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TESTING HECKSCHER-OHLIN-VANEK THEOREM BY USING NORMALIZED TRADE BALANCE APPROACH

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Abstract. *The study described here introduces new approach for testing the Heckscher-Ohlin-Vanek (HOV) theorem based on the normalized trade balance concept. The intention was to include in the analysis all countries worldwide but due to the lack of data a certain number of countries had to be excluded. Overall 111 countries were observed according to region and income level for the year 2014. The HOV model was estimated using the sign test. It compared the expected sign of the normalized trade balance or net exports, according to the SITC 2 product classification, with the relative endowment of production factors intensively used in the production of a specific product. Production factors were divided into groups such as produced capital, labour force and natural resources further divided into forests, metals and minerals, oil, coal and gas, pastureland and cropland. Researchers in R&D per million people variable represented the impact of technological differences across countries. The results of the sign test have shown that the HOV theorem held in 55% of cases. The percentage of matched signs was highest for the non-OECD high income countries (75%) and lowest for the lower middle income and low income countries (below 50%).*

Key words: *Heckscher-Ohlin-Vanek model, sign test, normalized trade balance approach, the World*

JEL Classification: F1, F2

1. INTRODUCTION

Classical theories of international trade observed price determination and trade pattern only from the supply side. At that time labour was the only factor of production. Adam Smith's theory of absolute advantages determined the pattern of trade and specialization from

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the different labour productivity in countries, while David Ricardo's theory of comparative advantages was based on different relative labour productivity. After the Industrial Revolution the capital was recognized as a factor of production as well. The neoclassical theory of international trade, established in 1920s and 1930s, was based on the Heckscher-Ohlin theory or also called the Factor Proportions Model (Heckscher, 1919 and Ohlin, 1924). In the Heckscher-Ohlin theory there are two factors of production, labour and capital. Comparative advantages are determined from the relative abundance of production factors. A country which is relatively abundant in a certain factor of production should export a commodity which intensively uses that factor of production. Leontief (1953) confronted the Heckscher-Ohlin theory with data for the United States using 1947 input-output tables. He came to the conclusion that the United States exported labour-intensive products and imported capital-intensive products, which was in contrast with the Heckscher-Ohlin theory, the result later named the Leontief paradox. The Heckscher-Ohlin theory has been subject of rigorous empirical investigation by many scientists but with little success. The results achieved on the sign test were often no better than flipping a coin. Vanek (1968) expanded the standard Heckscher-Ohlin model on a multi-country, multi-factor and multi-commodity framework and explained if a country's endowment in a certain factor of production exceeds that country's share in total World's GDP than that factor of production should be considered abundant. The so called Heckscher-Ohlin-Vanek (HOV) model or factor content model predicted that the content of relatively abundant factor embodied in export commodities should be larger than the content embodied in import commodities. The HOV theorem, however, did poorly in empirical research, primarily because of restrictive assumptions of the very theorem. According to Davis et al. (1997), the HOV theorem is a central theorem in international economics theory but empirically it is a flop. The empirical failure is owed extensively to examining the theory in its least realistic form.

The goal of this paper is to introduce a new approach for testing the Heckscher-Ohlin-Vanek theorem based on the normalized trade balance concept and its application by using sign test. The novelty of our approach is implementation of normalized trade balance concept alongside with the use of sign test instead of calculating the factor content of trade. Therefore, the main advantage of this approach is simplification of the overall model by replacing the complex and complicated input-output matrix calculation process with the normalized trade balance. In addition, this simplified approach allows the larger sample of countries to be included in the analysis. There are five chapters in the paper. After the introduction, the second chapter provides literature review about empirical findings on the HOV model. Data and methodology are presented in chapter three. In the fourth chapter the results of the HOV model analysis are presented and elaborated while the last chapter offers concluding remarks.

2. Literature Review

In this chapter, literature review of empirical studies on the HOV model after Vanek's (1968) seminal paper are to be presented and elaborated. Bowen, Leamer and Sveikauskas (1987) examined the factor content of trade in a multi-factor and multi-country framework. The HOV theorem was tested using sign and rank test on twelve factors of production for 27 countries for the year 1967 by using the 1966 United States technology matrix. The number of correctly matched sign on the sign test was greater than 50% for eleven out of twelve factors and but greater than 70% for only four factors of production. The authors found that the main reasons why the HOV theorem has no strong support in data are disproportionate consumption, technological differences across countries and measurement errors. Kim (1991) used the factor content model to evaluate the trade patterns of Korea in trade with the United States and Japan using 1978 Korea's and the United States' total input requirements. He observed whether the factor abundance determines the sign of net exports. It was shown that the HOV theorem does not perform well in predicting trade patterns when differences in technological capabilities are ignored. Trefler (1995) investigated the features of data that led to the poor performance of the HOV theorem identifying pronounced patterns in the deviations from the HOV model. Important facts such as the case of missing trade and the endowments paradox have often gone unnoticed. Davis et al. (1997) used Japanese regional data to test the HOV model. The strict HOV theorem performed poorly. The authors made two modifications regarding the general model; they abandoned the notion of identical technologies across countries and focused on production and absorption instead of using trade data. Furthermore, when the assumption of universal factor price equalization was relaxed, the HOV model performed remarkably well. Maskus and Webster (1999) developed a version of the HOV theorem with parametric technological differences. The econometric model on factor contents of trade data, output and consumption for the United States and the United Kingdom allowed for factor-specific and industry-specific productivity differences. Davis and Weinsten (2001) emphasized the importance of intermediates, aggregation bias and differences in patterns of absorption. Choi (2004) relaxed the assumption of ideal factor price equalization deriving a modified HOV theorem to predict the factor content of trade. The modified HOV theorem used input-output coefficients of the source country for each traded good which resulted in approval of theorem validity. Romalis (2004) derived and examined the factor proportions model in commodity markets. He made modifications in the standard Heckscher-Ohlin model by introducing transport costs and monopolistic competition. There was support in data for the Rybczynski effect for fast-growing economies. Chakrabarti (2005) demonstrated the importance of accounting for the absorption of inputs in a factor augmenting model of international productivity differences. The absence of such accounting can lead to biases in calculation of productivity parameters and could raise concerns about the decision about the HOV theorem acceptance or rejection. Requena et al. (2005) studied the HOV model empirically using Spanish regional data. After relaxing the strict assumptions of the HOV theorem such as factor price equalization, identical homothetic preferences and Hicks neutral technological differences, the model performed poorly.

Nishioka (2005) explored the international trade within the HOV model for the developed OECD countries. The knowledge factor was introduced into the HOV framework. It played an important role in determining comparative advantages for technologically advanced OECD countries. The strict HOV model with the inclusion of knowledge capital held on its own. Maskus and Nishioka (2006) estimated factor productivities from individual technology data for 15 OECD countries. The HOV theorem showed ability to explain North-South factor trade depending on factor abundance and productivity gaps. Factor-augmenting productivity differences were found as appropriate modification of the HOV theorem. Artal-Tur et al. (2008) built an assemble dataset for 17 Spanish regions for the years 1995, 2001 and 2004 by employing regional specific input-output tables. The inclusion of intermediate inputs in the computation of technology matrix slightly improved the number of correct matches on the sign test. Lu, Milner and Yu (2009) applied factor content tests using data for 58 countries and six factors of production. The results in general showed weak support for the HOV model with minor improvements achieved after adjusting for technology differences across countries.

Srivastava (2012) tackled the HOV theorem with the help of the excess supply approach by examining trade performances of ten manufacturing industries in 46 countries for the year 2009. The major source of comparative advantages were capital stock and secondary and higher educated labour. The HOV theorem proved to be valid in more than 60% of cases. Srivastava and Mathur (2014) performed partial and complete tests to investigate the validity of the HOV theorem using India's industry level data from 1989 to 2008 and five factors of production (primary educated labour force, secondary and tertiary level of educated labour force, capital and arable land). Measured signs were correct in more than 50% of cases. Zimring (2015) observed a large and rapid expansion of labour force in West Bank due to near-elimination of commuting into Israel. Production shifted to more labour-intensive industries (the Rybczynski effect). Allowing for district specific deviations the changes in production were consistent with the HOV model of trade. Jošić (2016) tested the factor proportions model in the case of Croatia based on the bilateral merchandise trade data between Croatia and the countries of the European Union and worldwide using the sign test. The results of the sign test have shown that Croatia does not use its comparative advantages effectively, leading to the rejection of the factor proportions model. Wu et al. (2017) investigated the greenhouse gas emissions intensities in Canadian agriculture and processed food industry. Natural resources were found to be the determining factor of Canadian agricultural structure whereby Canadian exports were more capital-intensive than imports.

3. Data and Methodology

The intention was to include in the analysis all countries worldwide. Unfortunately, due to the lack of data a certain number of countries had to be excluded from the analysis. Despite that, 111 countries were observed overall. Table 1 reveals that all parts of the World are well represented regionally. Table 2 shows the distribution of observed countries according to their income. The full list of observed countries is displayed in Table 7.

Table 1 Distribution of observed countries according to their geographic region

Region	Number of countries
East Asia & Pacific	13
Europe & Central Asia	37
Latin America & Caribbean	16
Middle East & North Africa	12
North America	2
South Asia	4
Sub-Saharan Africa	27
Total	111

Source: authors according to World Bank (2018, 2019a-d) and Trade Map (2019).

Table 2 Distribution of observed countries according to their income

Income level	Number of countries
Low income	17
Lower middle income	27
Upper middle income	24
High income: non-OECD	14
High income: OECD	29
Total	111

Source: authors according to World Bank (2018, 2019a-d) and Trade Map (2019).

In order to perform the factor endowment analysis, the data have been collected for 10 different variables representing factors of production, GDP and technology differences. The starting point for the variable selection were the previous findings in this field of research with papers presented in the literature review. The final decision upon the list of variables which were included in the analysis, was made based on data availability. World Bank (2018, 2019a-d) and Trade Map (2019) databases were used as data sources. The complete list of observed variables is displayed in Table 3.

Table 3 List of observed variables

Variable group	Variable code	Variable
Income	GDP	Gross domestic product (GDP) (in USD)
Production factors	PCAP	Produced capital (in USD)
	LABF	Labour force (number of persons)
Natural resources	FOR	Forests (in USD)
	MMIN	Metals and minerals (in USD)
	OCNG	Oil, coal and natural gas (in USD)
	PAST	Pastureland (in USD)
	CROP	Cropland (in USD)
	FISH	Fishing (in metric tons)
Technology	R&D	Number of researchers in R&D per million people

Source: authors according to World Bank (2018, 2019a-d) and Trade Map (2019).

Furthermore, the data availability determined the observed period as well. It has been decided that data which are available for the most recent period will be collected. According to the observed databases it turned out that the data for the year 2014 are the most recent one for the most of observed variables. Unfortunately, the R&D variable had missing data for 46 countries (41.44%). In these cases, the data for the period closest to the year 2014 were used as an approximation for 2014 data. The fact that the missing values were imputed by using data from different periods should be taken as a limitation of the research. Therefore, the results where R&D variable was included in the analysis should be observed and discussed with special attention. According to Erlat and Erlat (2003) products can be grouped into five groups with a different product factor intensity level. The goods have been classified into five product groups according to their product intensity. Those are raw material intensive goods (RMIG), labour-intensive goods (LIG), capital-intensive goods (CIG), easy-to-imitate research-intensive goods (EIRIG) and difficult-to-imitate research-intensive goods (DIRIG). The HOV model is defined as follows (Feenstra, 2003):

$$F_i = V_i - s_i V_w \quad (1)$$

where F_i is the factor content of trade of country i, V_i is the factor abundance of the country i, s_i is the share of i -th country's GDP in the World GDP and V_w is the World factor abundance. In the traditional HOV model the signs on the left and right side of the Equation 1 are compared. Standard sign tests of the HOV theorem go roughly as follows: (1) calculate the imports and exports of a country in terms of factors embodied in the goods that are traded, (2) compare the country's share of World's GDP to a country's share of each factor of endowment in the total World's endowment of that factor and (3) a country should be a net exporter of products that intensively uses abundant factor of production.

This paper implements new approach to explore the validity of the Heckscher-Ohlin-Vanek theorem by using normalized trade balance concept on the left side of the Equation 1. Therefore, instead of calculating net factor content of trade from input-output tables, the normalized trade balance was calculated. The normalized trade balance is calculated using the following equation:

$$TB_{ij} = \frac{E_{ij} - I_{ij}}{E_{ij} + I_{ij}} \tag{2}$$

where TB_{ij} is trade balance of country i for the product group j, E_{ij} is export of country i for product group j and I_{ij} is the import of country i for the product group j. According to the Equation 2, if the export of products in a country i is larger than the import of the same product groups, the resulting sign is positive and vice versa. The Equation 2 assumes identical technology and factor content of imports and exports, which can be observed as a disadvantage of new the approach. The normalized trade balance alone, however, does not measure the factor content of trade. It has been used as a concept in the literature for decades as an alternative measure for the revealed comparative advantage. Therefore, in the paper the sign test is conducted by comparing the expected sign of the net exports of SITC 2 product classification with the relative endowment of production factors intensively used in the production of a specific product, as given here:

$$Sign(TB) = Sign\left(V_i^k - s_i V_w^k\right) \tag{3}$$

This paper takes a different approach, testing the HOV theorem good-by-good. That is, instead of testing whether country's total trade in a factor is as we would expect from the country's factor abundance, it tests, for each good the country trades, whether it is traded (on net) in the right direction. For example, if a country is labour abundant, it tests whether each good that is produced with the labour intensive technology is (on net) exported. The whole analysis procedure can be briefly described as follows. Firstly, the standardized trade balances for each of 96 product groups (there are no groups of products with codes 00, 77 and 98 whereas the product group 99 includes everything that was not classified before and because of that it is omitted from the analysis) of all 111 countries are calculated separately. Afterwards, the values of variables for each observed country are compared to the World value and the corresponding share (proportion) is calculated. Due to the specific characteristics of the R&D variable, for this variable the countries values are compared to the World average value. The resulting shares or proportions are then compared to the GDP share of the observed country in the overall World GDP value. If the calculated share is higher than the GDP share, it is assumed that the observed country is abundant in that factor of production. Consequently, the conclusion is that the country should export product which intensively uses the abundant factor of production and in that case the positive sign will be achieved on the sign test. Finally, two estimated signs are compared and it is checked whether they match or not. It is assumed that the sign test will result in a match in at least 50% of cases.

4. RESULTS AND DISCUSSION

The sign test will be conducted by using the total of 10 variables observed in the data and methodology section. In order to get the insight about the distributions of the observed variables in Table 4, the basic descriptive statistics of results is provided.

Table 4 Descriptive statistics results of the observed variables, n=111 selected countries, data for 2014

Variable	Unit	Statistics							
		Average	St. Dev.	Coeff. var.	Min	1st quart.	Median	3rd quart.	Max
GDP	bil. USD	669	2,038	304	1	20	66	405	17,428
PCAP	bil. USD	2,688	8,164	304	3	66	236	1,425	68,943
LABF	mill. per.	27	89	332	0	2	6	19	787
MMIN	bil. USD	87	315	362	0	0	3	21	2,101
FOR	bil. USD	21	52	251	0	1	5	16	353
OCNG	bil. USD	275	765	279	0	0	4	80	4,952
PAST	bil. USD	119	350	295	0	10	29	75	2,848
CROP	bil. USD	225	963	427	0	10	43	123	9,676
FISH	mill. MT	2	8	479	0	0	0	1	76
R&D	no. per mill.	1,566	2,024	129	7	70	565	2,640	7,311

Source: authors' calculation.

According to the descriptive statistics results from the Table 4 it can be easily concluded that there are huge differences between 111 observed countries for each of the selected variables. The lowest variation in data, according to the coefficient of variation, seems to be for the R&D variable (129%) whereas the largest is for the FISH variable (479%). The comparison of differences between the minimum and the maximum values shows that data ranges are very wide. If the values of quartiles are observed, it can be concluded that all variables are highly positively skewed.

The main descriptive statistics results of calculated shares for the observed countries in the whole World value are shown in Table 5. As expected, according to the results from Table 4, huge differences in shares (proportions) are present here as well.

Table 5 Descriptive statistics of calculated shares for the observed countries in the whole World value, n=111 selected countries, data for 2014

Statistics	Variable									
	GDP	PCAP	LABF	MMIN	FOR	OCNG	PAST	CROP	FISH	R&D
Average	0.0085	0.0089	0.0081	0.0086	0.0087	0.0070	0.0085	0.0087	0.0081	1.0628
St.Dev.	0.0258	0.0269	0.0268	0.0310	0.0218	0.0196	0.0250	0.0372	0.0390	1.3742
Coeff.Var.	304	304	332	362	251	279	295	427	479	129
Min	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0049
1st quar.	0.0002	0.0002	0.0007	0.0000	0.0004	0.0000	0.0007	0.0004	0.0001	0.0476
Median	0.0008	0.0008	0.0019	0.0003	0.0019	0.0001	0.0021	0.0016	0.0009	0.3832
3rd quar.	0.0051	0.0047	0.0058	0.0021	0.0067	0.0020	0.0054	0.0048	0.0032	1.7920
Max	0.2202	0.2271	0.2360	0.2069	0.1471	0.1267	0.2036	0.3736	0.3934	4.9628

Source: authors' calculation.

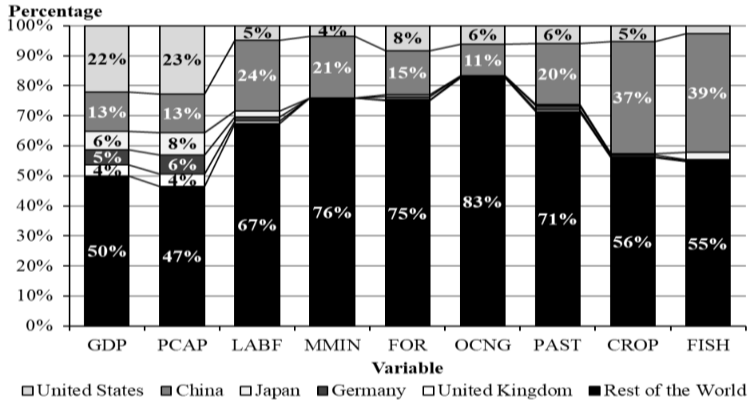

Fig. 1 Factor endowment shares, top five countries according to the GDP share in the World value and the rest of the World, data from 2014

In Figure 1 the top five countries according to the share of GDP value in the total World GDP value are emphasized. According to the Figure 1, those five countries (the United States of America, China, Japan, Germany and the United Kingdom) together encompass the half of the World's total GDP. What's more intriguing, they together dispose with more than half of the World's total produced capital. In other observed variables, the main contributor to the share of those five countries in the total World's values is China meaning that China is abundant in these factors of production. Whereas in Figure 1 five countries with the largest GDP share in the World value were pointed out, in Table 6 countries with the lowest shares of each variable in the whole World value were displayed.

Table 6 The last five observed countries according to observed variables values compared to the World level, data for 2014

Variable	Statistics	Rank 111	Rank 110	Rank 109	Rank 108	Rank 107
GDP	Country	Gambia	Swaziland	Togo	Malawi	Moldova
	Value	1.5911E-05	5.5317E-05	5.7738E-05	7.6427E-05	1.0089E-04
PCAP	Country	Gambia	Togo	Malawi	Rwanda	Madagascar
	Value	9.8129E-06	4.6023E-05	5.1648E-05	5.7452E-05	7.1365E-05
LABF	Country	Iceland	Malta	Luxembourg	Swaziland	Mauritius
	Value	5.9652E-05	5.9865E-05	8.2163E-05	1.2904E-04	1.7930E-04
MMIN	Country	Bahrain, Belgium, Cambodia, Denmark, El Salvador, Estonia, Gambia, Iceland, Italy, Kuwait, Latvia, Lithuania, Malta, Mauritius, Moldova, Nepal, Netherlands, Paraguay, Qatar, Singapore, Slovenia, Swaziland, United Arab Emirates, West Bank and Gaza				
	Value	0				
FOR	Country	Malta, West Bank and Gaza		Bahrain	Iceland	Oman
	Value	0		2.1372E-07	5.3979E-07	8.9456E-07
OCNG	Country	Belgium, Burkina Faso, Cambodia, Costa Rica, El Salvador, Finland, Gambia, Honduras, Iceland, Kenya, Latvia, Luxembourg, Madagascar, Mali, Malta, Mauritius, Namibia, Nicaragua, Panama, Paraguay, Portugal, Rwanda, Singapore, Sri Lanka, Sweden, Switzerland, Togo, Uganda, Uruguay, West Bank and Gaza				
	Value	0				
PAST	Country	Singapore	Malta	Bahrain	Mauritius	Qatar
	Value	1.4069E-07	1.4813E-05	3.4674E-05	3.5316E-05	6.5091E-05
CROP	Country	Iceland	Singapore	Bahrain	Malta	Luxembourg
	Value	2.4472E-06	6.9917E-06	1.0849E-05	1.7096E-05	1.7712E-05
FISH	Country	Luxembourg	Swaziland	Botswana	Macedonia, FYR	Jordan
	Value	0	8.5295E-07	6.0379E-06	7.7334E-06	9.0878E-06
R&D	Country	Congo, Dem. Rep.	Niger	Rwanda	Lao PDR	Tanzania
	Value	4.9069E-03	5.0343E-03	8.3818E-03	1.0743E-02	1.2448E-02

Source: authors' calculation.

Table 7 Results of the sign tests according to the observed countries, data for 2014

Country	Sign matching		Share of	Country	Sign matching		Share of
	Yes	No	matched signs		Yes	No	matched signs
Albania	27	68	28%	Madagascar	52	44	54%
Argentina	75	21	78%	Malawi	47	49	49%
Australia	57	39	59%	Malaysia	47	49	49%
Austria	58	38	60%	Mali	39	57	41%
Bahrain	84	12	88%	Malta	71	25	74%
Belgium	47	49	49%	Mauritius	59	37	61%
Bolivia	49	47	51%	Mexico	60	36	63%
Bosnia and Herzegovina	37	59	39%	Moldova	41	54	43%
Botswana	50	46	52%	Morocco	35	61	36%
Brazil	65	31	68%	Mozambique	40	56	42%
Bulgaria	35	61	36%	Namibia	54	42	56%
Burkina Faso	46	48	49%	Nepal	48	48	50%
Cambodia	50	45	53%	Netherlands	62	34	65%
Canada	54	42	56%	Nicaragua	39	57	41%
Chad	42	53	44%	Niger	23	70	25%
Chile	74	22	77%	Nigeria	36	60	38%
China	61	35	64%	Norway	65	31	68%
Colombia	48	48	50%	Oman	87	8	92%
Congo, Dem. Rep.	30	66	31%	Pakistan	57	39	59%
Congo, Rep.	23	72	24%	Panama	79	17	82%
Costa Rica	49	47	51%	Papua New Guinea	43	53	45%
Cote d'Ivoire	48	48	50%	Paraguay	49	47	51%
Croatia	63	33	66%	Philippines	52	44	54%
Denmark	49	47	51%	Poland	47	49	49%
Ecuador	44	52	46%	Portugal	44	52	46%
Egypt, Arab rep.	49	47	51%	Qatar	88	8	92%
El Salvador	45	51	47%	Romania	34	59	37%
Estonia	57	39	59%	Russian Federation	63	33	66%
Ethiopia	48	47	51%	Rwanda	43	53	45%
Finland	64	32	67%	Senegal	45	51	47%
France	59	37	61%	Singapore	67	29	70%
Gambia, The	41	53	44%	Slovak Republic	59	37	61%
Georgia	35	61	36%	Slovenia	58	38	60%
Germany	51	45	53%	South Africa	36	59	38%
Ghana	41	55	43%	Spain	45	51	47%
Greece	54	42	56%	Sri Lanka	60	36	63%
Guatemala	43	53	45%	Swaziland	35	61	36%
Honduras	39	57	41%	Sweden	63	33	66%
Hungary	45	51	47%	Switzerland	63	33	66%
Iceland	57	39	59%	Tanzania	50	46	52%
India	62	34	65%	Thailand	63	33	66%
Indonesia	59	37	61%	Togo	41	51	45%
Iraq	87	3	97%	Tunisia	43	53	45%
Ireland	66	30	69%	Turkey	64	32	67%
Italy	44	52	46%	Uganda	50	46	52%
Japan	68	28	71%	Ukraine	39	56	41%
Jordan	54	41	57%	United Arab Emirates	70	26	73%
Kazakhstan	72	23	76%	United Kingdom	68	28	71%
Kenya	50	46	52%	United States	59	37	61%
Korea, Rep.	64	32	67%	Uruguay	63	33	66%
Kuwait	89	7	93%	Venezuela, RB	75	21	78%
Lao PDR	45	51	47%	Vietnam	53	42	56%
Latvia	54	42	56%	West Bank and Gaza	30	62	33%
Lithuania	58	38	60%	Zambia	32	64	33%
Luxembourg	61	35	64%	Zimbabwe	43	53	45%
Macedonia, FYR	41	54	43%				

Source: authors' calculation.

The calculated shares for the observed countries in the whole World value are paired with a certain product groups and are compared with the GDP share. In the case when the calculated share for a certain product group in a country is larger than the share of GDP in total World's GDP value, a positive sign is attached to that product group. Namely, in that case, it is expected that the country should have a positive net exports in that product. The Equation 2 is used to calculate the normalized trade balances for each product groups and for each country. If the normalized trade balance results in a positive score, a positive sign should also be obtained for country's factor endowment. The sign test is conducted by checking whether the two estimated signs match or not. The assumption is that the factor endowment signs and normalized trade balance signs would match in at least 50% of cases.

In Table 7 the results of the sign tests for each of the observed countries are shown. Overall sign matching rate turned out to be 55% (5,845 matched signs and 4,774 unmatched signs) which is similar to what has been found out within the standard signs test in previous studies leading to the conclusion that HOV theorem does not offer a very good description of reality. The countries with the highest sign matching rates, which are above 90%, are Iraq (97%), Kuwait (93%), Qatar (92%) and Oman (92%). On the other hand, countries with the lowest sign matching rates, which are below 30%, are the Republic of the Congo (24%), Niger (25%) and Albania (28%).

Table 8 Results of the sign tests according to the groups of products, data for 2014

Code	Product	Sign matching		Share of matched signs
		Yes	No	
01	Live animals	44	67	40%
02	Meat and edible meat offal	52	59	47%
03	Fish and crustaceans, molluscs and other aquatic invertebrates	75	36	68%
04	Dairy produce; birds' eggs; natural honey; edible products of animal origin	45	66	41%
05	Products of animal origin, not elsewhere specified or included	55	56	50%
06	Live trees and other plants; bulbs, roots and the like; cut flowers etc.	65	46	59%
07	Edible vegetables and certain roots and tubers	68	43	61%
08	Edible fruit and nuts; peel of citrus fruit or melons	77	34	69%
09	Coffee, tea, maté and spices	77	34	69%
10	Cereals	49	62	44%
11	Products of the milling industry; malt; starches; inulin; wheat gluten	48	63	43%
12	Oil seeds and oleaginous fruits; miscellaneous grains, seeds and fruit; etc.	67	44	60%
13	Lac; gums, resins and other vegetable saps and extracts	54	57	49%
14	Vegetable plaiting materials; vegetable products not elsewhere spec. etc.	78	31	72%
15	Animal or vegetable fats and oils and their cleavage products; etc.	64	47	58%
16	Preparations of meat, of fish or of crustaceans, molluscs etc.	73	38	66%
17	Sugars and sugar confectionery	60	51	54%
18	Cocoa and cocoa preparations	58	53	52%
19	Preparations of cereals, flour, starch or milk; pastry cooks' products	46	65	41%
20	Preparations of vegetables, fruit, nuts or other parts of plants	64	47	58%
21	Miscellaneous edible preparations	43	68	39%
22	Beverages, spirits and vinegar	65	46	59%
23	Residues and waste from the food industries; prepared animal fodder	56	55	50%
24	Tobacco and manufactured tobacco substitutes	53	58	48%
25	Salt; sulphur; earths and stone; plastering materials, lime and cement	64	47	58%
26	Ores, slag and ash	81	30	73%
27	Mineral fuels, mineral oils and products of their distillation; etc.	95	16	86%
28	Inorganic chemicals; organic or inorganic compounds etc.	68	43	61%
29	Organic chemicals	76	35	68%
30	Pharmaceutical products	85	26	77%
31	Fertilisers	64	47	58%
32	Tanning or dyeing extracts; tannins and their derivatives; dyes, etc.	78	33	70%
33	Essential oils and resinoids; perfumery, cosmetic or toilet preparations	65	46	59%
34	Soap, organic surface-active agents, washing preparations, etc.	70	41	63%

Code	Product	Sign matching		Share of
		Yes	No	matched signs
35	Albuminoidal substances; modified starches; glues; enzymes	85	26	77%
36	Explosives; pyrotechnic products; matches; pyrophoric alloys; etc.	74	37	67%
37	Photographic or cinematographic goods	81	30	73%
38	Miscellaneous chemical products	82	29	74%
39	Plastics and articles thereof	85	26	77%
40	Rubber and articles thereof	35	76	32%
41	Raw hides and skins (other than fur skins) and leather	62	49	56%
42	Articles of leather; saddlery and harness; travel goods, handbags etc.	55	56	50%
43	Fur skins and artificial fur; manufactures thereof	45	60	43%
44	Wood and articles of wood; wood charcoal	78	33	70%
45	Cork and articles of cork	49	62	44%
46	Manufactures of straw, of esparto or of other plaiting materials; etc.	70	41	63%
47	Pulp of wood or of other fibrous cellulosic material; recovered etc.	60	50	55%
48	Paper and paperboard; articles of paper pulp, of paper or of paperboard	39	72	35%
49	Printed books, newspapers, pictures and other products of the printing etc.	37	74	33%
50	Silk	51	58	47%
51	Wool, fine or coarse animal hair; horsehair yarn and woven fabric	38	73	34%
52	Cotton	55	56	50%
53	Other vegetable textile fibres; paper yarn and woven fabrics of paper yarn	54	57	49%
54	Man-made filaments; strip and the like of man-made textile materials	44	67	40%
55	Man-made staple fibres	46	65	41%
56	Wadding, felt and nonwovens; special yarns; twine, cordage, ropes etc.	43	68	39%
57	Carpets and other textile floor coverings	50	61	45%
58	Special woven fabrics; tufted textile fabrics; lace; tapestries; etc.	42	69	38%
59	Impregnated, coated, covered or laminated textile fabrics; etc.	36	75	32%
60	Knitted or crocheted fabrics	36	74	33%
61	Articles of apparel and clothing accessories, knitted or crocheted	71	40	64%
62	Articles of apparel and clothing accessories, not knitted or crocheted	70	41	63%
63	Other made-up textile articles; sets; worn clothing, etc.	59	52	53%
64	Footwear, gaiters and the like; parts of such articles	61	50	55%
65	Headgear and parts thereof	57	54	51%
66	Umbrellas, sun umbrellas, walking sticks, seat-sticks, whips, etc.	49	61	45%
67	Prepared feathers and down and articles made of feathers or of down; etc.	60	51	54%
68	Articles of stone, plaster, cement, asbestos, mica or similar materials	42	69	38%
69	Ceramic products	47	64	42%
70	Glass and glassware	42	69	38%
71	Natural or cultured pearls, precious or semi-precious stones, etc.	65	45	59%
72	Iron and steel	70	41	63%
73	Articles of iron or steel	72	39	65%
74	Copper and articles thereof	72	39	65%
75	Nickel and articles thereof	66	45	59%
76	Aluminium and articles thereof	68	43	61%
78	Lead and articles thereof	55	55	50%
79	Zinc and articles thereof	72	38	65%
80	Tin and articles thereof	59	50	54%
81	Other base metals; cermets; articles thereof	59	49	55%
82	Tools, implements, cutlery, spoons and forks, of base metal; etc.	41	70	37%
83	Miscellaneous articles of base metal	42	69	38%
84	Machinery, mechanical appliances, nuclear reactors, boilers; parts thereof	87	24	78%
85	Electrical machinery and equipment and parts thereof; etc.	84	27	76%
86	Railway or tramway locomotives, rolling stock and parts thereof; etc.	81	30	73%
87	Vehicles other than railway or tramway rolling stock, and parts etc.	78	33	70%
88	Aircraft, spacecraft, and parts thereof	75	35	68%
89	Ships, boats and floating structures	76	34	69%
90	Optical, photographic, cinematographic, measuring, checking, etc.	91	20	82%
91	Clocks and watches and parts thereof	74	37	67%
92	Musical instruments; parts and accessories of such articles	54	57	49%
93	Arms and ammunition; parts and accessories thereof	32	66	33%
94	Furniture; bedding, mattresses, mattress supports, cushions etc.	50	61	45%
95	Toys, games and sports requisites; parts and accessories thereof	52	59	47%
96	Miscellaneous manufactured articles	43	68	39%
97	Works of art, collectors' pieces and antiques	55	55	50%
Total		5,845	4,774	55%

Note: due to the limited space, the titles of product groups have been cut.

Source: authors' calculation.

Table 8 shows the results of the sign tests according to the product groups. The product groups with the highest sign matching rates, which are above 80%, are Mineral fuels, mineral oils and products of their distillation; bituminous substances; etc. – code 27 (86%) and Optical, photographic, cinematographic, measuring, checking, precision, medical or surgical etc. – code 90 (82%). On the other hand, the product groups with the lowest sign matching rates, which are below 35%, are Rubber and articles thereof – code 40 (32%), Impregnated, coated, covered or laminated textile fabrics; textile articles of a kind suitable etc. – code 59 (32%), Arms and ammunition; parts and accessories thereof – code 93 (33%), Knitted or crocheted fabrics – code 60 (33%), Printed books, newspapers, pictures and other products of the printing industry; manuscripts – code 49 (33%) and Wool, fine or coarse animal hair; horsehair yarn and woven fabric – code 51 (34%).

In Figure 2 the percentages of matched signs according to geographical region of a country are shown. The most successful matched signs rate was achieved in countries from the Middle East and North Africa (69%). The key finding is that HOV mainly holds in oil-rich economies. One of the reasons for this could be a focus on exports of only one essential product, oil, but a more detailed analysis should be conducted to validate this result. On the other hand, only countries from Sub-Saharan Africa achieved the percentage of matched signs below 50%.

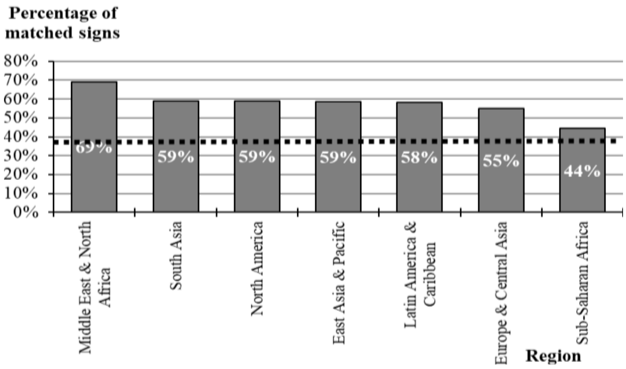

Fig. 2 Percentage of matched signs according to geographical region of a country, n=111 observed countries, data for 2014

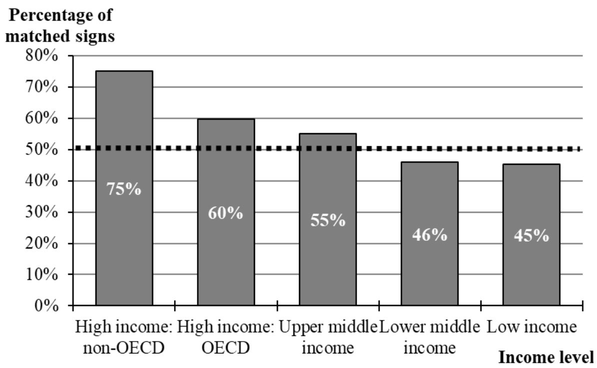

Fig. 3 Percentage of matched signs according to income level of countries, n=111 observed countries, data for 2014

The successfulness of signs matching was observed according to the country income level as well. Figure 3 shows that the highest percentage of matched signs is achieved for countries having high income and which are not members of the Organisation for Economic Cooperation and Development (OECD). Countries with lower middle income (46%) and low income (45%) achieved lower percentage of matched signs in comparison to the benchmark value of 50%. It could be asked: why do rich countries have higher matching rates than poor countries? The reason could be more efficient use of country's comparative advantages and the specialization in production and export.

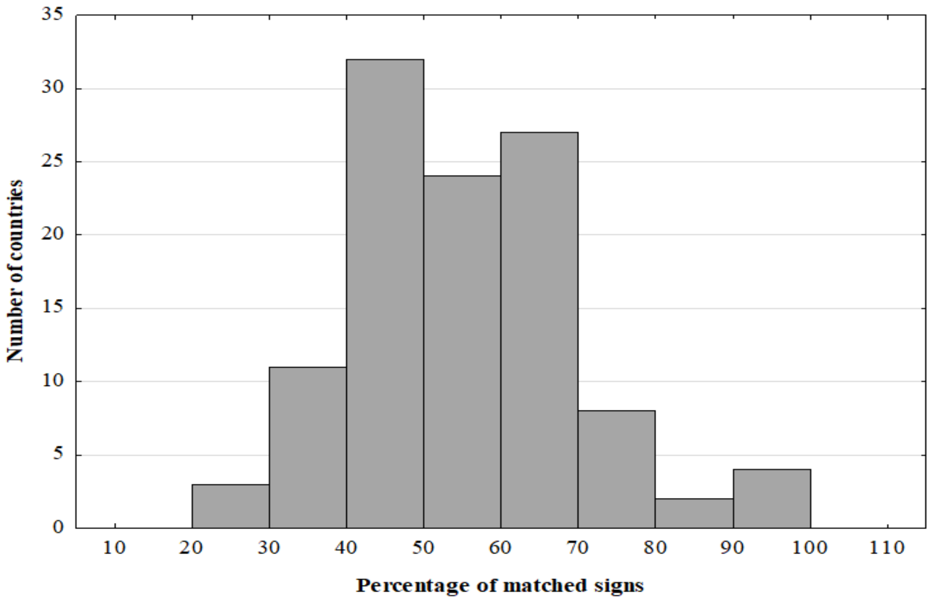

Fig. 4 Histogram of distribution of matched signs, n=111 observed countries, data for 2014

Finally, in Figure 4 the histogram of distribution of matched signs across countries is shown. It turned out that most countries (32) have a percentage of matched signs between 40% and 50%. It has to be emphasized that three countries, out of thirty-two, have a percentage of matched signs that equals 50%. However, 68 countries or 61% of observed countries have a percentage of matched signs above the benchmark value of 50%.

Previous empirical tests mainly failed to prove HOV theorem, or did so only in a certain extent, which provides ground for further (amended) tests. We should keep in mind that completely random pattern of signs, such as obtained by flipping a coin, would still generate correct signs 50% of the time in a large sample. Overall result of the sign test conducted in this paper is only 55% of matched signs, which is not enough to present it as a proof of HOV theorem validity. Therefore, the sign test must do considerably better in order to be concluded that the HOV theorem is empirically sound. The advantage of this approach is that it allows for the larger sample of countries to be included in the analysis. Disadvantage of this approach is that it assumes the identical technology in countries despite the inclusion of the R&D variable. Also gross value of trade flows does not reveal country's value added comprised in these flows. For example, China's huge exports of hitech electronics do not represent its net exports of capital intensive and R&D intensive products, because its value added in this sector is different from value added upward in the global value chain.

5. CONCLUSIONS

This paper introduces new approach for testing the Heckscher-Ohlin-Vanek theorem. The HOV theorem was tested in the case of 111 countries worldwide. Instead of calculating the factor content requirements based on the input-output tables, the normalized trade balance was calculated. The products or goods are divided into five groups according to their production intensity (labour-intensive goods, capital intensive goods, natural-resources intensive goods, easy-to-imitate technology intensive goods and hard-to-imitate technology intensive goods). Furthermore, the countries' factors of production are divided into produced capital, labour force and natural resources further divided into six factors. The sign test inspected correct matching signs between normalized trade balance indices and factor endowments for each country and product according to the SITC 2 classification of products. Overall sign matching rate turned out to be 55% (5,845 matched signs and 4,774 unmatched signs). Countries with the highest sign matching rates of above 90% were Iraq (97%), Kuwait (93%), Qatar (92%) and Oman (92%). Countries with the lowest sign matching rates, of below 30% were the Republic of the Congo (24%), Niger (25%) and Albania (28%). It seems that countries with a higher income level have higher percentage of matched signs (high-income non-OECD and high-income OECD countries with 75% and 60% of sign matches respectively). On the other hand, lower-middle income and low-income countries had a percentage of matched signs below 50%. The fact that the missing values were imputed by using data from other periods should be taken as a limitation of research so the results where the R&D variable was included in the analysis should be carefully discussed. Further research should be made by using this new approach. Improvement could be made by including productivity differences among countries by calculating the effective factor endowments.

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TESTIRANJE HECKSCHER-OHLIN-VANEKOVOG TEOREMA KORIŠĆENJEM PRISTUPA NORMALIZOVANOG TRGOVINSKOG BILANSA

Studija opisana ovde uvodi pristup normalizovanog trgovinskog bilansa za testiranje Heckscher-Ohlin-Vanekovog (HOV) teorema. Namera je bila da se sve zemlje širom sveta uključe u analizu, ali je zbog nedostatka podataka određeni broj zemalja morao da bude isključen iz analize. Zbog toga je ukupno 111 zemalja primećeno prema regionu i nivou prihoda u 2014. Pri proceni HOV modela koristio se test predznaka. Test je uporedio očekivani znak normalizovanog trgovinskog bilansa ili neto izvoza prema klasifikaciji proizvoda SITC 2 sa relativnom zadužbinom proizvodnih faktora koji se intenzivno *koriste u proizvodnji određenog proizvoda. Proizvodni faktori su podeljeni na grupe kao što su proizvedeni kapital, radna snaga i prirodni resursi koji su dodatno podeljeni na šume, metale i minerale, naftu, ugalj i gas, pašnjake i useve. Varijabla istraživači u R&D na milion ljudi predstavlja uticaj tehnoloških razlika širom zemalja. Rezultat testa predznaka je pokazao da HOV teorem drži u 55 odsto slučajeva. Procenat podudarnih predznakova je najveći za zemlje sa visokim prihodima koje nisu članice OECD-a (75%) i najniži za zemlje sa nižim srednjim prihodima i niskim prihodima (ispod 50%).*

Ključne reči: *Heckscher-Ohlin-Vanekov model, test predznaka, pristup normalizovanog trgovinskog bilansa, svet*