothesis. The hypothesis that all countries have the same technology is not realistic. Therefore, this paper adopts the hypothesis that each country uses different technology. This is a main hypothesis of the Ricardian model. Hypothesis 3 uses seven developed countries: France, Germany, Italy, the Netherlands, the UK, Denmark, and the US. We can interpret that this is a North-North trade. And, testing equation is like following equation (8).

$$B^c T^c - s^{cm} B^m T^m = V^c - s^{cm} V^m + (B^c - B^m) D^c \qquad (8)$$

Here, c and m denote country c and country m, respectively. Test results show like followings. The Slope test's result is negative 0.0088 that is a bad result. The result of the Sign test (0.66) is more than one half which is a good result. This means the HOV theory does work. The result of the Variance ratio test is 0.018. The Sign

2) The original HOV model uses the measured factor content of trade (MFCT) and the predicted factor content of trade (PFCT). Instead, the pair-wise HOV model uses the measured relative factor content of trade (MRFCT) and the predicted relative factor content of trade (PRFCT).

test shows that the pair-wise HOV model effectively explains the factor content of trade model.

Hypothesis 4: Hypothesis 4 uses the pair-wise HOV model without using s^{cm}. Namely, with this hypothesis 4, we omit s^{cm} and compare it with the result of the other tests. The equation (9) is a new equation without s^{cm}. To explain effects in using s^{cm}, let us assume that there are only two countries in the world. Two countries are, for example, Japan and the US. Let's assume that two countries' consumption patterns are similar to each other. With the similar consumption pattern, those two countries have the similar size of GDP assuming that consumption is a powerful component in measuring one country's GDP. And, we know that $s^{cm} = s^c/s^m = \frac{\frac{GDP^c}{GDP^w}}{\frac{GDP^m}{GDP^w}}$. When we assume that country c and country m are similar in the size of economy, s^{cm} is the same as unity. This means that s^{cm} is equal to one, thus $\frac{GDP^c}{GDP^m} = 1$. Here, s^{cm} means differences in economic size. Many trade economists doubt the role of s^{cm} in the pair-wise HOV model. However, we could not find previous researches explaining the factor content of trade's model without using s^{cm}. It is hard to make similar in size between the two factor content of theories by using s^{cm}. That is the main reason why this hypothesis investigates the factor content of trade's model without using s^{cm}.

This hypothesis assumes that each country's technologies are the same. This hypothesis also assumes the factor price equalization is valid.

$$
\begin{aligned}
&B^c T^c - B^m T^m \\
&\quad = B^c (Y^c - D^c) - B^m (Y^m - D^m)
\end{aligned}
$$

$$= V^c - B^c D^c - V^m + B^m D^m$$

$$= V^c - V^m - s^c V^w + s^m V^w$$

$$= V^c - V^m + (s^m - s^c) V^w$$

$$B^c T^c - B^m T^m = V^c - V^m + (s^m - s^c) V^w \tag{9}$$

Test results of equation (9) are explained like followings. The Slope test's result is negative 0.012 that is a bad result. The result of the Sign test (0.83) is more than one half which is not only a good result but also the second best result obtained in this paper. And, we can interpret it with the results that the HOV theory works. The result of the Variance ratio test is 0.00016, which is a bad result.

Hypothesis 5: Hypothesis 5 uses a newly constructed data. With this data, we test the Original HOV model. This paper does the similar test to T1 in the Davis and Weinstein's (2001) paper. T1 is explained in the chapter II of this paper. Test's results show like followings. The Slope test's result is positive 0.005, which is a bad result. The result of the Sign test (0.48) is less than one half which is not a good result. This means that the HOV theory does not work. The result of the Variance ratio test is 0.0006, which is a bad result.

Hypothesis 6: Hypothesis 6 uses the pair-wise HOV model with the data of France, Germany, Italy, the Netherlands, the UK, and Denmark. This hypothesis is also meaningful in that it is a trade between the European countries. For this test, this hypothesis assumes that each country has the same technology. This hypothesis also assumes that the factor price equalization is hold. We use Germany's technology for the other five countries' technology. We use data from Davis and Weinstein (2001). Dependent variable is the measured relative factor content of trade (MRFCT) and independent variable is the predicted relative factor content of trade (PRFCT). Test results show like followings. The Slope test's result is 0.02, which is a bad result. The Sign test's result is unity, which is an ideal result. The Variance ratio test's result is 0.0015, which is a bad result.

Hypothesis 7: Hypothesis 7 uses the original HOV model. For this test, we use the Hicks neutral efficiency adjustment to test the factor content of trade model. And, we use the following equation (10) for this test. For this hypothesis, we use Davis and Weinstein's (2001) data.

$$\hat{B}^{\lambda} T^{c} = V^{cE} - s^{c} V^{wE} \tag{10}$$

This test is similar to T3 of Davis and Weinstein's (2001) methodology. Test results show like followings. Test result of the Slope test is a negative 0.002. This result is far from unity. This means that it is not a good result. The Sign test's result is 0.50 which explains the HOV model with 50%. The Variance ratio's test result is 0.08, which is a better result than Davis and Weinstein's (2001) result.

Hypothesis 8: We test the original HOV model using the US' technology like equation (11). Namely, this hypothesis assumes that all countries have the same technology as the US' technology.

$$B^{us} T^{c} = B^{us}(Y^{c} - D^{c}) = V^{c} - s^{c} V^{w} \tag{11}$$

For this test, we use a newly constructed data in testing the factor content of trade model. Test's results show like following. The Slope test's result is negative 0.002. And this is not a good result. Test result of the Sign test is 0.32. It is less than 0.5 which means that it is not a good result. Test result of the Variance ratio test is 0.0005. It is far from the unity.

Table 2 summarizes our test results by using the above eight hypotheses. Overall, the Slope test's result (0.089) using H1 methodology has the best result among eight hypotheses. This test's result is also better result than Davis and Weinstein's (2001) result. Test's result of the Sign test (1 = the unity) using H6 has the best result among eight hypotheses. This test's result is also a better result than Davis and Weinstein's (2001) result. And, it is an ideal result because we get a unity. Test result of the Variance ratio test (0.099) using H2 has the best result among eight hypotheses. This test's result is also better than Davis and Weinstein's (2001) result. Our efforts using H1, H2, and H6 can get better results than Davis and Weinstein's (2001) result by using and modifying of the original HOV model and the pair-wise HOV model with a new and a modified data and Davis and Weinstein's (2001) data.

【Table 2】 Test Results

	DW	H1	H2	H3	H4	H5	H6	H7	H8
Slope Test	-0.05	0.089	0.012	-0.008	-0.01	0.005	0.02	-0.05	-0.002
Standard error	0.02	0.035	0.099	0.043	0.001	0.003	0.011	0.02	0.005
R^2	0.31	0.19	0.0015	0.004	0.887	0.034	0.26	0.31	0.01
Sign Test	0.5	0.45	0.66	0.66	0.83	0.48	1	0.50	0.32
Variance Ratio Test	0.07	0.03	*0.099*	0.018	0.0001	*0.0006*	0.0015	0.08	*0.0005*
Observation	22	20	14	14	14	36	14	22	36
Dependent variable	MFCT	MFCT	MRFCT	MRFCT	MRFCT	MFCT	MRFCT	MFCT	MFCT

Notes: 'MFCT' means the measured factor content of trade (by using the original HOV model), 'MRFCT' means the marginal relative factor content of trade (by using the pair-wise HOV model).

Ⅳ. Concluding Remarks

Some trade economists use the factor content of trade's model to prove the Heckscher-Ohlin-Vanek (HOV) model. The current empirical methodology known as the factor content of trade's model is the main stream especially for the supply-side determinants of trade. A research by Davis and Weinstein (2001) is a forerunner regarding the factor content of trade model with twisting and turning the original Heckscher-Ohlin-Vanek model.

This paper studies the modified factor content of trade model using new and modified methodologies in constructing our database from the OECD IO, the OECD STAN, and ISDB. Actually, when we test the factor content of trade, it is crucial how to construct data without error. We choose to construct our own dataset, for two reasons. First, sometime has elapsed since Davis and Weinstein's (2001) paper and we can now make calculations for 1995 instead of 1985. Second, and most importantly, the newer datasets provide almost double the number of countries, eighteen, instead of ten in the Davis and Weinstein's (2001) paper. This is one of the contributions of this paper.

This paper also modifies the original HOV model like followings. This paper uses the pair-wise HOV model. This model does not use s^{cm} in the pair-wise HOV model which is a H4 in this paper. This paper uses the same and different countries' technology. In our test, we use the US as a reference country to do the factor content of trade's test with hypothesis 1, 2, 5, and 8. Additionally, we use Germany as a reference country to do the test with hypothesis 6. This paper uses the Hicks-neutral efficiency assumption which is a H7 in this paper. With these efforts in modifying the original HOV model, and by amending previous errors when we construct database, we can get better results than previous methodology in proving the HOV model. This is one of the contributions of this paper.

This paper finds out the best model for each test. Here, each test means the Slope test, the Sign test, and the Variance ratio test. The Slope test means that we run a regression with the measured factor content of trade and the predicted factor content of trade model. The Sign test means that we compare the sign of the left-hand side of the factor content of trade with the sign of the right-hand side of the factor content of trade. The Variance ratio test means that we calculate the following equation, $\frac{VAR^{predicted\ factor\ content\ of\ trade}}{VAR^{measured\ factor\ content\ of\ trade}}$. When we get one for each of the tests, we interpret that we get an ideal model of the factor content of trade model.

Overall, the Slope test's result (0.089) using H1 methodology has the best result among eight hypotheses. This test's result is also a better result than Davis and Weinstein's (2001) result. Test result of the Sign test (1) using H6 has the best result among eight hypotheses. This test's result is also a better result than Davis and Weinstein's (2001) result. And, it is an ideal result because we get a unity. Test result of the Variance ratio test (0.099) using H2 has the best result among eight hypotheses. This test's result is also a better than Davis and Weinstein's (2001) result. Our efforts using H1, H2, and H6 can get better results than Davis and Weinstein's (2001) result by using and modifying of the original HOV model and the pair-wise HOV model with a new and a modified data and Davis and Weinstein's (2001) data.

Currently, the factor content of trade's model uses three tests (the Slope test, the Sign test, and the Variance ratio test) in proving the theory. However, these tests are used for a long time and alternative tests for these tests do not appear yet. So, we need a new test's methodology other than the three tests. I would like to postpone this research to my next research's topic.

Received: August 31, 2012. Revised: October 20, 2012. Accepted: October 24, 2012.

◈ *References* ◈

Barroso, J. M. (2007), *Hands across the Ocean*, The International Herald Tribune, Wednesday April 25.

Bowen, H. P., E. E. Leamer and L. Svikauskas (1987), "Multicountry, Multifactor Tests of the Factor Abundance Theory," *American Economic Review*, Vol. 77, pp. 791-809.

Davis, D. R. and D. E. Weinstein (2001), "An Account of Global Factor Trade," *American Economic Review*, Vol. 91, pp. 1423-1453.

Feenstra, R. C. (2003), *Advanced International Trade*, Princeton University Press.

Hakura, D. (2001), "Why the HOV Fail? The Role of Technological Differences within the EC," *Journal of International Economics*, Vol. 54, pp. 361-382.

Leamer, E. E. (1980), "The Leontief Paradox, Reconsidered," *Journal of Political Economy*, Vol. 88, pp. 495-503.

Leontieff, W. W. (1953), "Domestic Production and Foreign Trade: The American Capital Position Re-Examined," *Proceedings of the American Philosophical Society*, Vol. 97, pp. 332-349.

OECD (2002), "The OECD Input-Output (IO) Database, the International Sectoral Data Base (ISDB), and the OECD Structural Analysis (STAN) Data Base," OECD Economic and Statistic Division.

Penn World Table 6.2, University of Pennsylvania.

Schott, P. K. (2003), "One Size Fits All? Heckscher - Ohlin Specialization in Global Production," *American Economic Review*, Vol. 93, pp. 686-708.

Trefler, D. (1995), "The Case of the Missing Trade and Other Mysteries," *American Economic Review*, Vol. 85, pp. 1029-1046.

Vanek, J. (1968), "The Factor Proportions Theory: The N-Factor Case," *Kyklos*, Vol. 21, pp. 749-756.

World Development Indicators, World Bank, 2007.

Data Appendix

We use data from a variety of sources for our data construction. Data on capital and labor stocks for the manufacturing sector comes from the OECD Structural Analysis (STAN) Industrial Database. We also use the International Sectoral Database (ISDB) for this research regarding Davis and Weinstein's (2001) data. The OECD Input – Output database provides input-output tables, trade, production, and consumption data. We use manufacturing labor data from the OECD Structural Analysis (STAN) and the Number Engaged (NE). For non-manufacturing sectors, we use the International Sectoral Database (ISDB) and Total Employment (ET). We use production data from the column of the Gross Output in the OECD Input-Output table. The OECD Input-Output database provides information on input flows between all industry pairs. The OECD STAN has the following information by country: year, industry, production, labor, and investment. Modified data uses eighteen countries.[3)]

Two countries are presented in the IO but not in the STAN: Brazil and China. And eleven countries are in the STAN but not in the IO: Austria, Belgium, Iceland, Ireland, Luxembourg, Mexico, New Zealand, Portugal, Slovak Republic, Sweden, and Switzerland. The data in the IO covers 41 industries, listed in table A. Even though the STAN has somewhat more disaggregated industries, for consistency, we define industries as in the IO. This paper uses 41 industries which is more than the industries that Davis and Weinstein (2001) use in their paper.

---

3) Here, eighteen countries are like followings: Australia, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, Japan, Korea, the Netherlands, Norway, Poland, Spain, the United Kingdom, and the US.

【Table A】 List of Industries

OECD IO Industry	Description	ISIC Rev.3
1	Agriculture, hunting, forestry and fishing	01-05
2	Mining and quarrying	10-14
3	Food products, beverages and tobacco	15-16
4	Textiles, textile products, leather and footwear	17-19
5	Wood and products of wood and cork	20
6	Pulp, paper, paper products, printing and publishing	21-22
7	Coke, refined petroleum products and nuclear fuel	23
8	Chemicals excluding pharmaceuticals	24ex2423
9	Pharmaceuticals	2423
10	Rubber and plastics products	25
11	Other non-metallic mineral products	26
12	Iron and steel	271, 2731
13	Non-ferrous metals	272, 2732
14	Fabricated metal products, except machinery and equipment	28
15	Machinery and equipment, n. e. c.	29
16	Office, accounting and computing machinery	30
17	Electrical machinery and apparatus, n. e. c.	31
18	Radio, television and communication equipment	32
19	Medical, precision and optical instruments	33
20	Motor vehicles, trailers and semi-trailers	34
21	Building and repairing of ships and boats	351
22	Aircraft and spacecraft	353
23	Railroad equipment and transport equipment n. e. c.	352, 359
24	Manufacturing n. e. c.; recycling	36-37
25	Electricity, gas and water supply	40-41
26	Construction	45
27	Wholesale and retail trade; repairs	50-52
28	Hotels and restaurants	55
29	Transport and storage	60-63
30	Post and telecommunications	64
31	Finance, insurance	65-67
32	Real estate activities	70
33	Renting of machinery and equipment	71
34	Computer and related activities	72
35	Research and development	73
36	Other business activities	74
37	Public admin. and defense; compulsory social security	75
38	Education	80
39	Health and social work	85
40	Other community, social and personal services	90-93
41	Private households with employed persons and extra territorial organizations and bodies	95-99

Notes: 'IO' means the Input-Output. 'ISIC Rev.3'means International Standard Industrial Classification Revision 3.

Note that the ultimate source of the data is not the OECD itself. But the national accounts of the source countries are supplemented by questionnaires drawn up by the OECD. And the OECD countries respond them. Lately, a great part of the OECD countries use the United Nations' Standard for the Systems of National Accounts (SNA). And this SNA was published in 1993, so we call this SNA93. However, SNA93 has some inconsistencies. For example, different countries have different industry's definitions. They also differ in the years in which the data are reported, and so on. One important reason in using the OECD data is that the OECD's statistical group has worked towards evening out some of these inconsistencies. We detail below how we deal with data problems that remain.

We need to construct net output (Y^c), net demand (D^c), and trade (T^c). Also, we need to construct the total factor requirements matrix (B^c) and the factor endowment vector (V^c). We now explain the successive steps to construct these data for eighteen principal countries. We also list all data problems and issues. And we also list how these problems and issues are addressed. We follow many of the procedures in Davis and Weinstein (2001), while in some instances taking a different approach. One obvious choice would have been to simply use the data that Davis and Weinstein (2001) construct. We choose to construct our own dataset, for two reasons. First, sometime has elapsed since Davis and Weinstein's (2001) paper and we can now make calculations for 1995, instead of 1985. Second, and most importantly, the newer datasets provide almost double the number of countries 18 instead of 10[4] in the Davis and Weinstein's (2001) paper. They are also better suited for this study in several ways that we indicate below.

In order to present the detailed mechanics of data set construction

4) Ten countries are like followings: Australia, Canada, Denmark, France, Germany, Italy, Japan, the Netherlands, the UK, and the US.

that we construct here in this paper, it proves useful to work with a simplified example, in which there are six industries. Table B shows simplified format of the Input-Output data. Under such an example, the data from the IO tables for country c would look as follows (superscript c omitted for convenience).

【Table B】 Format of the Input-Output data

	Ind. 1	Ind. 2	Ind. 3	Ind. 4	Ind. 5	Ind. 6	D	E	M
Ind. 1	I_{11}	I_{12}	I_{13}	I_{14}	I_{15}	I_{16}	D_1	E_1	M_1
Ind. 2	I_{21}	I_{22}	I_{23}	I_{24}	I_{25}	I_{26}	D_2	E_2	M_2
Ind. 3	I_{31}	I_{32}	I_{33}	I_{34}	I_{35}	I_{36}	D_3	E_3	M_3
Ind. 4	I_{41}	I_{42}	I_{43}	I_{44}	I_{45}	I_{46}	D_4	E_4	M_4
Ind. 5	I_{51}	I_{52}	I_{53}	I_{54}	I_{55}	I_{56}	D_5	E_5	M_5
Ind. 6	I_{61}	I_{62}	I_{63}	I_{64}	I_{65}	I_{66}	D_6	E_6	M_6
Tax	TI_1	TI_2	TI_3	TI_4	TI_5	TI_6			
VA	VA_1	VA_2	VA_3	VA_4	VA_5	VA_6			
X	X_1	X_2	X_3	X_4	X_5	X_6			

Notes: 'Ind.' means industry. In this dataset, 'I_{ij}' denotes how much output of industry i is used as an input in industry j; 'TI_i' represents taxes on intermediate inputs for industry i; 'VA_i' is the value added in industry i; 'X_i' is total (gross) output in industry i; and 'D_i,' 'E_i,' and 'M_i' are final demand, exports and imports for industry i, respectively.

Note that the following two restrictions are applied here,

$$X_i^c = \sum_k I_{ki}^c + TI_i^c + VA_i^c, \text{ and} \quad \text{(A1)}$$

$$X_i^c = \sum_j I_{ij}^c + D_i^c + E_i^c - M_i^c. \quad \text{(A2)}$$

Equation (A1) is true by the definition of value-added. Equation (A2) makes explicit all possible uses of gross output (as an intermediate for all the other industries, as domestic demand, or as net exports).

As a preliminary step, we construct a matrix of intermediate input coefficients. We denote A^c, whose elements are ratios between each input usage and industry output. That is, the element a_{ij}^c of the matrix is given by equation (A3).

$$a_{ij}^{c} = \frac{I_{ij}^{c}}{X_{j}^{c}} \tag{A3}$$

For some countries and industries, the values reported in the IO are all zero, that is $I_{ij}^{c} = 0$ for a whole row i and the corresponding column i. Typically, this is due to the country aggregating two industries together, and reporting them under one single industry. For example, Canada includes all of industry 13 (Non-ferrous metals) in industry 12 (Iron and steel). And consequently all data in row 13 and column 13 are reported as zero. Table C shows data format with aggregate industries.

【Table C】 Data Format with Aggregate Industries

	Ind. 1	Ind. 2	Ind. 3	Ind. 4	Ind. 5	Ind. 6
Ind. 1	I_{11}	$I_{12}^{*}+I_{13}^{*}$	0	0	$I_{14}^{*}+I_{15}^{*}+I_{16}^{*}+$	0
Ind. 2	$I_{21}^{*}+$ I_{31}^{*}	$I_{22}^{*}+I_{23}^{*}+$ $I_{32}^{*}+I_{33}^{*}$	0	0	$I_{24}^{*}+I_{25}^{*}+I_{26}^{*}+$ $I_{34}^{*}+I_{35}^{*}+I_{36}^{*}$	0
Ind. 3	0	0	0	0	0	0
Ind. 4	0	0	0	0	0	0
Ind. 5	$I_{51}^{*}+$ $I_{41}^{*}+$ I_{61}^{*}	$I_{42}^{*}+I_{43}^{*}+$ $I_{52}^{*}+I_{53}^{*}+$ $I_{62}^{*}+I_{63}^{*}$	0	0	$I_{44}^{*}+I_{45}^{*}+I_{46}^{*}+$ $I_{54}^{*}+I_{55}^{*}+I_{56}^{*}+$ $I_{64}^{*}+I_{65}^{*}+I_{66}^{*}$	0
Ind. 6	0	0	0	0	0	0

Continuing with our example above, suppose that industry 3 is aggregated with industry 2 (and the whole is reported under industry 2). And industries 4, 5, and 6 are all reported under industry 5. The actually reported data can be obtained from the "true" data in table 3 in the following way. We add column 3 to column 2. Then we add row 3 to row 2. Then we add columns 4 and 6 to column 5. And, finally, we add rows 4 and 6 to row 5. For the input-output portion of the data, we have the table C.

In one case, we represent with arrows the direction in which the variables are summed. Here, any variables with stars (*) represent the real "latent" data that would obtain if all industries are in fact reported independently. These are of course not known, but are reported as aggregates. Note that the only without star (*) variable in the table C is I_{11}^{c}, which stands for the sub-matrix of all non-problematic entries. Thus, for example, the actual reported element 21 in the data matrix is $I_{21}^{c} = I_{21}^{c^*} + I_{31}^{c^*}$ where variables not starred denote actual data. Dividing this expression we obtain

$$1 = \frac{I_{21}^{c^*}}{I_{21}^{c}} + \frac{I_{31}^{c^*}}{I_{21}^{c}} . \qquad \text{(A4)}$$

Note that the version of the last equation for a country c' that does disaggregate industries 2 and 3 would be

$$1 = \frac{I_{21}^{c'}}{I_{21}^{c'} + I_{31}^{c'}} + \frac{I_{31}^{c'}}{I_{21}^{c'} + I_{31}^{c'}} . \qquad \text{(A5)}$$

We make use of this fact to calculate the average proportions of industry 2 and industry 3 that enter in industry 1. And, we estimate $I_{21}^{c^*}$ and $I_{31}^{c^*}$ as follows:

$$\tilde{I}_{21}^{c} = Avg\left[\frac{I_{21}^{c'}}{I_{21}^{c'} + I_{31}^{c'}}\right] I_{21}^{c} ,$$

$$\tilde{I}_{31}^{c} = Avg\left[\frac{I_{31}^{c'}}{I_{21}^{c'} + I_{31}^{c'}}\right] I_{21}^{c} . \qquad \text{(A6)}$$

In equation (A6), the average is performed over all countries c' that report industries 2 and 3 independently, and for which $I_{21}^{c'}$ and $I_{31}^{c'}$ are not both zero. Note that by construction $Avg[I_{21}^{c'}/(I_{21}^{c'}+I_{31}^{c'})]+Avg[I_{31}^{c'}/(I_{21}^{c'}+I_{31}^{c'})]=1$. Equation (A6) takes care of elements (21) and (31) of the data matrix above. All other zero elements of columns 2, 3, 4 and 6 and of rows 2, 3, 4 and 6 are estimated in an analogous fashion. To give just one more example, element (43) is given by:

$$\tilde{I}_{43}^{c} = Avg\left[\frac{I_{43}^{c'}}{I_{42}^{c'}+I_{43}^{c'}+I_{52}^{c'}+I_{53}^{c'}+I_{62}^{c'}+I_{63}^{c'}}\right] I_{52}^{c}\,. \tag{A7}$$

In sum, the strategy isto split aggregated measures, such as the one within the larger rectangle, into its individual components, using averages from other countries that have no corresponding problems. Note that from equation (A7) and it's analogous that we have $\tilde{I}_{42}^{c}+\tilde{I}_{43}^{c}+\tilde{I}_{52}^{c}+\tilde{I}_{53}^{c}+\tilde{I}_{62}^{c}+\tilde{I}_{63}^{c}=I_{52}^{c}$.

At the end of this procedure, we have filled out the data matrix. This methodology in constructing the data is a unique method that this paper is different from Davis and Weinstein's (2001) paper in constructing the data. Davis and Weinstein (2001) use other countries' average in filling out the zero or blanks in the raw data. Namely, they use equation (A8) in calculating the data.

$$\tilde{a}_{21}^{c,\,Davis\text{ and }Weinstein} = Avg\left[\frac{I_{21}^{c'}}{X_{1}^{c'}}\right] \tag{A8}$$

However, this paper calculate, for example for element "21",

$$\tilde{a}_{21}^{c,\,New} = \left[Avg\left[\frac{I_{21}^{c'}}{I_{21}^{c'}+I_{31}^{c'}}\right]\right]\frac{I_{21}^{c}}{X_{1}^{c}}\,. \tag{A9}$$

Then, it is a straightforward matter to calculate matrix $\mathbf{A}^c$ with the aid of equation (A5). The country and sectors with zero data are: Australia (18, 33, 35), Canada (9, 13, 19, 33, 35, 41), Denmark (22), Finland (9, 22, 33, 34, 35, 41), Germany (9, 13, 22, 23), Greece (9, 13, 22, 23), Hungary (9, 13, 21, 22, 41), Italy (13, 33), the Netherlands (9,13), Norway (41), Poland (9, 13, 22, 23, 41), Spain (13). In one case (Canada, sector 19), the sector is reported in two different sectors (18 and 24). In this case, we use a procedure similar to the one above, but averaging between sectors 18 and 24.

For production data, IO also provides the vector of gross output $\mathbf{X}^c$ for each country c. We are the most interested in the vector of net output, used here to mean the output of each goods tripped from its use as an intermediate. It is defined as

$$\mathbf{Y}^c = (\mathbf{I} - \mathbf{A}^c)\mathbf{X}^c, \qquad \text{(A10)}$$

where $\mathbf{I}$ is the identity matrix. Note that $Y_i^c = X_i^c - \sum_j a_{ij}^c X_j^c = X_i^c - \sum_j I_{ij}^c$. Here, $\mathbf{Y}^c$ is called the net output. The vector of final demand $\mathbf{D}^c$, excluding demand of intermediates, is calculated using summation of Household Final Consumption (HHFC), consumption by Non-Profit Institutions, Serving Households (NPISH), General Government Final Consumption (GGFC), Gross Fixed Capital Formation (GFCF), Changes in Inventories, and Valuables. When the IO table for country c collapses sector j into sector k, we construct the final demand directly from the output data for both sectors.

Note that if there are no data problems, then the second data restriction in equation and our comments following equation imply that $\mathbf{Y}^c = \mathbf{D}^c + (\mathbf{E}^c - \mathbf{M}^c)$. Investment's data for each country and sector is taken from the STAN (Gross Fixed Capital Formation, GFCF). For each country, data is collected beginning ten years prior to their IO table, including the year of the IO table, for a total of eleven years. All the data is deflated to 1995 with the use of the volume index series (GFCFK) also provided by the STAN.

Note that depending on each country's methodology, the volume indices may not be additive. Therefore, for sectors that are reported at a more disaggregated level in the STAN than we end up using, we deflate all series before we aggregate them. Finally the data is converted to the US dollars. We then use the perpetual inventory method to construct a stock of capital. Each country and industry uses the same year as the IO table, in 1995 the US dollar. We do this with the equation (A11).

$$K_t = I_t + (1-\delta)K_{t-1} \tag{A11}$$

Here, K_t is the capital stock, I_t is the investment series (GFCF), t is the year, and δ is the rate of depreciation of the capital stock, which we take to be 0.133 (the same value that Davis and Weinstein (2001) use). Labor data is also taken from the STAN (variable EMPN). We construct matrix $\mathbf{F}^c$, whose element f^c_{kl} is the amount of direct factor k (capital or labor) input in industry l for country c.

It is now straightforward to construct the remaining pieces. The matrix of total (direct plus indirect) factor input requirements is defined as equation (A12).

$$\mathbf{B}^c = \mathbf{F}^c(\mathbf{I}-\mathbf{A}^c)^{-1} \tag{A12}$$

The best way to interpret equation (A12) is to post-multiply it by $(\mathbf{I}-\mathbf{A}^c)$, then to write out element ki and rearrange to obtain: $b^c_{ki} = f^c_{ki} + \sum_j b^c_{kj} a^c_{ji}$, where b^c_{ki} is element (ki) of matrix $\mathbf{B}^c$, that is, the total input of factor k into industry i. It is given by the direct factor input (f^c_{ki}) plus the sum for each industry j of the indirect factor input ($b_{kj}^c a_{ji}^c$), where the latter, in turn, takes into account all indirect factor inputs in industry j. We would now like to construct the vector of factor endowments for country c, denoted by $\mathbf{V}^c$ and defined as the sum of either the capital or labor used in all industries.

데이터 재구성과 모델 변경을 통한 Factor Content of Trade 모델에 관한 연구*

김 연 준**

논문초록

국제무역학자들은 헥셔-오린-바넥 모델을 증명하는데 Factor Content of Trade 모형을 사용한다. Factor Content of Trade 모형을 통한 실증분석 방법론은 무역의 공급 측 결정요인의 연구에 있어서 주류이다. Davis와 Weinstein의 2001년 연구는 Factor Content of Trade 모형 연구에 있어서 선구자적 연구이며 이들의 연구는 원래의 헥셔-오린-바넥 모델을 몇 가지 방법론을 이용해 변경시켜 분석한다. 본 연구는 OECD IO와 OECD STAN과 ISDB 등을 이용해서 새로운 방법론으로 본 연구에서 구하고자 하는 새로운 데이터를 계산하고 기존 전통적 HOV 모델과 the pair-wise HOV 모델을 변경시켜 Sign 테스트와 Slope 테스트와 Variance ratio 테스트를 시행하여 Davis와Weinstein(2001)의 연구를 포함해 기존 연구 보다 더 좋은 결론을 얻고자 함이 목적이다. 테스트 분석 결과 모든 국가가 독일과 동일한 기술력을 가진다고 가정하고 일곱 국가를 이용하여 the pair-wise HOV모델을 사용할 경우 Sign 테스트에서 가장 좋은 결과(1)를 얻었다. 이는 물론 Davis와 Weinstein(2001)의 연구 보다 좋은 결론이다. 또한 열 개의 국가를 이용하여 모든 국가가 미국과 동일한 기술력을 가진다고 가정하고 전통적 HOV 모델을 사용할 경우 Slope 테스트에서 가장 좋은 결과(0.089)를 얻었다. 모든 국가가 미국과 동일한 기술력을 가진다고 가정하고 새로운 데이터를 사용하여 the pair-wise HOV 모델을 분석한 경우 Variance ratio 테스트에서 가장 좋은 결론(0.099)을 얻었다. 본 연구 결과 새로운 데이터와 기존 Factor Content of Trade 모델의 가정들을 변형하여 테스트 함으로 기존 연구보다 더 좋은 결과를 얻을 수 있다는 결론을 도출하였다.

주제분류 : B030800
핵심 주제어 : 팩터콘텐트 이론, 공급측 요인, 헥셔-오린-바넥 모형, 페어와이즈 헥셔-오린-바넥 모형

---

* 이 논문은 2012학년도 경성대학교 학술연구비지원에 의하여 연구되었음.
** 경성대학교 국제무역통상학과 조교수, e-mail: yeonjoonkim@ks.ac.kr