Factor Content of Agricultural Trade

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Abstract

The paper studies the factor content of agricultural trade in the EU. We examine the relative abundance for labour, capital and land in old and new EU member states, and test the Heckscher-Ohlin (HO) hypothesis in two different settings: the standard and a more general. Our empirical findings suggest that the HO model performs better in the developed market economy trade than in the CEE transition country trade. The relative factor price distortions during the central planning period might be responsible for this. Second, we find that the HO model performs considerable better when relaxing the factor price equalisation between countries. These findings support the more general versions of the HO model.

Keywords: Heckscher-Ohlin, Factor Content, Agricultural Trade, Factor Abundance.

JEL classification: F12, F14, D23, Q12, Q17.

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1 Introduction

Relative factor endowment models continue to play a prominent role in international trade literature. There are two principal reasons why one of the key objectives of the international economic research has been to account for the factor content of trade. The first is that economists want to trace the effects of international influences on relative and absolute factor prices within a country. The Heckscher-Ohlin (HO) model and its variants, with their emphasis on trade arising from differences in the availability of productive factors, provide a natural setting for such investigations (*Davis* and *Weinstein* 2001; *Debaere* 2003).

The second reason for the focus on the factor content of trade is that it provides a precise prediction against which to measure how well do trade models work. The relative factor endowment models are extraordinary in their ambition. They propose to describe, with a few parameters and in a unified constellation, the endowments, technologies, production, absorption, and trade of all countries in the world. This juxtaposition of extraordinary ambition and parsimonious specification have made these theories irresistible to empirical researchers (*Davis* and *Weinstein* 2001; *Debaere* 2003).

Both drivers of the relative factor endowment literature are important in the present study. On the one hand, we indirectly examine the effects of the central planning and market restructuring influences on relative and absolute factor prices within the CEE transition economies.[1] On the other hand, we compare the performance of two different versions of the HO model. Unlike most other studies on the relative factor abundance, which usually test the developed country factor intensities in the manufacturing trade (*Deardorff* 1984), the present study examines the factor content of the EU agricultural trade.

Complementing the previous work of *Schluter* and *Lee* (1978); *Lee*, *Wills* and *Schluter* (1988); *Kancs* and *Ciaian* (2009), the present study makes three contributions to the existing literature: (i) it assesses the performance of two alternative versions of the HO model - the standard and a more general; (ii) it extends the empirical literature on the factor content of agricultural trade and, as in *Leamer* (1987), includes land among the primary factors; (iii) it provides empirical evidence of the factor price distortions in the the post-communist transition country trade, which we compare with the developed EU countries.

In the empirical analysis we use data for 2004. The agricultural trade data is extracted from the COMEXT trade data base *Eurostat* (2007) and the GTAP 7 data base. The COMEXT data base provides data for Member States of the European Union on external trade with each other and with non-member countries. The technology coefficients are calculated from the Farm Accountancy Data Network (FADN) firm-level data.

[1] In the present study Central and Eastern Europe (CEE) refers to Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia and Slovenia.

The paper is organised as follows. Section 2 introduces the theoretical framework for examining the factor content of trade. Section 2.1 presents the standard Heckscher-Ohlin-Vanek (HOV) setup, where countries trade because of differences in the relative factor endowments. Section 2.2 extends the general framework by allowing for factor price variation across countries. In section 3 we examine factor intensities of the CEE agricultural trade and test the HO hypothesis of both models. Section 4 concludes and outlines avenues for future research.

2 Theoretical framework

2.1 The Heckscher-Ohlin-Vanek model

The standard multifactor, multicommodity, and multicountry model for predicting factor content of trade is the HOV model, which relates the factor content of trade to the relative country endowment with production factors. The key assumptions are identical technologies and identical and homothetical preferences across countries, differences in factor endowment, and free trade in goods and services. The HOV model predicts that if all countries would have their endowments within their cone of diversification, then factor prices were equalised across countries.

Assume that $r = 1, .., o, .., d, .., w, .., R$ index countries, $i = 1, ..., I$ are industries; and $f = 1, .., f, .., g, .., F$ index factors. Let a_{io} be the amount of production factors used to produce one unit in each industry. Let Y_o be output in o, and let D_o be the demand in origin country o. The net export vector of goods, E_o, originating from country o can then be written as:

$$E_o = Y_o - D_o \tag{1}$$

The factor content of trade, A_o, i.e. the $F \times 1$ vector of trade in factor services, can then be defined as:

$$A_o = a_o E_o \tag{2}$$

where a_o is the amount of production factors used to produce one unit of output in country o. Identical technologies across countries and factor price equalisation imply that $a_o = a$, which makes the interpretation of $A_o = aE_o$ straightforward: a positive value of an element in A_o indicates that the factor is exported and a negative value indicates that the factor is imported.

The factor content of trade can be calculated either for trade with the rest of the world or between country pairs. In the former case country o's consumption, D_o, must be proportional to the total world consumption, D_w:

$$D_o = s_o D_w \tag{3}$$

where s_o is o's share in the world demand, D_w. Assuming that the world production is equal to the world consumption we obtain:

$$aD_o = s_o aD_w = s_o aY_w = s_o F_w \tag{4}$$

Assuming full employment of all primary factors we can write $aY_o = F_o$, where F_o is the factor endowment in country o. Together with the expressions for aE_o and aD_o yields the standard HO hypothesis:

$$A_o \equiv aE_o = F_o - s_o F_w \tag{5}$$

The left hand side of equation (5) captures the production side of the HOV theorem and is often labelled as the measured factor content of trade. The right hand side of equation (5) captures the consumption/demand and is referred to as the predicted factor content of trade.

For factor f the HO hypothesis can be rewritten as:

$$A_o^f = F_o^f - s_o F_w^f \tag{6}$$

where F_o^f and F_w^f are factors f's endowments of country o and the world w. Equation (6) relates country o's factor f's net content of trade to its own and the world's endowments. This world version of the HO hypothesis (6) has been tested in many previous studies yielding both supporting and rejecting results (*Bowen*, *Leamer* and *Sveikauskus* 1987; *Trefler* 1995).

According to *Davis* and *Weinstein* (2001), the world version has several conceptual disadvantages over the country pair version for assessing the success of the HO hypothesis. First, in the country pair version one does not have to employ and construct endowment data for the whole world. This is important because the world endowment figures are wrong as soon as countries are missing, or as soon as the data for a particular country are unreliable. Second, and more importantly, the two-country version requires that the specific HO assumptions hold only for the two countries considered (*Brecher* and *Choudri* 1988). This is important, because as soon as the assumptions of the HO do not hold for the world as a whole, relying on the world endowments is not correct.

As shown in Appendix 5.1, the country pair version of the HO hypothesis can be expressed as follows:

$$\left(\frac{F_d^g}{F_d^f} - \frac{F_o^g}{F_o^f}\right)\left(\frac{A_{od}^f}{A_{od}^g} - \frac{A_{do}^f}{A_{do}^g}\right) \geq 0 \tag{7}$$

where A_{od}^f is factor f's content of trade from o to d. Inequality (7) suggests that if country d is more abundant in g than country o, i.e. $F_d^g/F_d^f > F_o^g/F_o^f$, then the g/f ratio embodied in country d's exports to country o cannot be lower than the g/f ratio embodied in country o's exports to d, i.e. $A_{do}^g/A_{do}^f \geq A_{od}^g/A_{od}^f$.

2.2 The augmented HOV framework

Several authors argue that the unrealistic assumptions of the HOV model is one reason why the HO hypothesis has often been rejected (*Leamer* 1980; *Schott* 2003). In particular, the factor price equalisation is often questioned in the recent literature.

In order to account for the cross-country differences in the relative factor prices, we extend the theoretical framework by following *Brecher* and *Choudhri* (1982); *Helpman* (1984), who consider a trade equilibrium in which factor prices are allowed to differ across countries.[2]

Let w_o be the vector of factor prices in country o. With constant-returns to scale technology, the unit cost, c_{io}, of producing good i in country o is given by

$$c_{io} = w_o a_{io} \tag{8}$$

Perfect competition implies zero profits on exports of good i from origin country o to destination country d. Hence, $c_{io} = p_{io}$ where p_{io} is good i's output price in country o. Under free trade $p_{io} = p_i$ implying that

$$p_i = w_o a_{io} \tag{9}$$

For importing country d, unit profits on good i must be non-positive:

$$p_i \leq w_d a_{id} \tag{10}$$

With constant returns to scale technology and homogenous firms within industries, equation (10) holds for all industry i's firms in importing country d. Combining equations (9) and (10) yields the relationship of unit costs in exporting country, o, and hypothetical unit costs in importing country, d:[3]

$$w_o a_{io} \leq w_d a_{io} \tag{11}$$

Equation (11) describes the predicted relationship between the direct factor requirements, a_{ir}, and factor prices, w_r, for industry i in the trade equilibrium. According to equation (11), direct factor requirement, a_{io}, in exporting country may differ from the direct factor requirement, a_{id}, in importing country due to differences in factor prices, $w_o \neq w_d$.

The aggregate amount, A_{iod}, of factors that is used to produce one unit of sector i's exports from o to d is derived by aggregating (11) over i using industry-level trade volume shares as weights $A_{iod} \equiv a_{io}\left(\frac{E_{iod}}{\sum_i E_{iod}}\right)$:

[2] *Choi* and *Krishna* (2004) are the first to note the implications of these relaxed assumptions for HO testing. Using a sample of 8 OECD countries they test the theoretical predictions of *Helpman* (1984) and find strong evidence supporting the 'augmented' HO hypothesis.

[3] These results are identical with those of free trade in intermediates and uniform technology. For the implications of costly trade of intermediate inputs see *Staiger* (1986).

$$\sum_i w_o A_{iod} \leq \sum_i w_d A_{iod} \tag{12}$$

Alternatively, for importing country d:

$$\sum_i w_d A_{ido} \leq \sum_i w_o A_{ido} \tag{13}$$

where E_{iod} denotes the volume of gross exports of good i from origin country o to destination country d and A_{iod} denotes the vector of weighted factors required directly to produce each unit of E_{iod}. Equations (12) and (13) predict the factor content of bilateral trade between o and d.

As shown in Appendix 5.2, equations (12) and (13) can be rearranged to derive the HO hypothesis of the extended HOV model:

$$\left(\frac{w_d^f}{w_d^g} - \frac{w_o^f}{w_o^g}\right)\left(\frac{A_{do}^g}{A_{do}^f} - \frac{A_{od}^g}{A_{od}^f}\right) \geq 0 \tag{14}$$

Equation (14) implies that if country d has a higher f/g factor price ratio than country o, $(w_d^f/w_d^g > w_o^f/w_o^g)$, then the f/g ratio embodied in country d's exports to o cannot be higher than the f/g ratio embodied in country o's exports to d $(A_{do}^g/A_{do}^f \geq A_{od}^g/A_{od}^f)$.

Several issues need to be noted about equation (14). First, it allows for (although it does not require) cross-country differences in factor prices, $w_o \neq w_d$. Hence we are able to account for the empirically observed variation in factor prices across countries. Second, equation (14) can be used to directly compare factor content of bilateral trade. However, according to *Staiger* (1986), it is not valid for comparing the indirect factor content of bilateral trade. Third, given that all variables are observable in the data, equation (14) can be tested empirically.

3 Empirical results

3.1 Factor content of trade under factor price equalisation

We test two versions of the HO hypothesis: the world version and the country-pair version. For the world version we rewrite equation (6) as a difference between the observed and the predicted factor content of trade. As a result, we obtain testable HO hypothesis for the *world version* of the HOV model:

$$HO_{fo} \equiv A_{od}^f - \left(F_o^f - s_o F_w^f\right) = 0 \tag{15}$$

We estimate equation (15) for two groups of EU countries instead of the whole world.[4] This allows us to avoid constructing and employing endowment data for the world as a whole, which is not available for agricultural activities at a reasonable confidence level. In addition, by restricting trade within the EU, we hope that the HO model's theoretical requirements would be satisfied at least approximately.

We test the HO hypothesis using a sing and rank tests. The sign test asks whether the sign of the measured factor content of trade, A_r^f, is the same as that of the predicted factor content of trade, $F_r^f - s_r F_w^f$. A strength of the sign test is that large outliers are unlikely to affect the results. A weakness of the sign test is that countries with small predicted factor content of trade may have many sign errors (weak test performance) without it indicating a major problem for the theory. Rank test puts considerably more structure on the data by asking whether countries that are predicted to be large exporters/importers of a factor are measured to do so.

Given that agricultural trade is not balanced between the EU countries, we calculate the observed factor content of agricultural trade and the predicted factor content of agricultural trade per unit of trade flow. The HO sign and rank test results obtained estimating equation (15) are reported in Tables 1 and 2, respectively.

Table 1: HO sign test results for the net agricultural trade in the EU

	$HO_{CEE8} = 0$	$HO_{EU25} = 0$
	(1)	(2)
Labour	0.63	0.71
	(0.16)	(0.07)
Land	0.50	0.53
	(0.19)	(0.11)
Capital	0.75	0.82
	(0.12)	(0.08)
No of observations	24 (8×3)	75 (25×3)

Notes: Sign tests results calculated using equation (15) based on input value per one unit of the net agricultural trade in 2004. The unweighted averages are calculated as a percentage of the respective maximum values; p-values in parenthesis.

According to the test results reported in Tables 1 and 2, the average HO test performance is rather poor. However, there is a significant variation in the HO test performance between countries and factors. Generally, the HO test performance is higher in the case of full sample (EU-25). This is true both for the sign and rank tests and for all three factors. On average, the rank test performance (Table 2) is

[4]The CEE-8 group includes the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia and Slovenia. The EU-25 group contains the 25 countries (including the CEE-8) which were EU Member States by the end of 2004.

higher than the sign test performance (Table 1). As noted above, this might be due to the fact that in the sign test countries with small predicted factor content of trade may have many sign errors (weak test performance). This is corrected for in the rank test.

Table 2: HO rank test results for the net agricultural trade in the EU

	$HO_{CEE8} = 0$	$HO_{EU25} = 0$
	(1)	(2)
Labour	0.75	0.79
	(0.15)	(0.08)
Land	0.66	0.67
	(0.17)	(0.18)
Capital	0.73	0.77
	(0.13)	(0.03)
No of observations	24 (8×3)	75 (25×3)

Notes: Rank tests results calculated using equation (15) based on input value per one unit of the net agricultural trade in 2004. The unweighted averages are calculated as a percentage of the respective maximum values; p-values in parenthesis.

The sign test results reported in Table 1 suggest that in the case of labour the hypothesis $HO_{fo} = 0$ is satisfied in trade flows of approximately two thirds of countries (63% of the CEE-8 and 71% of the EU-25). The rank test results for labour are even better (75% and 79%, respectively). According to the sign test, the hypothesis $HO_{fo} = 0$ is most often satisfied for the capital content of agricultural trade (75% for the CEE-8 and 82% for the EU-25). The rank test results (Table 2) confirm the sign test's results that the HO prediction for capital (15) is satisfied in roughly three-fourth country's agricultural trade. The sign test's performance is relatively poor for land - only half of the tested CEE countries and just above the half (53%) of the EU-25 countries match the predicted import/export content of land with the observed import/export content of land. The relatively poor HO performance for land is also confirmed by the rank test - it has the highest average rank deviation (34% and 33% for the CEE-8 and EU-25, respectively). One way how to interpret these results is that they provide an indirect evidence of transaction costs and market imperfections, which are particularly high for land compared to the mobile factors labour and capital (*Kancs* and *Ciaian* 2009).[5]

[5] As a robustness check, we test the hypothesis $HO_{fo} = 0$ with respect to the factor content of the total trade (not per unit). This alternative evaluation allows us to assess the magnitude of the deviations across factors. Again, the HO test results suggest significant discrepancies between the predicted and observed factor content of aggregate trade in CEE. As an additional robustness check, we also perform the HO sign and rank tests for factor quantities of agricultural trade. The quantity

Second, we test the *country-pair version* of the HO hypothesis, which is derived from equation (7):

$$HO_{od} \equiv \left(\frac{F_d^g}{F_d^f} - \frac{F_o^g}{F_o^f}\right)\left(\frac{A_{od}^f}{A_{od}^g} - \frac{A_{do}^f}{A_{do}^g}\right) \geq 0 \tag{16}$$

Hypothesis $HO_{od} \geq 0$ predicts that if country d is more factor g abundant than country o, i.e. $F_d^g/F_d^f > F_o^g/F_o^f$, then the g/f factor ratio embodied in country d's exports to country o cannot be lower than the g/f factor ratio embodied in country o's exports to d, i.e. $A_{do}^g/A_{do}^f \geq A_{od}^g/A_{od}^f$.

In the case of three factors the hypothesis $HO_{od} \geq 0$ allows for testing of three unique factor ratio hypothesis: capital-labour, capital-land and land-labour. The test results for the CEE-8 and EU-25 are reported in Table 3.

Table 3: HO test results for the bilateral trade in the EU

	$HO_{CEE8} \geq 0$	$HO_{EU25} \geq 0$
	(1)	(2)
Labour/Capital	0.57	0.69
	(0.10)	(0.03)
Land/Labour	0.46	0.57
	(0.17)	(0.08)
Capital/Land	0.53	0.61
	(0.19)	(0.13)
No of observations	84 (28×3)	900 (300×3)

Notes: Sign test results based on equations (16); p-values in parenthesis.

According to the sign statistics reported in Table 3, the HO test performance is rather weak. On average, just more than half of all country pairs satisfy the hypothesis $HO_{od} \geq 0$. Compared to the hypothesis $HO_{fo} = 0$ (Tables 1 and 2), the HO test performance is poorer for the bilateral trade (Table 3). However, as above, there is a significant variation in the HO test performance between countries and factors. Generally, the HO test performance is higher in the case of full sample (EU-25). This is true for all three factor ratios reported in Table 3.

The sign statistics reported in Table 3 suggests that for the labour/capital ratio the hypothesis $HO_{od} \geq 0$ is satisfied for 57% of bilateral trade flows between CEE-8 countries and 69% EU-25 countries. The $p-$value of the sign test are 0.10 and 0.03, which means that the probability of having $HO_{od} \geq 0$ for more than 57% and 69% of the time is about 10% and 3%. According to the third row 3 in Table 3, the

tests yield qualitatively similar results, though the magnitudes of both the predicted and observed factor content of trade change. Therefore, the results presented above are not repeated.

test statistics is lower for the land/labour ratio, where the hypothesis $HO_{od} \geq 0$ is satisfied for 46% (CEE-8) and 57% (EU-25) of bilateral trade flows of agricultural goods. The hypothesis $HO_{od} \geq 0$ cannot be rejected at the 17% and 8% significance level, respectively. The test performance is slightly higher for the capital/land ratio. For the CEE-8 the hypothesis $HO_{od} \geq 0$ is satisfied for 53% and for EU-25 for 61% of bilateral trade flows. However, the results are less significant. Hence, the sign statistics reported in Table 3 also suggests that the best test performance (69%) is for labour/capital content of the bilateral trade between the EU-25 countries.

Generally, the results reported in Tables 1, 2 and 3 are in line with the previous studies on the factor content of agricultural trade in the USA (*Schluter* and *Lee* 1978; *Lee*, *Wills* and *Schluter* 1988). In particular, the average HO test performance of the three studies is of the same order of magnitude as the EU-25 in Tables 1, 2 and 3. Our estimates for the CEE-8 are somewhat lower than those in the previous literature. This may be explained by the factor price distortions in the post-centrally planned CEE transition economies.

3.2 Factor content of trade without factor price equalisation

In this section we test the HO hypothesis of the extended model, which was given in equation (14):

$$HO_{od} \equiv \left(\frac{w_d^f}{w_d^g} - \frac{w_o^f}{w_o^g} \right) \left(\frac{A_{do}^g}{A_{do}^f} - \frac{A_{od}^g}{A_{od}^f} \right) \geq 0 \tag{17}$$

Hypothesis (17) implies that if country d has a higher f/g factor price ratio than country o, $(w_d^f/w_d^g > w_o^f/w_o^g)$, then the f/g ratio embodied in country d's exports to o cannot be higher than the f/g ratio embodied in country o's exports to d $(A_{do}^g/A_{do}^f \geq A_{od}^g/A_{od}^f)$.

As above, in the case of three factors the hypothesis $HO_{od} \geq 0$ allows for testing of three unique factor ratio hypothesis: capital-labour, capital-land and land-labour. The test results for the CEE-8 and EU-25 are reported in Table 4.

According to the sign statistics reported in Table 4, the average test performance is reasonable and most of the $p-$values are reasonably small. On average, about two-thirds of all country pairs satisfy the hypothesis $HO_{od} \geq 0$. Compared to Table 3, the HO test performance has increased in Table 4. These results are in line with HO models without factor price equalisation (*Helpman* 1984 and *Staiger* 1986). However, as above, there is a significant variation in the HO test performance between countries and factors. Again, the HO test performance is higher in the case of full sample (EU-25). This is true for all three factor ratios reported in Table 4.

The sign statistics reported in Table 4 suggests that for the labour/capital ratio the hypothesis $HO_{od} \geq 0$ is satisfied for 62% of bilateral trade flows between the CEE-8 countries and 78% between the EU-25 countries. Both values have increased

Table 4: Augmented HO test results for the bilateral trade in the EU

	$HO_{CEE8} \geq 0$	$HO_{EU25} \geq 0$
	(1)	(2)
Labour/Capital	0.62	0.78
	(0.08)	(0.02)
Land/Labour	0.55	0.67
	(0.14)	(0.05)
Capital/Land	0.64	0.70
	(0.11)	(0.09)
No of observations	84 (28×3)	900 (300×3)

Notes: Sign test results based on equations (17); p-values in parenthesis.

compared to Table 3, suggesting that relaxing the assumption of factor price equalisation increases the HO test performance. The $p-$value of the sign test are 0.08 and 0.02 suggesting that the statistical significance of the results has increased in the augmented HO model (without factor price equalisation). As in Table 3, the test statistics is lower for the land/labour ratio, where the hypothesis $HO_{od} \geq 0$ is satisfied for 55% (CEE-8) and 67% (EU-25) of bilateral trade flows of agricultural goods. Note, however, that in the augmented model the test statistics has improved for both groups of countries. The hypothesis $HO_{od} \geq 0$ cannot be rejected at the 14% and 5% significance level, respectively, which is an improvement compared to the standard HO model. The capital/land test performance is between the labour/capital and land/labour test performances. For the CEE-8 the hypothesis $HO_{od} \geq 0$ is satisfied for 64% and for EU-25 for 70% of bilateral trade flows, which is an improvement of about 10% compared to hypothesis (16). Also the significance of the results has improved - the $p-$value of the sign tests decreased from 0.19 to 0.11 and from 0.13 to 0.09 for the CEE-8 and EU-25 country pairs, respectively.

Generally, we may conclude that the test statistics reported in Tables 1 - 4 is robust with respect to two alternative specifications: (i) factor content of net trade (world version); and (ii) factor content of bilateral trade (country pair version). Second, the group of EU-25 countries perform better than the group of CEE-8 countries. Third, the observed labour and capital content of agricultural trade is more consistent with the predicted factor content of trade than land. One way how to interpret these results are transaction costs and market imperfections, which are considerably higher for agricultural land than the mobile factors labour and capital (*Ciaian* and *Swinnen* 2006). Fourth, the sign statistics of the augmented HO model is considerably better than of the standard HO model. This in turn implies that, at least in the agricultural trade, factor price equalisation is a limiting assumption which distorts empirical results of the relative factor endowment theory. These results are in line

with previous studies testing a generalised version of the HO model (*Choi* and *Krishna* 2004; *Lai* and *Zhu* 2007; *Kancs* and *Ciaian* 2009).

4 Conclusions

The paper studies the factor content of agricultural trade in the EU. We examine the relative abundance for labour, capital and land in the post-centrally planned CEE transition countries and the developed EU economies, and test the HO hypothesis in two different settings: the standard and a more general.

Our empirical findings suggest the following conclusions. First, testing different versions of the HO model we conclude that the results are robust with respect to two alternative specifications: (i) factor content of net trade (world version); and (ii) factor content of bilateral trade (country pair version). Second, the group of EU-25 countries perform better than the group of CEE-8 countries. Third, the observed labour and capital content of agricultural trade is more consistent with the predicted factor content of trade than land. One way how to interpret these results are transaction costs and market imperfections, which are considerably higher for agricultural land than the mobile factors labour and capital (*Ciaian* and *Swinnen* 2006). Fourth, the sign statistics of the augmented HO model is considerably better than of the standard HO model. This in turn implies that, at least in the agricultural trade, factor price equalisation is a limiting assumption which distorts empirical results of the relative factor endowment theory. These results are in line with previous studies testing more general versions of the HO model (*Choi* and *Krishna* 2004; *Lai* and *Zhu* 2007; *Kancs* and *Ciaian* 2009).

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5 Appendix

5.1 Derivation of equation (7)

In order to derive a country-pair version of the HO hypothesis, rewrite equation (5) as:

$$A_{od}^{f} = \left(F_{o}^{f} - s_{o}F_{w}^{f}\right) s_{od} \tag{18}$$

where s_{od} is share of country d's imports from country o in country o's total imports. Rewriting equation (18) for factors f and g yields:

$$\frac{A_{od}^{f}}{s_{od}F_{w}^{f}} = \frac{\left(F_{o}^{f} - s_{o}F_{w}^{f}\right)}{F_{w}^{f}} \tag{19}$$

$$\frac{A_{od}^{g}}{s_{od}F_{w}^{g}} = \frac{\left(F_{o}^{g} - s_{o}F_{w}^{g}\right)}{F_{w}^{g}} \tag{20}$$

Analogously, the factor content of trade can be derived also for country d. For the country-pair version we assume that origin country o is relatively abundant in factor f and destination country d is relatively abundant in factor g. This implies that

$$\frac{F_{o}^{f}}{F_{w}^{f}} > \frac{F_{o}^{g}}{F_{w}^{g}} \qquad \Longrightarrow \qquad \frac{F_{o}^{f}}{F_{o}^{g}} > \frac{F_{w}^{f}}{F_{w}^{g}} \tag{21}$$

$$\frac{F_{d}^{f}}{F_{w}^{f}} < \frac{F_{d}^{g}}{F_{w}^{g}} \qquad \Longrightarrow \qquad \frac{F_{d}^{f}}{F_{d}^{g}} < \frac{F_{w}^{f}}{F_{w}^{g}} \tag{22}$$

and

$$\frac{A_{od}^{f}}{s_{od}F_{w}^{f}} > \frac{A_{od}^{g}}{s_{od}F_{w}^{g}} \qquad \Longrightarrow \qquad \frac{A_{od}^{f}}{A_{od}^{g}} > \frac{F_{w}^{f}}{F_{w}^{g}} \tag{23}$$

$$\frac{A_{do}^{f}}{s_{do}F_{w}^{f}} < \frac{A_{do}^{g}}{s_{do}F_{w}^{g}} \qquad \Longrightarrow \qquad \frac{A_{do}^{f}}{A_{do}^{g}} < \frac{F_{w}^{f}}{F_{w}^{g}} \tag{24}$$

Combining equations 21 - 24 yields:

$$\frac{A_{od}^{f}}{A_{od}^{g}} + \frac{F_{o}^{f}}{F_{o}^{g}} > \frac{A_{do}^{f}}{A_{do}^{g}} + \frac{F_{d}^{f}}{F_{d}^{g}} \tag{25}$$

Rearranging terms in equation (25) yields:

$$\frac{A_{od}^{f}}{A_{od}^{g}} - \frac{A_{do}^{f}}{A_{do}^{g}} > \frac{F_{d}^{f}}{F_{d}^{g}} - \frac{F_{o}^{f}}{F_{o}^{g}} \tag{26}$$

which can be rewritten as:

$$\left(\frac{F_d^g}{F_d^f} - \frac{F_o^g}{F_o^f}\right)\left(\frac{A_{od}^f}{A_{od}^g} - \frac{A_{do}^f}{A_{do}^g}\right) \geq 0 \tag{27}$$

5.2 Derivation of equation (14)

Expanding equations (12) and (13) along factors, f, yields:

$$\sum_f \left(w_o^f - w_d^f\right) A_{od}^f \leq 0 \tag{28}$$

$$\sum_f \left(w_d^f - w_o^f\right) A_{do}^f \leq 0 \tag{29}$$

Combining inequalities (28) and (29) yields

$$\sum_f w_o^f A_{od}^f \sum_f w_d^f A_{do}^f \leq \sum_f w_d^f A_{od}^f \sum_f w_o^f A_{do}^f \tag{30}$$

In the case of two factors, f and g, equation (30) can be rewritten as:

$$w_o^f A_{od}^f w_d^g A_{do}^g + w_o^g A_{od}^g w_d^f A_{do}^f \leq w_d^f A_{od}^f w_o^g A_{do}^g + w_d^g A_{od}^g w_o^f A_{do}^f \tag{31}$$

where A_{od}^g (A_{od}^f) is the amount of g (f) required to produce gross exports from o to d. Dividing both sides of equation (31) by $w_d^g A_{do}^g w_o^g A_{od}^g$ yields equation 14:

$$\left(\frac{w_d^f}{w_d^g} - \frac{w_o^f}{w_o^g}\right)\left(\frac{A_{do}^g}{A_{do}^f} - \frac{A_{od}^g}{A_{od}^f}\right) \geq 0 \tag{32}$$

5.3 Data

In the empirical analysis we use data for 2004. The agricultural trade data is extracted from the COMEXT trade data base *Eurostat* (2007) and the GTAP 7 data base. The COMEXT data base provides data for Member States of the European Union on external trade with each other and with non-member countries. It contains data on external trade collected and processed by all EU Member States and more than 100 trade partners, including U.S.A., Japan and the EFTA countries. COMEXT contains several types of data from various sources (European Union, United Nations, IMF etc) and with different structures (corresponding to different nomenclatures like CN, SITC Rev2, SITC Rev3 etc). The key advantage of the GTAP Data Base compared to EU member countries' trade in the COMEXT Data Base is that it is a global data base representing the whole world economy.

The technology coefficients are calculated from the Farm Accountancy Data Network (FADN) firm-level data. The FADN is a European system of sample surveys

that take place each year and collect structural and accountancy data on the farms. In total there is information about 150 variables on farm structure and yield, output, costs, subsidies and taxes, income, balance sheet, and financial indicators. The annual sample of FADN covers approximately 80.000 agricultural farms. In 2004 they represented a population of about 5.000.000 farms in the 25 Member States, covering approximately 90% of the total utilised agricultural area (UAA) and accounting for more than 90% of the total agricultural production of the EU. Farm-level data are confidential and, for the purposes of this study, accessed under a special agreement.