# Validity of Heckscher-Ohlin-Vanek Hypothesis – A Complete and Partial Test Approach

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## Abstract

The paper uses partial and complete tests to confirm the validity of the Heckscher-Ohlin-Vanek hypothesis (H-O-V). H-O-V relates factor abundance and scarcity to the factor content of net trade. Partial test is performed using India's industry level data from the year 1989-2008. The results reveal that India is abundant in unskilled labour and capital and it is scarce in skilled labour, energy and services as an input in manufacturing sector. Further, a complete test is performed by considering five factors of production, such as primary educated labour force, labour force with secondary and tertiary education, capital and arable land and a set of ten important industries such as mineral, chemical, plastics and rubber, leather, wood, textile, stone/glass, metal, machinery and transportation industries for the year 2009. The complete test is a test of the modified H-O-V theorem which defines abundance and scarcity of factors using excess supply approach. The results justify the H-O-V theorem in more than 50% of the cases. This supports the immense importance of factors and their productivity differentials in explaining India's trade with its trading partners.

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## I. Introduction

The explanation of international trade on the basis of scarcity or abundance of factors of production was first independently propounded by Eli Heckscher (1919) and Bertil Ohlin (1933). Heckscher-Ohlin (H-O) theorem has been one of the most prominent theorems of international trade and there was a huge debate on it, which continued for years with several criticisms and appreciations. However, it is still regarded as one of the most powerful theories in the literature of international trade.

The formal literature of international trade goes back to Adam Smith (1776), who had propounded the theory of absolute advantage. He advocated that the international trade would take place between the countries if and only if they have some absolute advantage from trade. There would be no trade if there is absence of absolute advantage. Later, Ricardo (1817) proposed his theory of comparative advantage. The idea behind the theory was that countries would trade among themselves so long as they have lower opportunity cost of producing some goods than the rest of the world. This production cost advantage comes because of differences in technologies among the participant countries. He did not go into the details to explain why such differences in comparative costs arise.

The basic H-O theorem propagates that the country exports those commodities which require abundant factors of production and are relatively cheap and imports those goods which require the use of relatively scarce factors of production. Ohlin was aware of the fact that the differences in relative factor prices that arise due to the differences in relative factor endowment could be offset by relative differences in consumer's preferences. But he believed that the differences in relative factor endowments are more important than the differences in relative consumer's preferences. He was also concerned about the economies of scale and qualitative differences in factors. He also tried to integrate the factor prepositions framework into a general equilibrium pricing system, assuming that there were constant returns to scale in production functions. Instead of ordering the ratio of a country's endowment of each factor to the world endowment of that factor, he connected to the ordering of a country's net export of each factor to the world endowment of that factor. Although, he had adopted a very broad approach to analyse the factors shaping the trade patterns, yet he did not attempt to undertake rigorous empirical testing of the H-O preposition. He only relied upon the historical examples.

Samuelson (1948-49) had transformed these creative ideas into a general equilibrium (two goods, two factors and two countries) model. Earlier the theorem was proved with the help of geometrical analysis, which was based on very restricted assumptions. But later H-O-S theorem was proved through various rigorous empirical exercises. Beginning with Leontief (1954) numerous empirical studies have been conducted to verify the empirical validity of the H-O-S theorem.

Leontief (1954) and several other researchers focused on the factor content of exports and imports, which was later proved as the incorrect way of testing the H-O hypothesis. Vanek[3] (1968) had established the exact relationship between factor endowments and net exports. He proposed a test which could be performed on a set of multi-country, multi commodity and multifactor framework. In this method, the predictions were made on the basis of the factor content of consumption and production, instead of considering the factor content of exports and imports.

Earlier empirical studies of the H-O theorem had shown disappointing results, as the theorem was based on very restrictive assumptions. However, if few of the assumptions of the model would be relaxed, the modified model may yield satisfactory results. This study attempts to do the same. One of the restrictive assumptions of this model is that technology remained same across the country. Trefler (1995) had demonstrated the extent to which the predictions of the H-O-V model would confirm its validity, if technological differences among the countries were taken into consideration. The present study has also made an attempt to understand the current pattern of India's international trade on the basis of the H-O-V theorem by taking the productivity differences into consideration using excess supply approach.

In this paper, an attempt has been made to validate H-O-V theorem, which relates a country's relative factor endowments to the factor content of net trade. The description of the theorem is provided in section II, which has been further employed for performing partial and complete tests. The present paper is organized in the following manner: Section III presents the methodology used for the empirical analysis, construction of variables and data sources and results and discussion of partial test of H-O-V theorem; Section IV gives a detailed account of methodology, construction of variables and data sources and results and discussion of the complete test of the H-O-V theorem and the final Section, V concludes with a comprehensive discussion.

[3]See Baldwin, R. E. (2008).

## II. H-O-V (1968) Model

H-O-V model is based upon certain assumptions, such as identical technologies across the countries, factor price equalization under free trade condition and homothetic and identical tastes across the countries. The final equation of the H-O-V model[4] can be written as:

$$F_i = AT_i = V_i - s_i V_w \qquad (1)$$

Where the left hand term in equation (1) indicates the factor content of the trade ($F_i$) and the right hand side term indicates the factor abundance/scarcity (defined as country's endowment of a factor ($V_i$) relative to world endowment ($V_w$) with respect to that country's share of the world GDP ($s_i$)). The basic objective of this paper is to test the H-O-V theorem by taking technological differences into consideration in the Indian context (the partial test) as well as other countries of the world (the complete test).

## III. Partial Test of H-O-V Theorem

*Methodology*

As explained in the equation (1), the empirical testing of the basic H-O theorem requires three sets of variables: factor intensities, trade and endowments, but in reality it is difficult to get all sets of data independently. Similarly, as far as India is concerned, the major problem is the availability of the data. In the literature, Baldwin (1971) had made regression of the trade data ($T_i$) on technology matrix ($A$) and made the inference about endowments. But his work was criticized on the ground that the author should have done regression on inverse of technology matrix ($A$). Leamer (1984) had treated factor endowments ($V_i - s_i V_w$) as data while estimating the elements of $A^{-1}$. This procedure of taking two sets of data into consideration and making the approximations about the third set is called partial test of the theorem.

In our analysis, we have made regression of net exports on the inverse of the technology matrix ($A^{-1}$) to get the estimation of the endowments in India's manufacturing sector. All the assumptions of the model are taken for granted as the partial test is performed using the Indian data only. The study has used Annual Survey of Industries (ASI) database. The construction of the technology matrix requires equal number of goods and factors. Therefore, the technology matrix is constructed by taking into account of six factor inputs, namely, capital, skilled labour, unskilled labour, energy, material and services and their contribution in the total output of each industry. Six industries are taken into account for the period 1989 – 2008 by clubbing the industries belonging to one group. The list of industries is provided in Appendix A.

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[4] For detailed derivation see appendix E.

*Construction of Variables and Data Sources*

For the partial testing of the theorem, we require data on net trade, factor endowments and outputs of the concerned industries. Data[5] for the construction of the technical coefficient ($A$) matrix is obtained from ASI database[6]. As stated earlier, the six inputs considered in the study are capital, skilled labour, unskilled labour, energy, materials and services and the concerned industries are classified into primary products, engineering goods, chemicals, textiles, leather and miscellaneous goods from the year 1989-2009. Availability of the data is the rationale behind the selection of this time period in this study.

The series for output and inputs of each industry at two digit level of aggregation[7] is obtained from ASI database. To measure the real output of each industry, we have deflated the output series by the Wholesale Price Index (WPI).

The total number of workers is regarded as unskilled labours in these aforesaid industries.

Furthermore, to find out the number of skilled labours in these industries, data series of total number of workers is deducted from the series of total persons engaged in that particular industry.

To find out the data for the capital stock[8], we have taken interest paid divided by the cost of capital. Here interest paid has been deflated by the implicit deflator. To obtain the cost of capital, we have taken value added minus wages paid to the workers divided by the value added and the whole multiplied by hundred.

To find out the material and energy inputs, reported series on the same has been deflated[9] to obtain it at constant prices.

Data for services as an input in manufacturing sector is not directly available in ASI database. For the construction of the series, the cost of materials and energy are deducted from the reported total input series.

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[5]See Appendix D for the definitions, concepts and methods used for the construction of the various variables.

[6]Annual Survey of Industries (ASI) database is published by Central Statistical Organization (CSO), India. The Economic and Political Weekly (EPW) provides an electronic database using ASI results for the period 1973-74 to 2003-04 in its volume II. It presents a consistent series based on NIC-1998 at the 2-digit and 3-digit level of disaggregation. Data series after the year 2003-04 can be obtained from CSO website.

[7] The data for two digit level of aggregation is used to find out the overall abundance/scarcity of factor endowment in various Indian manufacturing industries.

[8]See Sterner. T. (1985b).

[9]See Banga & Goldar (2004).

Net trade data is obtained from World Integrated Trade Solutions (WITS)[10] database. It gives access to UNCOMTRADE database which compiles exports and imports data of commodities under various trade classifications for a number of countries. Appendix B describes the trade data in detail.

*Results and Discussions*

For the partial test, the data is constructed in a pooled format for six major industries for the period 1989 - 2009. Table 1 contains descriptive statistics and diagnostics test for the dataset.

Summary statistics of the partial test variables shows that there are total one hundred twenty observations and there are no missing values in the dataset. Robust standard errors are used to avoid heteroscedasticity. Levin-Lin-Chu unit root test is also performed to check whether the variable series is stationary or not. The null hypothesis is that the series contains a unit root and the alternative is that the series is stationary. The Levin–Lin–Chu bias-adjusted $t$ statistic is −1.31 for net exports series, -8.01 for skilled labour, -8.10 for unskilled labour, -7.11 for capital, -7.97 for material, -5.09 for energy and -7.31 for services series, which are significant at all the usual testing levels. Therefore, we reject the null hypothesis and conclude that all the series are stationary.

**Table 1**
**Descriptive Statistics and Diagnostic Test Results for the H-O-V Partial Test**

| **Descriptive Statistics of the Partial Test Variables** | | | | | |
|---|---|---|---|---|---|
| **Variable** | **Obs** | **Mean** | **Std. Dev.** | **Min** | **Max** |
| Skilled Labour | 120 | 311305.6 | 201323.4 | 17320 | 932527 |
| Unskilled Labour | 120 | 1045184 | 593474.8 | 82675 | 2443436 |
| Capital | 120 | 107353 | 233577.4 | 210.7283 | 837264.3 |
| Material | 120 | 1.15E+07 | 1.06E+07 | 506923.5 | 5.73E+07 |
| Energy | 120 | 1352212 | 935836.1 | 25809.65 | 4044185 |
| Services | 120 | 5530211 | 5008337 | -2974304 | 2.33E+07 |

| **Unit Root Test Results of Partial Test Variables** | | |
|---|---|---|
| **Net Exports** | **Statistic** | **P-Value** |
| Unadjusted t | -7.46 | |
| Adjusted t* | -1.31 | 0.04 |
| **Skilled Labour** | **Statistic** | **P-Value** |
| Unadjusted t | -11.90 | |
| Adjusted t* | -8.01 | 0.00 |

[10] WITS is a software developed by World Bank in close collaboration and consultation with the various international organizations such as United Nations Conference on Trade and Development (UNCTAD), International Trade Centre (ITC) and the World Trade organization (WTO).

| Unskilled Labour | Statistic | P-Value |
|---|---|---|
| Unadjusted t | -12.80 | |
| Adjusted t* | -8.10 | 0.00 |
| **Capital** | **Statistic** | **P-Value** |
| Unadjusted t | -11.53 | |
| Adjusted t* | -7.11 | 0.00 |
| **Material** | **Statistic** | **P-Value** |
| Unadjusted t | -11.91 | |
| Adjusted t* | -7.97 | 0.00 |
| **Energy** | **Statistic** | **P-Value** |
| Unadjusted t | -10.16 | |
| Adjusted t* | -5.09 | 0.00 |
| **Services** | **Statistic** | **P-Value** |
| Unadjusted t | -11.76 | |
| Adjusted t* | -7.31 | 0.00 |
| **Hausman Test Statistics** | | |
| $Chi^2$=12.61 | | |
| Prob>$Chi^2$= 0.04 | | |
| **Variable Inflation Factor** | | |
| | **VIF** | |
| Skilled Labour | 117.01 | |
| Unskilled Labour | 5.85 | |
| Capital | 27.00 | |
| Energy | 82.50 | |
| Material | 14.95 | |
| Services | 135.07 | |

*Source: Author's own estimation*

Furthermore, Hausman test results above reveal that fixed effect model is preferred against the random effect model. However, Variable Inflation Factor (VIF) which is used to identify multi collinearity problem among the variables shows that the values are very high[11]. We used ridge regressions technique[12] to circumvent the same.

[11]According to Rogerson, P. (2001) the Variable Inflation Factor (VIF) should be less than five.

[12]Ridge regression technique is used to cure the multi-collinearity problem. Suppose the sample regression function is given by $y = \hat{\beta}_1 x_1 + \hat{\beta}_2 x_2 + e$ and our objective is to minimize $\sum e^2$ subject to $\hat{\beta}_1 + \hat{\beta}_2 = c$ . Therefore,

We have used Least Squares Dummy Variable (LSDV) technique for the analysis. The final results obtained by the partial test are provided in Table 2.

**Table 2**
**Partial Test Results**

| Variables | Coefficients |
|---|---|
| Dependent variable T (net trade) | |
| Skilled labor | -0.27 (0.02)*** |
| Unskilled labor | 0.19 (0.03)*** |
| Capital | 0.18 (0.04)*** |
| Energy | -0.12 (0.05)** |
| Material | 0.01 (0.04) |
| Services | -0.20 (0.05)*** |
| R-Square | 0.77 |

****, **, * significant at 1%, 5% and 10% level, respectively. Standard errors are in parenthesis.*
*Source: Author's own estimation*

The results of the partial test explain the abundance or scarcity of factors of production in India's manufacturing sector. R-square value in the Table 2 reveals that around 77% of the variability in net trade of the aforesaid industries is defined by these six factors of production. The coefficients of skilled labour, energy and services as an input in manufacturing sector are negative, but significant. This justifies the scarcity and their importance in India's manufacturing sector. Therefore, there is a need for the encouragement of these factors for the healthy growth of India's manufacturing industries. Furthermore, the coefficients of the unskilled labour and the capital inputs are positive and significant. It proves that India is abundant in unskilled labour and capital. The results truly represent the existing abundance of unskilled labour force in India and it achieved capital abundance due to its orientation towards more liberalized economy.

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summing them with the help of Lagrange multiplier gives

$$S=\sum\left(y-\hat{\beta}_1x_1-\hat{\beta}_2x_2\right)^2+\lambda\left[c-\hat{\beta}_1^{\,2}-\hat{\beta}_2^{\,2}\right],\frac{\partial S}{\partial\hat{\beta}_1}=0,\frac{\partial S}{\partial\hat{\beta}_2}=0$$

$$=-2\sum x_1\left(y-\hat{\beta}_1x_1-\hat{\beta}_2x_2\right)-2\hat{\beta}_1\lambda=0$$

$$=-2\sum x_2\left(y-\hat{\beta}_1x_1-\hat{\beta}_2x_2\right)-2\hat{\beta}_2\lambda=0$$

$$\Rightarrow\sum x_1y=\hat{\beta}_1\left(\sum x_1^2+\lambda\right)+\hat{\beta}_2\sum x_2x_1$$

$$\Rightarrow\sum x_2y=\hat{\beta}_1\sum x_1x_2+\hat{\beta}_2\left(\sum x_2^2+\lambda\right)$$

$$Varx_1=\frac{\sum x_2^2}{n},Varx_1=\frac{\sum x_1^2}{n}$$

Here λ is a coefficient which plays vital role in shrinking the regression coefficient and thus reduces multi collinearity among the variables.

## IV. Complete Test[13] of H-O-V Theorem

*Methodology*

For the complete testing of the theorem on world trade, excess supply approach is adopted. This approach takes productivity differences among countries into consideration. As per the earlier discussion, the major problem with the H-O-V testing is the availability of the data and the calculation of technology matrix. The crucial assumption for calculating the technology matrix is that it should be a square matrix, i.e., the number of factors should be equal to the number of goods otherwise the inversion of matrix will not be possible. This is an unrealistic assumption as usually number of goods is greater than the number of factors.

Alternatively, one can also use the excess supply approach to prove the theorem.[14] This is the complete test of the theorem. For the establishment of the relationship between the trade and endowments, there is a need to find out the link between the output and the endowments. The link between the two has been established by Rybczynski theorem. The Rybczynski theorem says that, at constant relative goods prices, a rise in the endowment of a factor will lead to a more than proportional expansion of the output in the sector which uses that factor intensively, and an absolute decline of the output of the other good.

To prove this, we begin with the GDP function. The GDP function records the maximum income that a country can achieve, if it faces the vector $p$ of commodity prices and vector $v$ of factor endowments. According to the accounting identity, the total value of GDP equals the payment made to the primary factors. The payment made to the factors should be such that the cost of production of goods should not be less than the price of the goods. Therefore, this dual identity can be written as[15]:

$$GDP(p,V) = yp = wV \tag{2}$$

Where, $y$ is the vector of commodity output and $w$ is the vector of payments made to the factors of production. The aim is to maximize $p$ subject to the constraint of endowments and to minimize $w$ subject to the constraint that cost should not be more than $p$. Differentiating the GDP with respect to prices gives:

$$\frac{\partial GDP}{\partial p_i} = y_i + \sum_i \frac{\partial y}{\partial p_j} p_j = y_i \tag{1}$$

Here, the totality term in equation (3) under the summation sign vanishes as a condition of maximization. Now the differentiation of the GDP function in equation (2) with respect to the endowment gives:

[13]See Woodland A. D. (1980) for more details.
[14]See Harrigan (1995)
[15]See Ethier. W. J. (1984)

$$\frac{\partial GDP}{\partial V_j} = w_j + \sum_i V_i \frac{\partial w_i}{\partial V_j} = w_j \tag{2}$$

Finally, the differentiation of the GDP function in equation (2) with respect to the endowment of factors gives:

$$\frac{\partial^2 GDP}{\partial p_i \partial V_j} = \frac{\partial y_j}{\partial V_i} \tag{3}$$

And the differentiation of equation (3) with respect to the price of the commodity gives:

$$\frac{\partial^2 GDP}{\partial p_i \partial V_j} = \frac{\partial w_j}{\partial p_i} \tag{4}$$

Young's theorem implies that,

$$\frac{\partial^2 GDP}{\partial p \partial V} = \frac{\partial^2 GDP}{\partial V \partial p} = \frac{\partial y_j}{\partial V_i} = \frac{\partial w_j}{\partial p_i} \tag{5}$$

Samuelson called this relation as *"reciprocity relation"*. This is the whole explanation of the supply side of the economy.

Now on the demand side, it is assumed that the tastes are homothetic, and therefore, expenditure on goods is a constant fraction of income.

$$e(p,u) = \beta GDP_i \tag{6}$$

Where GDP is the function of the price of goods and factor endowments. Now trade can be written as:

$$\begin{aligned} T &= y - c \\ T(p,V) &= y(p,V) - e(p,V) \end{aligned} \tag{7}$$

Differentiation of equation (8) with respect to the endowments provides,

$$\frac{\partial T}{\partial V} = \frac{\partial y}{\partial V} - \beta \frac{\partial GDP}{\partial V} \tag{8}$$

From equation (3),

$$\frac{\partial T}{\partial V} = \frac{\partial y}{\partial V} - \beta w_i \tag{9}$$

Multiplying equation (11) with ${V_i}/{y_j}$ affords,

$$\frac{\partial T_j}{\partial V_i}\frac{V_i}{y_j} = \frac{\partial y_j}{\partial V_i}\frac{V_i}{y_j} - \beta w_i \frac{V_i}{y_j} \tag{10}$$

In case of no trade, consumption equals production:

$$e(p,V) = \beta GDP = y_i \tag{11}$$

Therefore,

$$\beta = \frac{y_i}{GDP} \tag{12}$$

Substituting the expression (13) in the expression (11) furnishes:

$$\frac{\partial T_j}{\partial V_i}\frac{V_i}{y_j} = \frac{\partial y_j}{\partial V_i}\frac{V_i}{y_j} - w_i \frac{V_i}{GDP(p,V)} \tag{13}$$

Where $w_i \frac{V_i}{GDP(p,V)}$ is the share of the factor *i* in the national income and $\frac{\partial y_j}{\partial V_i}\frac{V_i}{y_j} = \frac{\partial \ln y}{\partial \ln V}$ is the percentage increase in the output of *j* due to a 1% increase in the endowment of factor *i.* So it is the Rybczynski elasticity of output of j with respect to the endowment i. The second term on the right hand side of the equation shows the percentage increase in the GDP caused by a 1% increase in the endowment of factor i. Now if we differentiate net trade with respect to factor endowment and multiply it with $(V_i / y_i)$, we can find out the left hand side of the equation. In equation (14) below, net trade is taken on the left hand side and factor endowments on the right hand side. Further, if we differentiate GDP with respect to endowments and multiply if with $(V_i / y_i)$, we can find out first term of the right hand side of equation (13). In equation (15) below GDP is taken on the left hand side and endowments on the right hand side. Thorugh this we can find out the third term on the right hand side and then correlate the factor content of trade with the factor endowments. The theory is generalized as a correlation between factor intensities, endowments and net trade level.

*Construction of Variables and Data Sources*

In order to check the applicability of the H-O-V theorem in the world trade, a complete test is performed on a set of 46 countries and the study utilizes a cross sectional data for the latest year 2009. As stated earlier, the rationale behind the use of a set of 46 countries is the availability of the data. Ten important manufacturing sectors are selected from the two digit HS classification. Industries belonging to the same category are clubbed in a group. A complete list is provided in Appendix B. Trade data is traced from WITS database.

The endowment data of five factors are taken into consideration for the analysis. The data for human capital endowment is obtained from Barro and Lee[16] data set. This data set presents the percentage of different educational attainments by those over 25 years of age in total population. We used these figures to construct our endowment variables. The data in percentages was converted to the levels by using relevant population figures. H1 stands for the number of people who have qualified the primary school level and those who have received some degree of secondary education without a diploma. H2 stands for those people who have passed high school and did not continue higher education as well as those who have received some years of higher education but did not graduate. H3 represents that part of the population which completed higher education.

[16]See Barro, R. J., & Lee, J. W. (2012).

For the construction of the capital stock, the perpetual inventory method has been used. The method for measuring capital stock series is provided in Appendix C. Data for the arable land is obtained from the Food and Agriculture Organization (FAO). The GDP data to estimate factor shares is obtained from World Development Indicators (WDI) database.

*Results and Discussion*

A modified test of the H-O-V theorem is executed considering the productivity differences among the countries. This is a complete test of the theorem and can be called an excess supply approach. In this approach trade can be expressed as excess supply functions, i.e., the difference between production and demand. Table 3 shows the descriptive statistics and diagnostics test results for dataset of complete test of the H-O-V theorem.

**Table 3**
**Descriptive Statistics and Diagnostic Test Results for the H-O-V Complete Test**

| **Descriptive Statistics of Complete Test Variables** | | | | | |
|---|---|---|---|---|---|
| **Variable** | **Obs** | **Mean** | **Std. Dev.** | **Min** | **Max** |
| Mineral Products | 46 | -12000000.00 | 54400000.00 | -225000000.00 | 188000000.00 |
| Chemicals | 46 | 503444.50 | 13800000.00 | -17900000.00 | 57200000.00 |
| Plastic Products | 46 | -728723.90 | 5188875.00 | -21100000.00 | 18400000.00 |
| Leather Goods | 46 | 127557.00 | 2090631.00 | -6553568.00 | 11300000.00 |
| Wood | 46 | 466914.70 | 3911491.00 | -7619396.00 | 12400000.00 |
| Textile | 46 | 720007.20 | 24400000.00 | -70200000.00 | 143000000.00 |
| Stone glass | 46 | 488559.00 | 4506564.00 | -15900000.00 | 17800000.00 |
| Metal | 46 | 518890.20 | 6910590.00 | -24800000.00 | 21800000.00 |
| Machinery | 46 | -1600460.00 | 51600000.00 | -212000000.00 | 237000000.00 |
| Transportation | 46 | 1227964.00 | 15300000.00 | -18400000.00 | 92300000.00 |
| GDP | 46 | 659000000000.00 | 1780000000000.00 | 6970000000.00 | 11700000000000.00 |
| H1 | 46 | 8772262.00 | 26200000.00 | 45717.00 | 150000000.00 |
| H2 | 46 | 14700000.00 | 52100000.00 | 42174.00 | 350000000.00 |
| H3 | 46 | 4811297.00 | 11300000.00 | 36234.00 | 65000000.00 |
| Capital | 46 | 4850000000000.00 | 11600000000000.00 | 30000000000.00 | 59000000000000.00 |
| Land | 46 | 19405.95 | 39591.52 | 7.00 | 162751.00 |

| **VIF for Complete Test Variables** | |
|---|---|
| **Variable** | **VIF** |
| H1 | 13.23 |
| H2 | 10.74 |

| | |
|---|---|
| H3 | 6.74 |
| Capital | 5.90 |
| Land | 2.77 |

*Source: Author's own estimation*

The summary statistics of the dataset reveals that there are forty six observations and no missing values. Robust standard errors are used to avoid heteroscedasticity. VIF is higher that H1, H2 and H3. Ridge regression is again used to circumvent the same.

The theorem is tested by using the equation (15) below.

*Trade and Endowments*

The expression on the left hand side of the equation (15) expounds the relationship between trade and endowments. On the basis of this, the equation which needs to be estimated for a particular industry is given by

$$T^{ci} = \phi 0 + \phi H_1^c + \phi H_2^c + \phi H_3^c + \phi K^c + \phi Land^c \quad (14)$$

Where $T^{ci}$ stands for trade of country c in industry i. $H_1^c, H_2^c, H_3^c$ are three categories for human capital endowments. K stands for capital stock in country c. The estimated coefficients for each industry for the year 2009 are shown in the Table 4, where in positive/negative coefficient indicates that the particular endowment creates comparative advantage/disadvantage for trade in an industry. The explanation of a negative coefficient also shows that an increase in particular endowment increases the domestic demand for that good more than its production. Table 4 depicts the contribution of different factors in ten major industries. Industries are clubbed into one category from HS commodity classification. The complete description of these industries is provided in Appendix B.

**Table 4**
**Trade and Endowments Results**

| **Industries** | **H1** | **H2** | **H3** | **Capital** | **Land** | **R-Square** |
|---|---|---|---|---|---|---|
| Mineral products | -0.33 (0.04)*** | -0.07 (0.06) | -0.57 (0.10)*** | -0.35 (0.18)* | 2.82 (0.37)*** | 0.80 |
| Chemical products | -0.15 (0.07)** | 0.14 (0.12) | 0.45 (0.20)** | 0.80 (0.36)** | 0.04 (0.72) | 0.27 |
| Plastics and rubber products | -0.18 (0.05)*** | 0.60 (0.08)*** | 0.25 (0.14)* | 0.93 (0.24)*** | -0.02 (0.48) | 0.67 |
| Leather products | 0.16 (0.03)*** | -0.78 (0.05)*** | 0.40 (0.07)*** | 0.28 (0.13)** | 0.96 (0.26)*** | 0.90 |
| Wood industry | -0.08 (0.07) | 0.15 (0.12) | 0.14 (0.20) | 0.30 (0.36) | 2.42 (0.72)*** | 0.27 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Textile industry | 0.19 (0.01)*** | -0.81 (0.02)*** | 0.38 (0.04)*** | 0.11 (0.07) | 0.59 (0.14)*** | 0.97 |
| Stone/Glass industry | 0.003 (0.05) | -0.58 (0.08)*** | 0.67 (0.12)*** | -0.12 (0.23) | 1.86 (0.45) | 0.70 |
| Metal industry | -0.16 (0.05)*** | 0.02 (0.09) | 0.16 (0.15) | 0.90 (0.26)*** | 3.34 (0.54)*** | 0.59 |
| Machinery | 0.05 (0.02)** | -0.64 (0.03)*** | 0.86 (0.06)*** | 0.72 (0.11)*** | 1.03 (0.22)*** | 0.93 |
| Transportation | 0.11 (0.05)** | 0.17 (0.08)** | 0.81 (0.13)*** | 1.49 (0.23)*** | 0.86 (0.46)* | 0.70 |

****, **, * significant at 1%, 5% and 10% level, respectively. Standard errors are in parenthesis.*
*Source: Author's own estimation*

The results expose that in all the ten industries, except in the stone/glass and mineral products, the coefficient of capital stock is positive and significant. This shows that the rise in overall capital endowment enhances exports of particular industry and creates comparative advantage. The coefficient of H1 is positive for the leather, stone/glass, textiles and machinery, but it is negative for the rest of the industries. The coefficient of H2 is also positive and significant in almost 50% of the cases. Here, it is notable that the higher education is creating comparative advantage in almost all the industries, except in the mineral products. Land endowments are also creating comparative advantage for the world trade. On the basis of the above results, it can be concluded that the capital, land and skilled labour are the most important factors enhancing the trade.

*Factor Shares*

As per the earlier derivations, the impact of factor endowments on the trade can be split into the impact of endowment on production and consumption. The second term on the right hand side of the equation (15) establishes the link between consumption and endowments. In this section, we estimate factor shares by the following equation

$$GDP^{ci} = \pi_0 + \pi H_1^c + \pi H_2^c + \pi H_3^c + \pi K^c + \pi Land^c + \pi R\&DSci^c \quad (15)$$

The results of the estimations are provided in the Table 5.

**Table 5**

**Factor Shares Estimation Results**

| | **H₁** | **H₂** | **H₃** | **Capital** | **Land** | **R-Square** |
|---|---|---|---|---|---|---|
| **GDP** | 0.42 (0.02)*** | 0.48 (0.03)*** | 0.14 (0.05)** | 0.48 (0.10)*** | -1.39 (0.19)*** | 0.94 |

****, **, * significant at 1%, 5% and 10% level, respectively. Standard errors are in parenthesis.*
*Source: Author's own estimation*

Using the estimated coefficients, we can estimate output of each industry by putting the average endowment in the following expression:

$$q^{ci} = (\phi_0 + \pi_0) + (\phi_1 + \pi_1 / G^c)H_1^c + (\phi_2 + \pi_2 / G^c)H_2^c + (\phi_3 + \pi_3 / G^c)H_3^c + (\phi_K + \pi_K / G^c)K^c + (\phi_{Land} + \pi_{Land} / G^c)Land^c$$

(16)

We have taken into account only significant coefficients for the calculation. Using the estimates of $q^{ci}$, we prepared technological coefficient matrix $a_{ij}$ by using $V_j / q_i$.

*Testing of H-O-V Theorem*

In the empirical testing of the H-O-V theorem, we have estimated the correlations between endowments and trade for each industry. Net trade is weighted by the average of technological coefficients. Next, the average of the difference between the actual endowment and the world endowment multiplied by the share of country's GDP in world GDP is calculated. The correlation results for each industry are provided in Table 4 below.

**Table 6**
**Correlation Results**

| **Industries** | **Correlation Coefficients** |
|---|---|
| Mineral products | 0.30** |
| Chemical products | 0.81*** |
| Plastics and rubber products | 0.68*** |
| Leather products | -0.23 |
| Wood industry | 0.61*** |
| Textile industry | -0.42*** |
| Stone/glass industry | 0.20 |
| Metal industry | 0.94*** |
| Machinery | 0.89*** |
| Transportation | 0.75*** |

****,**,* significant at 1%, 5% and 10% level, respectively.*
*Source: Author's own Estimation*

The Pearson correlation results suggest that H-O-V theorem applies to more than 50% of cases and in almost all the cases the results are positive and significant. This shows that there is positive correlation between factor content of trade and factor endowments. Results are positive and significant for mineral, chemical, plastic and rubber, wood, metal, machinery and transportation industry. This proves that the H-O-V theorem is still valid when the productivity differences across the countries are taken into consideration.

## V. Concluding Remarks

An attempt has been made in this paper to analyze the basis and pattern of India's international trade using the H-O-V theorem. India was primarily known as agriculture based economy, but after the economic reforms, the share of manufacturing and services sector has changed drastically. Subsequently, India has become a major exporter of engineering goods, textiles, gems and jewellery rather than primary products. This changing comparative advantage can be attributed to the advancement of communication services and computer based technology.

In such a changing scenario, the structure of factor endowments in the country has transformed. Such relation is appropriately explained by the modified H-O-V theorem which takes into account the productivity differences. The present study proves that Indian manufacturing sector is abundant in unskilled labour and capital, but there is scarcity of skilled labour, energy and services. The abundance of factors is justified by India's current trade pattern, which shows that the major exporting items are engineering and textiles goods, which are considered to be capital and unskilled or semi-skilled labour intensive. The scarcity of skilled labour can be attributed to the lack of adequate employment opportunities and if the skilled labour is properly utilized, the share of the total trade in manufacturing sector can further go up. Similarly, the improvement of the infrastructure would further boost the manufacturing sector.

The complete test results verify the importance of the productivity of factors and reveal that the capital stock, secondary and highly educated labour force create comparative advantage in the world trade pattern. This shows that the world trade and the production patterns seem to increase their requirement for more educated labour force.

In summary, it can be said that the effective factor endowments of a country play a vital role in determining the trade pattern of that country. Thus, it is important to make policies regarding improvement of education level and technical skills, etc., for the growth and progress of a country.

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## Appendix A

**Clubbing Indian Manufacturing Industry into One Category for the Partial Testing of the H-O-V Theorem**

| Grouped Industries Name | Industries (NIC Two Digit Classification Codes) | Trade Data (HS Classification Codes) |
|---|---|---|
| Primary Products | Mining and quarrying (14), | Meat and edible meat,Fish& crustacean etc. (16), Sugars and sugar |

| | | |
|---|---|---|
| | Manufacture food products and beverages (15), Manufacture of tobacco products (16) | confectionery.(17), Cocoa and cocoa preparations. (18), Preps. Of Cereals, Flour, Starch or Milk (19), Preps of Vegs, Fruits, Nuts etc. (20), Misc. Edible Preparations (21), Beverages, Spirits & Vinegar (22), Residues from food industries, animal feed (23), Tobacco & Manuf. Tobacco Substitutes (24), Salt, Sulphur, Earth & Stone, lime & cement (25), Ores, Slag & Ash (26), Mineral fuels, Oils, Waxes & Bituminous Sub (27) |
| Engineering Goods | Manufacture of Basic Metals (27), Manufacture of fabricated metal products, except machinery and equipment (28), Manufacture of machinery and equipment N.E.C ( 29), Manufacture of Office, Accounting and Computing Machinery (30), Manufacture of Electrical Machinery and Apparatus N.E.C (31), Manufacture of medical, precision and optical instruments, watches and clocks (33), Manufacture of motor vehicles, trailers and semi-trailers (34), Manufacture of other transport equipment (35), Manufacture of furniture; manufacturing N.E.C (36) | Nuclear Reactors, Boilers, Machinery & Mechanical Appliances, Computers (84), Electrical machinery & equipments & parts, Communication equipments, Sound recorders, television recorders (85), Railway or Tramway locomotives, Rolling stock, Track Fixtures & fittings, Signals (86), Vehicles other than Railway or tramway rolling stock (87), Aircraft, Spacecraft & Parts thereof (88), Ships, boats & floating structures (89) |
| Chemical | Manufacture of coke, refined petroleum products and nuclear fuel (23), Manufacture of chemical and products (24) | Inorganic chemicals, Organic compounds of precious metals, isotopes (28), Organic Chemicals (29), Pharmaceutical products (30), Fertilizers (31), Tanning or dying extracts, dyes, Pigments, Paints & varnishes, Putty & inks (32), Oils &resinoids, Perfumery, cosmetic or toilet preparations (33), Soaps, waxes, scouring products, candles, modelling pastes, dental waxes (34), Albuminoidal subs, Starches, glues, enzymes (35), Explosives, matches, pyrotechnic products (36), Photographic or cinematographic goods (37), Miscellaneous chemical products.(38) |
| Textile | Manufacture of Textiles (17), Manufacture of wearing apparel, dressing and dying of fur (18) | Silk, Inc.yarns& woven fabrics thereof (50), Wool, fine/coarse animal hair (51), Cotton, yarns and woven fabrics thereof (52), Veg. textile fibers, yarns and woven etc. (53), man-made filaments, yarns & woven etc. (54), Man-made staple fibres, yarns etc. (55), Wadding, felt & nonwovens, special yarns, Twine, cordage, ropes & cables & articles (56), Carpets & other textile floor coverings (57), Special woven fabrics, tufted textiles, lace (58), Impregnated, coated, covered or laminated textile products for industrial use (59), Knitted or crocheted fabrics (60), Articles of apparel & clothing accessories knitted or crocheted (61), Articles of apparel & clothing accessories- not knitted or crocheted (62), Made up textile articles, needlecraft sets, worn clothing, rags (63) |
| Leather | Tanning and Dressing of Leather, manufacture of luggage, handbags, saddlery, harness and footwear (19) | Raw hides & Skins & leather (41), Articles of leather; saddlery/harness; travel goods, handbags, articles of gut (42), Furskins& artificial fur, manufactures (43) |
| Miscellaneous | Manufacture of wood and products of wood and fork, except furniture, manufacture of articles of straw and planting materials (20), manufacture of paper and paper products (21), publishing, printing and reproduction of recorded media (22), manufacture of rubber and plastic products (25), manufacture of other non-metallic mineral products (26), manufacture of radio, television and communication equipments and apparatus (32) | Wood & Articles of wood, wood charcoal (44), Cork & articles of cork (45), Manufacture of straw., esparto or other plating materials, basketware and wickerwork (46), Pulp of wood, waste & scrap of paper (47), paper & paperboard, articles of paper pulp (48), Printed books, newspapers, pictures, manuscripts, typescripts & plans (49), Plastics & articles thereof (39), Rubber and articles thereof.(40), Articles of stone plaster, cement, asbestos, mica or similar materials (68), Ceramic products (69), Glass & glassware (70), Pearls, Stones, Prec. Metals, Imitation jewellery, coins (71), Optical, Photographic, Cinematographic, measuring, checking, precision, medical or surgical instruments & accessories (90), Clocks & watches & parts thereof (91), Musical instruments, parts & accessories (92), Arms & ammunition, parts & accessories (93), Furniture, bedding, cushions, lamps & lighting fittings, Illuminated |

| | | |
|---|---|---|
| | | signs, nameplates & the like prefabricated buildings (94), Toys, games & sports equipments, parts & accessories (95), Miscellaneous manufactured articles (96) |

## Appendix B
## Clubbing of Industries into Single Category for Complete Testing of the HOV Theorem

| Industries | Industries According to HS Classification Codes |
|---|---|
| Mineral Products | Salt, Sulphur, Earth & Stone, Lime & Cement(25), Ores, slag and Ash (26), Minerals, Fuel oils, waxes and Bituminous subs (27) |
| Chemicals and Allied Industries | Inorganic Chemicals, Organic/Inorganic compounds of precious metals and isotopes (28), Organic Chemicals (29), Pharmaceutical Products (30), Fertilizers (31), Tanning or Dyeing extracts, Dyes, pigments, Paints & varnishes, Putty, & Inks (32), Oils &Resinoids, Perfumery, Cosmetic or toilet preparations (33), Soaps, Waxes, Scouring products, Candles, Modelling pastes, Dental waxes (34), Albuminoidal sub, Starches, Glues, Enzymes (35), Explosives, Matches, Pyrotechnic products (36), Photographic or Cinematographic goods (37) , Miscellaneous chemical products (38) |
| Plastics/Rubbers | Plastics & articles thereof (39), Rubbers & articles thereof (40) |
| Leather Industry | Raw hides & skins & leather (41), Articles of leather, saddlery & harness, travel goods, Handbags, Articles of gut (42), Furskins& artificial fur manufactures (43), |
| Wood and Wood Products | Wood & articles of wood, Wood charcoal (44), Cork & articles of cork (45), Manu. Of straw, esparto, or other plaiting materials, Basketware and Wickerwork (46), Pulp of wood, waste & scrap of paper (47), Paper & paperboard, articles of paper pulp (48), Printed books, newspapers, pictures, manuscripts, typescripts & plans (49) |
| Textile Industry | Silk, inc. Yarns & woven fabrics thereof (50), Wool & fine or coarse animal hair, inc. Yarns & woven fabrics thereof (51), Cotton, inc. Yarns & woven fabrics thereof (52), Veg. Textile fibersnesoi, yarns & woven etc. (53), Man-made filaments, inc. Yarns & woven etc. (54), Man-made staple fibers, inc. Yarns etc. (55), Wadding, felt & nonwovens, special yarns, twine, cordage, ropes & cables & articles (56), Carpets & other textile floor coverings (57), Special woven fabrics, tufted textiles, lace (58), Impregnated, coated, covered, or laminated textile prod, textile prod for industrial use (59), Knitted or crocheted fabrics (60), Articles of apparel & clothing accessories-knitted or crocheted (61), Articles of apparel & clothing accessories-not knitted or crocheted (62), Made-up textile articles nesoi, needlecraft sets, worn clothing, rags (63) |
| Stone/Glass | Articles of stone, plaster, Cement, asbestos, mica or similar materials (68), Ceramic products (69), Glass & glassware (70), Pearls, stones, prec. Metals, imitation jewellery, coins (71) |
| Metals | Iron & steel(72), articles of iron or steel (73), copper & articles thereof(74), nickel & articles thereof (75), aluminium & articles thereof (76), lead & articles thereof (78), zinc & articles thereof (79), tin & articles thereof (80), base metals nesoi, cermets, articles etc.(81), tools, spoons & forks of base metal (82), miscellaneous articles of base metal (83) |
| Machinery and Electrical | Nuclear reactors, boilers, machinery & mechanical appliances, computers (84), electrical machinery & equip. & parts, telecommunications equip., sound recorders, television recorders (85) |
| Transportation | Railway or tramway locomotives, rolling stock, track fixtures & fittings, signals (86), vehicles other than railway or tramway rolling stock (87), aircraft, spacecraft, & parts thereof (88), ships, boats, & floating structures (89) |

## Appendix C
## Measurement of Capital Stock Series[17]

We measure the capital stock series in the form

$$K(t) = K(t-1) + I(t) - D(t), \qquad \text{(C1)}$$

where $K(t)$ is the real capital stock at period $t$, $I(t)$ is the real gross fixed investment, and $D(t)$ is the real capital depreciation allowance.

We calculate the initial stock by

[17] The approach of calculating initial capital stock is suggested by William W.F. Chao and Lawrence Lau(Chou,1993).

$$K(1) = \frac{I(0)e^{\theta}}{\theta}$$

(A2)

where $I(0)$ and $\theta$ are the estimated coefficients of the constant term and time variable in the following form by ordinary least squares estimation:

$$\ln I(t) = C + \theta Time$$

(3C)

The estimation is that (1) the capital stock in the first period is the sum of all past investments:

$$K(I) = \int_{t=-\infty}^{1} I(t)dt$$

(A4)

and (2) the investment series may be approximated by an exponential time trend:

$$I(t) = I(0)e^{\theta t}$$

(5C)

Inserting equation (5C) into equation (4C) yields equation (2C). Taking natural logarithms of equation (5C), we obtain equation (3C) where the constant term c is $\ln I(0)$.

## Appendix D

Concepts and Definitions of Annual Survey of Industries Variables

| **Variables** | **Concepts and Defitions** |
|---|---|
| Gross Output | Includes the ex-factory value of products and by-products manufactured during the accounting year. It also includes the receipts for non-industrial services rendered to others, the receipt for work done for others on materials supplied by them, value of electricity produced and sold and net balance of goods sold in the same condition as purchased. |
| Employees | Employees relate to all persons engaged by the factory whether for wages or not, in work connected directly or indirectly with the manufacturing process and include all administrative, technical and clerical staff as also labour in production of capital assets for factory's own use. This is inclusive of persons holding position of supervision or management or engaged in administrative office, store-keeping section and welfare section, watch and ward staff, sales department as also those engaged in the purchase of raw materials etc. and production of fixed assets for the factory. It also includes all working proprietors and their family members who are actively engaged in the work of the factory even without any pay and the unpaid members of the co-operative societies who work in or for the factory in any direct and productive capacity. Persons in the head office connected with the manufacturing activity of the factory are also included in this item. |
| Contract Workers | All persons who are not employed directly by an employer but through the third agency, i.e. contractor, are termed as contract workers. Those workers may be employed with or without the knowledge of the principal employer. |
| Net Value Added | This is the increment to the value of goods and services that is contributed by the factory and is obtained by deducting the value of total inputs and depreciation from gross value of output. |
| Wages to Workers | Wages are defined to include all remuneration capable of being expressed in monetary terms and also paid more or less regularly in each pay period to workers as compensation for work done during the accounting year. It includes: (i) Direct wages and salary (i.e. basic wages/salaries, payment of overtime, dearness, compensatory, house rent and other allowances; (ii) Remuneration for period not worked (i.e. basic wages), salaries and allowances payable for leave period, paid holidays, lay-off payments and compensation for unemployment (if not paid from source other than employers); (iii) Bonus and ex-gratia payment paid more or less regularly (i.e., incentive bonuses and good attendance bonuses, production bonuses etc.).Furthermore, it excludes layoff payments and compensation for employment except where such payments are for this purpose, i.e., payments not made by the employer. It excludes employer's contribution to old age benefits and other social security charges, direct expenditure on maternity benefits and creches and other group benefit in kind and travelling and other expenditure incurred for business purposes and reimbursed by the employer. The wages are expressed in terms of gross value, i.e., before deductions for fines, damages, taxes, provident fund, employee's state insurance contribution etc. Benefits in kind (perquisites) of individual nature are only included. |

| | |
|---|---|
| Materials Consumed | Materials consumed represent the total delivered value of all items of raw materials, components, chemicals, packing materials and stores which actually entered into the production process of the factory during the accounting year. It also includes the cost of all the materials used in the production of fixed assets, including construction work for factory's own use. Components and accessories fitted as purchased with the finished product during the accounting year are also to be included. It excludes intermediate products. Intermediate products in the above context mean all those products which are produced by the factory and consumed for further manufacturing process. |
| Fuels Consumed | This comprises gross value of fuel materials etc. consumed (as defined above) and also other inputs viz. (a) cost of non-industrial services received from others (b) cost of materials consumed for repair and maintenance of factory's fixed assets including cost of work done by others to the factory's fixed assets (c) cost of contract and commission work done by others on materials supplied by the factory (d) cost of office supplies and products reported for sale during last year & used for further manufacture during the accounting year. |
| Emoluments | These are defined in the same way as wages but paid to all employees plus imputed value of benefits in kind i.e. the net cost to the employers on those goods and services provided to employees free of charge or at markedly reduced cost which are clearly and primarily of benefit to the employees as consumers. It includes profit sharing, festival and other bonuses and ex-gratia payments paid at less frequent intervals (i.e. other than bonus paid more or less regularly for each period). Benefits in kind include supplies or services rendered such as housing, medical, education and recreation facilities. Personal insurance, income tax, house rent allowance, conveyance etc. for payment by the factory also is included in the emoluments. |
| Basic Materials | Basic materials are the materials which are important and of key nature to the industry on which the manufacturing process is based , viz. Metal for machine, leather for shoe. Such material is not lost through the process of production but only changes its forms. |
| Total Input | This comprises gross value of fuel materials etc. consumed (as defined above) and also other inputs viz. (a) cost of non-industrial services received from others (b) cost of materials consumed for repair and maintenance of factory's fixed assets including cost of work done by others to the factory's fixed assets (c) cost of contract and commission work done by others on materials supplied by the factory (d) cost of office supplies and products reported for sale during last year & used for further manufacture during the accounting year. |
| Compensation of Employees | Compensation of employees is the total of emoluments and supplement to emoluments. |

## Appendix E

To prove the H-O-V theorem, we begin with the macroeconomic equation

$$Y = C + I + G + (X - M) \tag{1E}$$

$$Y - \underbrace{C - I - G}_{D} = X - M$$

$$Y - D = T\ . \tag{2E}$$

Where $Y$ denotes the output or GDP of a country, $C$ is the consumption, $I$ is the investment, $G$ is the government expenditure, $X$ is the exports and $M$ denotes the imports. Equation (2E) shows that the trade is equal to the output minus domestic consumption. To prove the H-O-V theorem, we need to relate equation (2E) to the factor endowments of the country. Therefore, technological coefficient matrix (A matrix) is calculated. Technological coefficient matrix (A) is the matrix which denotes the amount of labour, capital, land and other primary factors required for producing one unit of the good in each industry. In expanded form, it is written as

$$A = \begin{bmatrix} a_{1L} & a_{2L} \\ a_{1K} & a_{2K} \end{bmatrix}\ , \tag{3E}$$

Here $a_{1L}$ in the equation (3E) denotes the amount of labour required for one unit of production in industry 1 and so on. Now if we multiply equation (2E) with the technological coefficient matrix to relate the technology with the trade, we get

$$AT = AY - AD \tag{4E}$$

The left hand side of the equation (4E) explains the factor content of trade. The multiplication of the technological coefficient matrix with the trade vector gives

$$AT = \begin{bmatrix} a_{1L} & a_{2L} \\ a_{1K} & a_{2K} \end{bmatrix} \begin{bmatrix} T_1 \\ T_2 \end{bmatrix} = \begin{bmatrix} a_{1L}T_1 + a_{2L}T_2 \\ a_{1K}T_1 + a_{2K}T_2 \end{bmatrix} = \begin{bmatrix} F_L^i \\ F_K^i \end{bmatrix}$$

For the first term on the right hand side of equation (4E), we get

$$AY = \begin{bmatrix} a_{1L} & a_{2L} \\ a_{1K} & a_{2K} \end{bmatrix} \begin{bmatrix} Y_1 \\ Y_2 \end{bmatrix} = \begin{bmatrix} a_{1L}Y_1 + a_{2L}Y_2 \\ a_{1K}Y_1 + a_{2K}Y_2 \end{bmatrix} = \begin{bmatrix} L^i \\ K^i \end{bmatrix}$$

The first term in the equation (4E) shows that the demand for factors in a country equals to the endowment of the country because of the condition of full employment. Further, the second term on the right hand side of equation (E4) implies that consumption vectors of all the countries are proportional to each other because of the assumption of homothetic preferences across the countries, i.e., $D^i = s^i D^w$. With the assumption of balanced trade, $s^i$ also equals the country $i$ 's share of the world GDP. We can equate the world consumption to the world production, $AD^i = s^i AD^w = s^i AY^w = s^i V^w$. Therefore, H-O-V equation can be written as

$$F^i = AT^i = V^i - s^i V^w \tag{5E}$$