Factor Content of Bilateral Trade: The Role of Firm Heterogeneity and Transaction Costs*

d'Artis Kancs[†] Pavel Ciaian [‡]

March 2009

Abstract

In this paper we study the determinants of the factor content of the CEE agricultural trade. Examining empirically three hypothesis, which relate cross-country differences in technology, relative factor abundance and transaction costs and market imperfections to the factor content of trade, we find that the first two hypotheses are confirmed by the majority of the developed EU countries, but rejected by roughly one half of the CEE transition country pairs. Second, we find that when accounting for transaction costs of farm (re)organisation, both hypotheses are confirmed by the majority of the CEE country pairs. These findings provide empirical evidence of market imperfections, and particularly, of transaction costs of farm (re)organisation in the CEE.

Keywords: Factor content, bilateral trade, relative factor abundance, technological differences, agriculture, transaction costs.

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

*The authors acknowledge helpful comments from Rafal Raciborski and Susan Chun Zhu as well as GTAP and EAAE conference participants in Helsinki and Ghent. The authors are grateful to Unit G.3 Microeconomic analysis of EU agricultural holdings from the European Commission for granting access to the FADN data. The authors acknowledge financial support from the European Commission FP7 project 'New Issues in Agricultural Trade' (AgFoodTrade). The authors are solely responsible for the content of the paper. The views expressed are purely those of the authors and may not in any circumstances be regarded as stating an official position of the European Commission.

[†]European Commission - Joint Research Centre (IPTS), Catholic University of Leuven (LICOS), and Economics and Econometrics Research Institute (EERI). E-mail: d'artis.kancs@ec.europa.eu.

[‡]European Commission - Joint Research Centre (IPTS), Economics and Econometrics Research Institute (EERI), and Catholic University of Leuven (LICOS). E-mail: pavel.ciaian@ec.europa.eu.

1 Introduction

The present study analyses the factor content of the CEE agricultural trade. More precisely, adopting a relative factor endowment model we test for the relative importance of cross-country technology differences and the relative factor abundance in the factor content of the CEE agricultural trade.[1] According to *Davis* and *Weinstein* (2001), 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. In addition to these two 'traditional' determinants of the factor content of trade, we also examine the role of transaction costs and market imperfections in the CEE transition country agricultural trade as, according to previous evidence,[2] transaction costs may prevent the adjustment of the distorted centrally-planned factor allocation, specialisation and hence the factor content of the CEE transition country agricultural trade.

There are several reasons why our paper focuses on the CEE agricultural trade. First, though declining, agricultural sector is still important in terms of the GDP and employment in the CEE. Second, agricultural policy (CAP) has the largest expenditure share in the EU budget. Our findings serve toward a better understanding of efficient allocation of these funds. Third, agricultural sector was one of the most biased during the central planning period. Hence, the transition toward a market economy offers a natural experiment for investigating the role transaction costs and market imperfections in agricultural production and trade.

Compared to the studies of factor content of the developed country trade, which usually rely on the HOV model, our study is considerably complicated by the fact that across the CEE there are sizeable differences in technology and factor prices. Given that these differences strongly violate the key assumptions of the HOV theorem, the traditional HOV model would yield biased results if applied in the present study. In order to get around these issues, we build our theoretical framework on previous work of *Helpman* (1984) and *Staiger* (1986), who consider a trade equilibrium in which factor prices are allowed to differ across countries and *Lai* and *Zhu* (2007), who account for international technology differences. In the absence of factor price equalisation, we are able to predict the factor content of trade from post-trade data without restricting technology, and this can be done for bilateral trade flows. Hence, our approach is less restrictive and more consistent with the empirical evidence than the HOV model.

Our study makes three contributions to the existing literature of factor content of trade. First, we derive three testable predictions against which to measure how well

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

[2] See *Ciaian* and *Swinnen* (2006, 2009) for land and capital market imperfections; *Pollak* (1985) for transaction costs; and *Kancs*, *Ciaian* and *Pokrivcak* (2008) for the role of transaction costs in farm specialisation.

do the theoretical trade models of relative factor endowment work. Inspired by *Lai* and *Zhu* (2007), our first hypothesis relates the factor content of bilateral trade to cross-country differences in technology. It says that, on average, a country imports the services of those factors that are cheaper in its trading partner and exports the content of those factors that are more expensive for its trading partner. Following *Debaere* (2003), our second hypothesis relates the factor content of bilateral trade to the relative factor abundance. It says that exports of capital abundant countries embody a higher capital labour ratio than exports of labour abundant countries.[3] Inspired by *Allen* and *Lueck* (1998), our third hypothesis relates the factor content of bilateral trade to transaction costs of farm (re)organisation in transition countries. It says that if transaction costs of farm (re)organisation are negligible, then farm organisation does not affect factor content of output and trade and vice versa.

Second, employing a unique data set of agricultural production and trade for the CEE, our study provides empirical evidence of the three theoretical hypothesis. More precisely, testing the theoretical hypothesis empirically, we examine how well does the underlying relative factor endowment model work in the context of transition country agricultural trade. Testing the first two predictions (the factor content of bilateral trade and cross-country differences in technology, and the factor content of bilateral trade and relative factor abundance) we find that they are confirmed by the majority of developed countries, but rejected by roughly one half of the CEE transition country pairs. The obtained test results for the developed countries are in line with *Debaere* (2003); *Choi* and *Krishna* (2004); and *Lai* and *Zhu* (2007).

The third contribution consists of assessing the impact of central planning and transition processes on the relative and absolute factor prices within the CEE transition economies as, according to *Davis* and *Weinstein* (2001), the HO model allows to trace the effects of international influences on relative and absolute factor prices within a country. The empirical test of the transaction cost hypothesis suggests that when accounting for transaction costs of farm (re)organisation, both the endowment and technology hypotheses are confirmed by majority of the CEE transition country pairs. These results are new and have not been reported in the literature before.

Our paper is organised as follows. Section 2 provides an overview of agriculture in the CEE. Section 3 outlines the theoretical framework. Section 4 derives three testable hypothesis, which are empirically tested in section 5. Section 6 concludes and provides policy recommendations.

[3] Differing from *Debaere* (2003), who examines the relationship between relative factor abundance and trade in factor services from the Heckscher-Ohlin-Vanek (HOV) perspective, the present study focuses on the factor content of gross trade rather than on the factor content of net trade.

2 Agriculture in Central and Eastern Europe

We start with introducing the agricultural sector which, due to the central planning past, is specific in the CEE. The transition-specific background is important, as it may have implications for the conceptual framework of the present study.

2.1 Data

Our study covers agricultural production and trade in CEE transition economies. In order to reveal the sectoral differences in the production and trade, we disaggregate the agricultural sector into eight sub-sectors, which are summarised in Table 9 in Appendix. In order to account for international differences in production and demand, we disaggregate the CEE into eight countries (Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia and Slovenia).

The three principal data sources are the COMEXT trade data from the *Eurostat* (2007), the GTAP v7 data base and the Farm Accountancy Data Network (FADN) firm level survey data (see Table 10 in Appendix). For the empirical analysis of factor content of trade we use the production and trade data for 2004.

The agricultural trade data is extracted from the COMEXT trade data base *Eurostat* (2007). The COMEXT data base provides trade data for all Member States of the EU 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 such as CN, SITC Rev2, SITC Rev3 etc).

Factor endowments are extracted from the GTAP v7 data base which, in addition to aggregated input-output tables, provide also data for macroeconomic variables such as consumption, GDP. Together with the GTAP data we use FADN data to calculate the factor input requirements by farm type. The FADN covers approximately 80.000 agricultural farms. In 2004 they represented a population of about 5.000.000 farms in the 25 EU 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.

For the TFP estimations we make use of a panel data for 25 EU economies covering two years - 2004 and 2005. The unbalanced panel contains 151,434 observations: 38,981 for the new EU member states (CEE) and 112,454 for the old EU member states (EU-15).

2.2 Dual farm structure

In Western Europe, North America and other developed countries, where agricultural sector is dominated by relatively small and compared to the CEE homogenous family farms, and where input and output markets are integrated, the production technology is little affected by farm organisation (*Jensen* and *Meckling* 1976; *Pollak* 1985; *Schmitt* 1991, *Allen* and *Lueck* 1998). Hence, farms can straightforwardly adjust their organisation and production structure according to changes in market conditions, and a given farm organisation does not constrain the re-specialisation. This is the usual evidence from the developed market economies.

In contrast, in the post-Soviet CEE transition economies some regions and countries are dominated by large corporate farms (CF), whereas in other regions and countries small individual farms (IF) cultivate most of the land. These cross-country differences in the CEE farm organisation are summarised in Table 1, which reports percentage shares of land cultivated by IFs and their share in the total agricultural output. The last column of Table 1 reports the average farm size in hectares.

Table 1: Farm organisation and size in the CEE in 2004

	IF share land %	IF share output %	Average farm size ha
Czech Republic	11.8	19.5	250.1
Estonia	63.5	48.9	119.6
Latvia	55.2	63.9	64.0
Lithuania	77.4	83.8	42.5
Hungary	36.2	47.5	53.2
Poland	94.5	96.2	15.8
Slovenia	99.9	99.9	12.7
Slovakia	10.8	13.6	535.5
the CEE	56.16	59.16	136.68

Source: Authors' calculations based on the FADN (2008) data.

According to columns 2 and 3, Slovenia and Poland have the highest share of IFs in both land use and agricultural output. In contrast, Slovakia and the Czech Republic have the lowest share of IFs. Table 1 confirms the evidence documented in the previous literature that the share of IFs is negatively and strongly correlated with the average farm size (e.g. *Pollak* 1985; *Allen* and *Lueck* 1998). Countries with relatively high share of CFs (low share of IFs), e.g. the Czech Republic and Slovakia, have considerably larger farms than countries with high share of IFs (e.g. Slovenia and Poland).

Table 1 also suggests that, on average, the IF share in land use is lower than the IF share in output (columns 2 and 3). This can be explained by the fact that, on average, IFs tend to specialise in more labour intensive products, which are also more cost intensive and hence have a higher value per hectare of cultivated land and physical output unit compared to CFs. For example horticulture, the production of which is dominated by IFs, has a considerably higher value per output unit and the cultivated land hectare than cereals and oilseeds, the production of which is dominated by CFs.

These findings suggest that the farming sector in the CEE is rather heterogenous, in particular, it is characterised by a dual farm organisation, and the structure of farm organisation is rather rigid and persistent over time - the dual farm structure changed little in the last decade. Farm ability to reorganise the production structure in turn depends on transaction costs and differences in profits between the two dominant types of farms.[4] Hence, historical institutions may help to explain why a particular type of farm organisation emerged in particular country/region, whereas transaction costs of farm re-organisation may help to explain why the dual farm structure is persistent over time in the CEE.

2.3 Technological and factor income differences

In terms of farm specialisation and factor content of agricultural trade, the share of IFs and CFs is important, if the relative factor requirements in producing the same product are different between the two types of farms, i.e. they use different technologies. The empirical evidence for the CEE is summarised in Table 2, which reports the labour-capital ratio in CF and IF farm output by sector in 2004. Columns 2 and 3 report the labour/capital ratio in IF and CF output, respectively. The last column reports the relative factor intensity of IF compared to CF.

The relative factor intensity estimates reported in column 4 suggest that in the CEE transition countries IFs tend to use more labour in all agricultural activities - the share of labour/capital ratio is higher for IFs in all activities. These results are consistent with Table 1. Given that cultivating 12 or 15 ha land, as in Slovenia and Poland, requires a considerably different technology than cultivating 535 ha land, as in Slovakia, both farm organisation and size co-determine production technology in the CEE.

Column 4 also suggests that farm-type technological differences are rather heterogenous across agricultural activities. The most sizeable differences in terms of factor use are calculated for mixed livestock, mainly granivores, where the relative capital labour content in IF output amounts only to 43% of CF output. Most of IF belonging to this category are weakly specialised semi-subsistance farms. In contrast, pig and poultry production is nearly equally capital intensive - IF output contains 2950.3 EUR capital per worker and CF output contains EUR capital per worker 2974.0.

These results are in line with previous literature. According to *Pollak* (1985) and *Allen* and *Lueck* (1998), one of the key distinctive differences in production technology

[4]The transaction costs of farm (re)organisation include costs involved in bargaining with farm management, in obtaining information on land and tenure regulations, in implementing the delineation of the land and dealing with inheritance and co-owners etc. (*Prosterman* and *Rolfes* 2000).

Table 2: Capital-labour ratio in CF and IF farm output by sector in 2004, EUR/worker

Sector (1)	$(K/L)_I$ (2)	$(K/L)_C$ (3)	$\frac{(K/L)_I}{(K/L)_C}$ (4)
Cereals, oilseed and protein crops	3789.7	6266.2	0.60
General field cropping	3433.2	3651.6	0.94
Horticulture	3173.6	3350.3	0.95
Vineyards	3417.6	4192.2	0.82
Fruit and citrus fruit	4003.6	4175.6	0.96
Olives	4872.9	na	na
Other fruit	2246.1	2654.8	0.85
Dairying	2543.7	2731.0	0.93
Cattle-rearing and fattening	2500.4	4445.2	0.56
Cattle-dairying, rearing and fattening	2200.0	2261.2	0.97
Grazing livestock (sheep and goats)	2311.4	4049.8	0.57
Granivores (pigs and poultry)	2950.3	2974.0	0.99
Mixed cropping	2355.8	2734.0	0.86
Mixed livestock, mainly grazing livestock	1751.8	2483.9	0.71
Mixed livestock, mainly granivores	1983.4	4619.3	0.43
Field crops and grazing livestock	2383.2	2628.6	0.91
Rest of agricultural activities	2575.2	2826.2	0.91

Source: Authors' calculations based on the FADN (2008) data. Notes: $(K/L)_I$-capital/labour ratio in IF output in EURO per worker, $(K/L)_C$-capital/labour ratio in CF output, $(K/L)_I\,/\,(K/L)_C$-relative factor intensity of IF compared to CF.

between IFs and CFs is the relative labour and capital intensity. On average, IFs tend to use less capital compared to CFs, whereas CFs tend to use less labour compared to IFs in producing the same good.[5]

[5] According to *Pollak* (1985) and *Allen* and *Lueck* (1998), these farm-type differences in labour/capital intensity are largely determined by differences in the relative factor costs and factor productivity. In terms of labour, usually, IFs face lower labour costs. Given that farmer is the residual income claimant, IFs do not suffer from moral hazard problem, which is an important issue in CFs (*Schmitt* 1991). This leads to higher labour productivity in IFs compared to CFs. On the other hand, labour productivity of IFs might be hindered by lack of labour specialisation, which reduces marginal product of labour. Most of the previous studies find that the former effect is larger than the latter (*Pollak* 1985; *Allen* and *Lueck* 1998). In terms of capital, usually IFs face higher per-unit capital costs. In the presence of fixed capital transaction costs, IFs face higher per-unit capital costs than CFs. Moreover, capital productivity of IFs is often lower compared to CFs because of sub-optimal production scale and underemployment of fixed farm equipment and machinery (*Pollak* 1985; *Allen* and *Lueck* 1998). Hence, large CFs tend to have higher marginal productivity of capital than small IFs. In addition, because of missing collateral, IFs are more credit constrained than CFs.

In order to gain empirical evidence about the farm-type productivity differences in CEE, we estimate the Total Factor Productivity (TFP) for IF and CF. The TFP estimates are based on a two year (2004 and 2005) firm-level panel data from the FADN. The unbalanced panel contains 37,409 observations for CF and IF in the eight CEE countries. The distinction between IF and CF is done using variable A18 (organisational form), which is also provided for in the FADN data.

We apply the *Olley* and *Pakes* (1996) estimator, which allows to address the simultaneity and selection problems while estimating the production function parameters and firm-level productivity. The simultaneity problems are addressed by using investment to proxy for an unobserved time-varying productivity shock, whereas the selection problems are addressed by using survival probabilities. The *Olley* and *Pakes* estimator is implemented in STATA using command *opreg*.

The obtained TFP estimates by sector and farm type are reported in Table 3. Columns 2 and 3 report the TFP estimates for IF and CF, respectively. The last column reports the TFP ratio of IF to CF.

Table 3: Total Factor Productivity by farm type and sector in the CEE

Sector (1)	TFP_I (2)	TFP_C (3)	$\frac{TFP_I}{TFP_C}$ (4)
Cereals, oilseed and protein crops	0.6331	0.8561	0.74
General field cropping	0.7030	0.7374	0.95
Horticulture	0.7338	0.7301	1.01
Vineyards	0.7167	0.7848	0.91
Fruit and citrus fruit	0.5430	0.7643	0.71
Olives	1.0000	n.a.	n.a.
Other fruit	0.8475	0.6623	1.28
Dairying	0.7451	0.6792	1.10
Cattle-rearing and fattening	0.7516	0.8354	0.90
Cattle-dairying, rearing and fattening	0.8509	0.5786	1.47
Grazing livestock (sheep and goats)	0.7969	0.7396	1.08
Granivores (pigs and poultry)	0.7388	0.7208	1.02
Mixed cropping	0.7673	0.6885	1.11
Mixed livestock, mainly grazing livestock	0.8632	0.5786	1.49
Mixed livestock, mainly granivores	0.8551	0.8384	1.02
Field crops and grazing livestock	0.7582	0.6501	1.17
Rest of agricultural activities	0.7421	0.7203	1.03

Source: Olley-Pakes estimates based on FADN (2008) firm-level panel data. Notes: TFP_I, TFP_C-TFP estimates for IF and CF, respectively; TFP_I/TFP_C-TFP ratio.

The results reported in Table 3 suggest a considerable inter-sectoral and farm-type variation in productivity between CF and IF. Generally, IF tend to be more productive than CF when the capital/labour ratio is small (labour share is large) (see also Table 2). The opposite holds for CF. However, the capital/labour ratio seems not to be the only determinant of farm TFP. For example, sectors 41 (dairying) and 14 (root crops and technical crops) have nearly the same capital/labour ratio in IF and CF output (0.93 and 0.94), but significant differences in farm-type TFP ratios (1.10 and 0.95). According to our estimates, in milk sector IF are more productive than CF, whereas the opposite holds for root and technical crops.

Based on these findings we may conclude that there exist significant differences in production technology between the CEE transition countries and sizeable differences. In addition, the *Eurostat*'s (2009) data suggest that in CEE there are sizeable differences in the relative factor rewards both with respect to the CEE and the EU. For example, in 2004 the average labour wage in Latvia was 2.40 and Lithuania 2.65 EUR/hour. In contrast, in Slovenia it was 6.70, in Ireland 18.30, and in Luxembourg 29.95 EUR/hour *Eurostat* (2009). There were also significant cross-country differences in the price for capital. In addition, the FADN data suggest significant differences in the relative factor rewards between different types of farms and sectors within the same region/country.

3 Theoretical framework

Findings from section 2 suggest that: (i) farming sector in the CEE is rather heterogenous, in particular, it is characterised by a dual farm organisation; (ii) the structure of farm organisation is rather rigid and persistent over time suggesting a presence of transaction costs of farm (re)organisation in the CEE; (iii) significant differences in production technology exist both within and between the CEE countries; and (iv) differences in the relative factor rewards between countries and sectors are sizeable. These issues, some of which are characteristic to transition economies, have implications for the conceptual framework for analysing the factor content of trade, which we present in this section.

3.1 The setup

As in the canonical HO model, production exhibits constant returns to scale and product markets are perfectly competitive. There are no barriers to trade. Following *Staiger* (1986), final goods are produced using primary factors and intermediate inputs. Given that also intermediates are traded freely, we have to assume that the requirement for intermediate inputs is identical across countries.[6] This assumption

[6] It is straightforward to extend the framework to allow for non-traded intermediates. However, given that the assumption whether intermediate inputs are freely traded or non-traded does not make any difference empirically, we assume them freely traded.

is in line with the empirical evidence. As argued by *Davis* et al (1997), a car may be produced with varying capital and labour input across countries. Yet the same car may require a certain amount of steel, rubber and other intermediate inputs.

In order to account for cross-country differences in the relative factor prices discussed in section 2.3, we build our theoretical framework on the previous work of *Brecher* and *Choudhri* (1982); *Helpman* (1984); *Staiger* (1986), who consider a trade equilibrium in which factor prices are allowed to differ across countries. In addition, without imposing factor price equalisation, we are able to predict the factor content of trade from the observed trade data without imposing any restrictions on consumer preferences. Moreover, this can be done not only for every country's net trade vector but also for the bilateral trade flows.[7]

Following *Lai* and *Zhu* (2007), we further take into account international technology differences.[8] More precisely, we allow technology differences to be country- and industry-specific. This extension is particularly important for the CEE, as countries in our sample face sizeable technological differences in the agricultural production (see section 2.3). As usual, we assume that technology differences are factor-augmenting and Hicks-neutral.[9]

In order to account for farm heterogeneity in the CEE and transaction costs of farm (re)organisation, in section 3.4 we extend the model building on previous work of *Ciaian* and *Swinnen* (2006), who explicitly model the farm heterogeneity and factor market imperfections in the CEE transition countries. More precisely, we introduce two types of farms - corporate farms (CF) and individual farms (IF) - and transaction costs of (re)organising farm production from CF into IF and vice versa.

3.2 Industry-level trade

The world consists of R regions/countries indexed $r \in \{1,..,o,..,d,..R\}$. Origin country is denoted by o and destination country is denoted by d. Industries are denoted by i, factors (capital and labour) are denoted by $f \in \{K, L\}$. Assume that q_{ir} is the production function for good i in region/country r. Further, let a_{ir} be a vector of factors needed directly to produce one unit of good i in region/country r. By definition, $q_{ir}(a_{ir}) = 1$. To simplify the notation, in q_{ir} we suppress the

[7] *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 theory.

[8] *Lai* and *Zhu* (2007) are the first who incorporate international technology differences into the empirical HO test. In particular, they allow technology differences to be country- and industry-specific, i.e., Ricardian technology differences. Using a sample of 41 developed and developing countries with sufficiently disparate factor abundance and productivity they test the theoretical predictions of technological differences and relative factor abundance and find strong evidence in support of the theory.

[9] The framework can be easily extended to account for factor-biased technology differences. However, data limitations prevent us from pursuing any empirical test for this interesting case.

requirement for intermediate inputs, because it is identical across countries. Let ω_{ir} denote productivity of industry i in country r. The higher is productivity parameter, ω_{ir}, the more productive is country r in industry i, or the less inputs per unit of output are required. According to *Trefler* (1995), with factor-augmenting and Hicks-neutral technology differences $q_{ir}(a_{ir}) = q_i(\omega_{ir}a_{ir})$ for some internationally common production functions q_i. Given that $q_{ir}(a_{ir}) = 1$, it follows that also $q_i(\omega_{ir}a_{ir}) = 1$.

Let z_i be the cost of intermediates used to produce one unit of good i and w_r be the vector of factor prices in country r. Given that intermediates are traded freely and their requirement is identical across countries, the price and costs of intermediate inputs are equal across countries too (*Lai* and *Zhu* 2007). With constant-returns to scale technology, the unit cost, c_{ir}, of producing good i in country r is given by

$$c_{ir} = w_r a_{ir} + z_i \tag{1}$$

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

$$p_i = w_o a_{io} + z_i \tag{2}$$

Equation (2) implies that for importing country d, unit profits on good i must be non-positive:

$$p_i \leq w_d a_{id} + z_i \tag{3}$$

Assuming homogenous firms within industries, inequality (3) holds for all industry i's firms in importing country d (*Lai* and *Zhu* 2007).

Combining equations (2) and (3) yields an inequality of unit costs in exporting country, o, and importing country, d. The cost of intermediates, z_i, cancels out, because their requirement per output unit and free trade price both are equal across countries.[10]

$$w_o a_{io} \leq w_d a_{id} \tag{4}$$

According to inequality (4), there are two reasons why direct factor requirements, a_{ir}, may differ across countries, i.e., $a_{io} \neq a_{id}$. First, because of international differences in technology. With Hicks-neutral differences in factor efficiency, if exporting and importing countries had the same factor prices, importing country d would need $a_{id} = (\omega_{io}/\omega_{id})\, a_{io}$ directly to produce one unit of good i. Second, because of international differences in factor prices. If exporting and importing countries face different factor prices, although $(\omega_{io}/\omega_{id})\, a_{io}$ is a feasible way for country d's to produce one unit of i, it may not be the least cost efficient. Country d can reduce its production

[10] For implications of costly trade of intermediate inputs see *Staiger* (1986).

cost through factor substitution. Given the optimal bundle of factors, a_{id}, the cost minimisation implies:

$$w_d a_{id} \leq w_d \left(\omega_{io}/\omega_{id}\right) a_{io} \tag{5}$$

Combining inequalities (4) and (5) yields

$$\frac{w_o}{\omega_{io}} a_{io} \leq \frac{w_d}{\omega_{id}} a_{io} \tag{6}$$

Inequality (6) describes the theoretical hypothesis of direct factor requirements, a_{ir}, factor prices, w_r, and the Ricardian technology differences, ω_{ir}, for industry i in the trade equilibrium. According to equation (6), direct factor requirement, a_{io}, in exporting country o may differ from direct factor requirement, a_{id}, in importing country d either due to differences in factor prices, $w_o \neq w_d$, or due to differences in factor efficiency, $\omega_{io} \neq \omega_{id}$, or due to differences in both.[11]

3.3 Aggregate trade

The volume of gross exports of good i from origin country o to destination country d is denoted by E_{iod} and A_{iod} denotes the vector of weighted factors required directly to produce each unit of E_{iod}. The amount, A_{iod}, of factors that is used to produce one unit of exports from o to d is defined as: $A_{iod} \equiv a_{io}\left(\frac{E_{iod}}{\sum_i E_{iod}}\right)$. Hence, we derive, A_{iod}, by aggregating (6) over i using industry-level trade volume shares, $\frac{E_{iod}}{\sum_i E_{iod}}$, as weights:

$$\sum_i \frac{w_o}{\omega_{io}} \omega_{io} A_{iod} \leq \sum_i \frac{w_d}{\omega_{id}} \omega_{io} A_{iod} \tag{7}$$

Alternatively, for importing country d:

$$\sum_i \frac{w_d}{\omega_{id}} \omega_{id} A_{ido} \leq \sum_i \frac{w_o}{\omega_{io}} \omega_{id} A_{ido} \tag{8}$$

Inequalities (7) and (8) predict the factor content of bilateral trade between exporting country o and importing country d.

Several issues need to be noted about the two equations. First, they allow for (although they do 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, particularly wages, across the CEE countries. Second, in equations (7) and (8) both factor prices and the factor content of bilateral trade are normalised by productivity. I.e., for industry i the productivity-adjusted factor costs in country o are $\frac{w_o}{\omega_{io}}$, and productivity-adjusted factor content of per-unit exports from country o to country d

[11] Note that hypothesis (6) does not require an equalisation of productivity adjusted factor prices $w_r/\omega_{ir} = w/\omega_i$.

is $\omega_{io}A_{ido}$. This is in line with *Trefler* (1995). Third, according to *Lai* and *Zhu* (2007), if bilateral trade is balanced, equations (7) and (8) can be used to compare factor content of aggregate exports. In the CEE, however, bilateral trade is not balanced. Therefore, both equations are normalised by the value of gross exports. Fourth, equations (7) and (8) can be used to directly compare factor content of bilateral trade. However, according to *Staiger* (1986), they are not valid for comparing the indirect factor content of bilateral trade. Finally, given that all variables are observable in the data, equations (7) and (8) can be tested empirically.

3.4 Firm heterogeneity

In this section we extend the basic model of *Lai* and *Zhu* (2007) by introducing firm-level heterogeneity. Accounting for firm heterogeneity is important for analysing the role of market imperfections and transaction costs in the factor content of trade because, as shown in section 2, production technology (input use and farm output) is different between different types of farms. In line with the dual farm structure observed in the CEE (see section 2.2), we introduce two types of firms - corporate farms (CF) and individual farms (IF).[12]

In order to introduce firm-level heterogeneity into the underlying trade model, three equations need to be modified: factor input requirement, a_{ir}, input price equation, w_r, and factor productivity, ω_{ir}. First, we account for farm-type differences in direct factor requirement which, according to section 2.2, are significant in the CEE.[13] The average factor input requirement, a_{ir}, is decomposed into farm type-specific factor input requirement, a_{ir}^C and a_{ir}^I, as follows:

$$a_{ir} = \alpha_{ir}^A a_{ir}^C + \left(1 - \alpha_{ir}^A\right) a_{ir}^I \tag{9}$$

where direct factor requirement, a_{ir}, is a weighted sum of IF factor requirement, a_{ir}^I, and CF factor requirement, a_{ir}^C, in sector i, country r. The weight, α_{ir}^A, is calculated by dividing the equilibrium CF input quantity, A_{ir}^C, in sector i, region r by the total equilibrium input use, A_{ir}, in sector i, region r.

Next, we account for farm type-specific input prices, w_r which according to section 2.2 usually differ between different types of farms.[14] Similarly to factor input

[12] For simplicity, in the present study we assume two types of farms producing homogenous goods. However, the results derived here are more general. See e.g. *Melitz* 2003 for a heterogenous firm model in a continuous firm setting and *Kancs* 2007 for an application to the CEE transition economies.

[13] For example, given that on average IF are smaller than CF, they can better address the problem of labour monitoring in farm production. This results in more labour usage in IF production compared to CF production (*Allen* and *Lueck* 2002; *Pollak* 1985).

[14] For example, IF face higher costs for capital compared to CF mostly because IF have more difficult access to credit than CF (*Bezemer* 2003, *Ciaian* and *Swinnen* 2007). As a result, IF will use less capital, implying a smaller farm with less equipment as compared to CF. In the same time, labour employed in CF may face different opportunity costs compared to labour employed in IF.

requirement, the aggregate input prices are calculated as a weighted sum of the IF and CF input prices:

$$w_r = \alpha_r^A w_r^C + \left(1 - \alpha_r^A\right) w_r^I \tag{10}$$

As in equation (9), aggregate input prices, w_r, are weighted by factor input shares α_r^A and $1 - \alpha_r^A$.

Finally, we introduce farm type-specific productivities, ω_{ir}^C and ω_{ir}^I. Productivity may differ between IF and CF because each farm type creates different incentives at farm level, which may lead to productivity differences between farms and sectors. Weighting the farm type-specific productivities with output weights, α_{ir}^q and $(1 - \alpha_{ir}^q)$ yields the region r's average productivity of all farms producing good i:

$$\omega_{ir} = \alpha_{ir}^q \omega_{ir}^C + (1 - \alpha_{ir}^q)\, \omega_{ir}^I \tag{11}$$

where the share parameter, α_{ir}^q, is calculated by dividing the equilibrium CF output, q_{ir}^C, in sector i by the total equilibrium output, q_{ir}, of sector i: $\alpha_{ir}^q = \frac{q_{ir}^C}{q_{ir}}$.

Using the same output weights, α_{ir}^q, yields also the aggregated amount of factors that is used to produce one unit of exports from o to d:

$$A_{iod} = \alpha_{io}^q A_{iod}^C + (1 - \alpha_{io}^q)\, A_{iod}^I \tag{12}$$

where A_{iod}^C and A_{iod}^I is factor content of CF and IF exports, respectively.

Note that equations (9)-(12) per se do not change the results of the underlying trade model outlined in sections 3.1-3.3. Instead, they allow to account for CF and IF specific technology and factor rewards, which are required for analysing the role of farm heterogeneity, market imperfections and transaction costs in the factor content of agricultural trade.

4 Testable hypothesis

In sections 4.1 and 4.2 we derive an empirically testable relationship between the factor content of bilateral trade and cross-country technological differences and Heckscher-Ohlin endowment differences. In section 4.3 we derive a hypothesis relating the transaction costs of farm reorganisation to factor content of trade.

4.1 Ricardian technology differences

We start with deriving an empirically testable relationship between the factor content of bilateral trade and cross-country technological differences. In order to derive the empirical hypothesis, first, we combine inequalities (7) and (8):

$$\sum_i \left(\frac{w_d}{\omega_{id}} - \frac{w_o}{\omega_{io}}\right) (\omega_{io} A_{ido} - \omega_{id} A_{iod}) \geq 0 \tag{13}$$

Inequality (13) captures the Ricardian technological differences through productivity adjusted factor prices, $\frac{w_o}{\omega_{io}}$, and the factor content of bilateral trade, $\omega_{io}A_{ido}$. It says that, on average, country d is a net importer from country o of those factors that are cheaper in o than in d and vice versa.

Next, by expanding inequality (13) and dividing both sides by $\sum_i \frac{w_d}{\omega_{id}}\omega_{id}A_{ido} + \sum_i \frac{w_o}{\omega_{io}}\omega_{io}A_{iod}$ we obtain the empirical hypothesis of the Ricardian technological differences and factor content of bilateral trade, R_{do}:

$$R_{od} = \frac{\sum_i \left(\frac{w_d}{\omega_{id}}\right)\omega_{io}A_{iod} + \sum_i \left(\frac{w_o}{\omega_{io}}\right)\omega_{id}A_{ido}}{\sum_i w_d A_{ido} + \sum_i w_o A_{iod}} \geq 1 \tag{14}$$

The nominator in inequality (14) represents the importer d's hypothetical unit cost of production, which is calculated using the importer d's factor prices and exporter o's factor usage. The denominator represents the exporter o's actual unit cost of production, which is calculated using the actual exporter o's factor prices and factor usage. In the trade equilibrium the unit cost of production in the importing country cannot be lower than that in the exporting country. Hence, the Ricardian cost ratio, R_{od}, should not be less than 1.

We also derive the hypothesis of Ricardian technological differences and factor content of bilateral trade at the sectoral level:

$$R_{ido} = \frac{\left(\frac{w_d}{\omega_{id}}\right)\omega_{io}a_{io} + \left(\frac{w_o}{\omega_{io}}\right)\omega_{id}a_{id}}{w_d a_{id} + w_o a_{io}} \geq 1 \tag{15}$$

The industry-level hypothesis (15) provides an additional test for the robustness of the model's results.[15]

4.2 Heckscher-Ohlin endowment differences

Next, we derive an empirically testable relationship between the factor content of bilateral trade and the relative factor abundance. First, we expand inequalities (7) and (8) along factors, f:

$$\sum_f \left(\frac{w_o^f}{\omega_o} - \frac{w_d^f}{\omega_d}\right)\omega_o A_{od}^f \leq 0 \tag{16}$$

$$\sum_f \left(\frac{w_d^f}{\omega_d} - \frac{w_o^f}{\omega_o}\right)\omega_d A_{od}^f \leq 0 \tag{17}$$

Combining inequalities (16) and (17) yields

[15] Note that, in contrast to equation (14), inequality (15) is not directly related to country specialisation.

$$\sum_f w_o^f A_{od}^f \sum_f w_d^f A_{do}^f \leq \sum_f \left(\frac{w_d^f}{\omega_d}\right)\left(\omega_o A_{od}^f\right) \sum_f \left(\frac{w_o^f}{\omega_o}\right)\left(\omega_d A_{do}^f\right) \tag{18}$$

In the case of two factors (capital and labour), inequality (18) can be rewritten as:

$$w_o^L A_{od}^L w_d^K A_{do}^K + w_o^K A_{od}^K w_d^L A_{do}^L \leq w_d^L A_{od}^L w_o^K A_{do}^K + w_d^K A_{od}^K w_o^L A_{do}^L \tag{19}$$

where A_{od}^K (A_{od}^L) is the amount of capital (labour) required to produce gross exports from o to d. Dividing both sides of inequality (19) by $w_d^K A_{do}^K w_o^K A_{od}^K$ yields the empirical hypothesis of the relative factor endowment, HO_{od}:

$$HO_{do} = \left(\frac{w_d^L}{w_d^K} - \frac{w_o^L}{w_o^K}\right)\left(\frac{A_{do}^K}{A_{do}^L} - \frac{A_{od}^K}{A_{od}^L}\right) \geq 0 \tag{20}$$

Equation (20) implies that if country d has a higher wage/rental ratio than country o, ($w_d^L/w_d^K > w_o^L/w_o^K$), then the capital/labour ratio embodied in country d's exports to o cannot be lower than the capital/labour ratio embodied in country o's exports to d ($A_{do}^K/A_{do}^L \geq A_{od}^K/A_{od}^L$).

According to *Debaere* (2003), the hypothesis $HO_{od} \geq 0$ is robust to Hicks-neutral and factor augmenting technology differences, when calculating relative factor abundance. This property allows us to compute the endowment ratio, HO_{od}, without first imputing technology parameters, and hence avoiding the potential problem of measurement error in the estimated technology parameters.

In a two-factor model the wage-rental ratio is a non-decreasing function of the capital-labour ratio (*Helpman* 1984). Hence, we can straightforwardly derive the quantity version of the definition of relative factor abundance:

$$HO_{od} = \left(\frac{F_d^K}{F_d^L} - \frac{F_o^K}{F_o^L}\right)\left(\frac{A_{od}^K}{A_{od}^L} - \frac{A_{do}^K}{A_{do}^L}\right) \geq 0 \tag{21}$$

where F_r^K and F_r^L are capital and labour endowments of country r. Inequality (21) suggests that if country d is more capital abundant than country o, i.e. $F_d^K/F_d^L > F_o^K/F_o^L$, then the capital-labour ratio embodied in country d's exports to country o cannot be lower than the capital-labour ratio embodied in country o's exports to d, i.e. $A_{do}^K/A_{do}^L \geq A_{od}^K/A_{od}^L$.

4.3 Market imperfections and transaction costs

In this section we derive the theoretical hypothesis of market imperfections and transaction costs. Our null hypothesis serve equations (14) and (20) in sections 4.1 and 4.2, where the factor content corresponds to the actual (measured) factor input use, implying that $A_{iod}(\tau_{io}(t_{io})) = A_{iod}$, where τ_{io} is a measure of market completeness and t_{ir} are transaction costs. This is the situation we observe in the agricultural trade data for the CEE. Hence, the results obtained from estimating equations (14) and (20) will serve as a benchmark for assessing the role of transaction costs.

Next we derive the transaction cost hypothesis. Generally, there are two approaches how to infer transaction costs of farm (re)organisation: (i) calculating productivity ratios from the production data; and (ii) estimating transaction cost functions. Each of the two approaches has conceptual advantages and disadvantages. For example, the implied transaction cost approach does not require to arbitrary assume a specific functional form and estimation method, does not need to select/exclude explanatory variables and by construction accounts for the unobservable component of transaction cost. The approach of estimating a transaction cost function has the advantage that it avoids additional regularity conditions, such as symmetric and homogenous transaction costs.

In the present study we model transaction costs following the former approach, where transaction costs are assumed to be an increasing function of the ratio of equilibrium productivity of heterogenous firms. We assume that: (i) transaction costs are symmetric (transaction cost of transforming CF into IF = transaction cost of transforming IF into CF); and (ii) transaction costs are proportional to the productivity ratio of the two types of firms. In the case of two types of firms, the implied measure of market completeness, τ_{ir}, (which is inversely related to transaction costs) can be expressed as follows:

$$\tau_{ir} = \left(\frac{\omega_{ir}^{I}}{\omega_{ir}^{C}}\right)^{-\xi} \tag{22}$$

where $\xi > 0$ is the elasticity of farm (re)organisation, defined as the ratio of changes in transaction costs over changes in productivity differences between different types of farms. It measures how transaction costs are translated into productivity differences. Low values of elasticity imply that transaction costs cause small productivity differences between IF and CF. The measure of market completeness, τ_{ir}, is normalised to the interval [0,1] with zero denoting prohibitive transaction costs and one denoting perfect markets with no transaction costs.

According to the underlying trade model outlined in section 3, transaction costs of farm (re)organisation may affect both factor input and farm output. Factor input ratios, factor input levels and output levels, in turn, determine the total direct input requirement, A_{iod}. We model transaction costs by assuming that the total factor content of exports, $A_{iod}(\tau_{io})$, in sector i from region r is a weighted sum of inputs used in producing export goods by CF, $A_{iod}^{C}(\tau_{or})$, and IF, $A_{iod}^{I}(\tau_{or})$, the adjustment of which can (though do not need to) be constrained by transaction costs:[16]

[16] Note that A_{iod} refers to factor content of trade between two countries (o and d), hence, it is a flow variable. In contrast, τ_{ir} and a_{ir} refer to a single (exporting) country. Therefore, only one geographic subscript (either d (importer), o (exporter) or r) is used.

$$A_{iod}(\tau_{io}) = \alpha^q_{io} A^C_{iod}\left(a^C_{io}(\tau_{io}), \omega^C_{io}(\tau_{io})\right) + (1-\alpha^q_{io}) A^I_{iod}\left(a^I_{io}(\tau_{io}), \omega^I_{io}(\tau_{io})\right) \quad (23)$$

According to equation (23), factor use by CF and IF is a function of transaction costs, which constrain farm (re)organisation and hence the optimisation possibilities in input use. Distortions in input use cause distortions in factor content of farm output and exports. For example, CFs (or IFs) may use more some (or all) inputs per unit of output in sector i than IFs. Equation (23) reflects these distortions in the total factor content of exports, $A_{iod}(\tau_{io})$. For example, for an individual farm higher transaction costs imply higher opportunity cost of producing in an IF type of farm, which leads to lower CF equilibrium production and lower input use, $\frac{\partial L^I_{ir}}{\partial t_{ir}} < 0$. The opposite holds for CF, implying that $\frac{\partial L^C_{ir}}{\partial t_{ir}} > 0$. This also implies that the CF production and factor input shares are increasing in transaction costs, $\frac{\partial \alpha^A_{ir}}{\partial t_{ir}} > 0$. With higher transaction costs the aggregate factor requirement, a_{ir}, will be more determined by the CF factor requirement, a^C_{ir}, and less by the IF factor requirement, a^I_{ir}.

In order to examine the role of transaction costs and market imperfections in determining the factor content of agricultural trade, we replace the measured output shares, α^q_{ir} and $1-\alpha^q_{ir}$, with hypothetical weights $\tilde{\alpha}^q_{ir}(\tau_{ir})$ and $1-\tilde{\alpha}^q_{ir}(\tau_r)$ and re-estimate equations (14) and (20). The hypothetical output shares are calculated as follows:

$$\tilde{\alpha}^q_{ir}(\tau_{ir}) = \begin{cases} 1 & \text{if} \quad \omega^C_{ir} > \omega^I_{ir} \\ 0 & \text{if} \quad \omega^C_{ir} < \omega^I_{ir} \end{cases} \quad (24)$$

$$1-\tilde{\alpha}^q_{ir}(\tau_{ir}) = \begin{cases} 1 & \text{if} \quad \omega^I_{ir} > \omega^C_{ir} \\ 0 & \text{if} \quad \omega^I_{ir} < \omega^C_{ir} \end{cases} \quad (25)$$

This hypothetical scenario implies zero transaction costs as we assume that in each country and sector only the most productive type of farms produce and export.

In order to test for transaction costs of farm (re)organisation and their impact on factor content of the CEE trade, we need to adjust weights in equations (9)-(11). Imposing the weights from equations (24) and (25) yields adjusted (predicted) factor wages, $\tilde{w}_r(\tau_r)$, productivity $\tilde{\omega}_{ir}(\tau_{ir})$ and factor content of trade, $\tilde{A}_{iod}(\tau_{io})$. Substituting these into equation (14) yields an empirically testable relationship of factor content of bilateral trade, cross-country technological differences and transaction costs of farm (re)organisation:

$$\tilde{R}_{od}(\tau_o) = \frac{\sum_i \left(\frac{\tilde{w}_d(\tau_d)}{\tilde{\omega}_{id}(\tau_{id})}\right) \tilde{\omega}_{io}(\tau_{io}) \tilde{A}_{iod}(\tau_{io}) + \sum_i \left(\frac{\tilde{w}_o(\tau_o)}{\tilde{\omega}_{io}(\tau_{io})}\right) \tilde{\omega}_{id}(\tau_{id}) \tilde{A}_{ido}(\tau_{id})}{\sum_i \tilde{w}_d(\tau_d) \tilde{A}_{ido}(\tau_{id}) + \sum_i \tilde{w}_o(\tau_o) \tilde{A}_{iod}(\tau_{io})} \geq 1 \quad (26)$$

Given that transaction costs are now reduced to zero, $\tau_{io}(t_{io}) = \tau_{id}(t_{id}) = 1$, equation (26) simplifies to:

$$\tilde{R}_{od} = \frac{\sum_i \left(\frac{\tilde{w}_d}{\tilde{\omega}_{id}}\right) \tilde{\omega}_{io} \tilde{A}_{iod} + \sum_i \left(\frac{\tilde{w}_o}{\tilde{\omega}_{io}}\right) \tilde{\omega}_{id} \tilde{A}_{ido}}{\sum_i \tilde{w}_d \tilde{A}_{ido} + \sum_i \tilde{w}_o \tilde{A}_{iod}} \geq 1 \tag{27}$$

Analogously to equation (27), we substitute the adjusted (predicted) labour wage, $\tilde{w}_r^L(\tau_r)$, capital rental rate, $\tilde{w}_r^K(\tau_r)$, labour content of trade, $\tilde{A}_{od}^L(\tau_{io})$, and capital content of trade, $\tilde{A}_{od}^K(\tau_{io})$, into equation (20) and obtain an empirically testable relationship of factor content of bilateral trade, relative factor abundance and transaction costs of farm (re)organisation:

$$\widetilde{HO}_{od}(\tau_o) = \left(\frac{\tilde{w}_d^L(\tau_d)}{\tilde{w}_d^K(\tau_d)} - \frac{\tilde{w}_o^L(\tau_o)}{\tilde{w}_o^K(\tau_o)}\right)\left(\frac{\tilde{A}_{do}^K(\tau_d)}{\tilde{A}_{do}^L(\tau_d)} - \frac{\tilde{A}_{od}^K(\tau_o)}{\tilde{A}_{od}^L(\tau_o)}\right) \geq 0 \tag{28}$$

As above, given that transaction costs are now reduced to zero, $\tau_{io}(t_{io}) = \tau_{id}(t_{id}) = 1$, equation (28) simplifies to:

$$\widetilde{HO}_{od} = \left(\frac{\tilde{w}_d^L}{\tilde{w}_d^K} - \frac{\tilde{w}_o^L}{\tilde{w}_o^K}\right)\left(\frac{\tilde{A}_{do}^K}{\tilde{A}_{do}^L} - \frac{\tilde{A}_{od}^K}{\tilde{A}_{od}^L}\right) \geq 0 \tag{29}$$

The key difference between equations (14) and (27), and equations (20) and (29) is in the CF and IF factor input and farm output shares, $\tilde{\alpha}_{ir}^q(\tau_{ir})$ and $1 - \tilde{\alpha}_{ir}^q(\tau_{ir})$. In order to study the impact of transaction costs, t_{ir}, in equations (27) and (29) we relax the assumption $\tau_{id}(t_{id}) = \tau_{io}(t_{io}) = 1$ and weight the primary factor use in each industry and in each region/country by τ_{ir} according to farm-type productivity differences. For example, if CF are less productive than IF in industry i in region r, then a lower weight is given to CF. Note that this does not change the total sectoral output. Hence, farm-type productivity-weighted adjustments of $\tilde{\alpha}_{ir}^q$ is the main (and only) source of adjustments induced in factor wages, $\tilde{w}_r(\tau_r)$, productivity $\tilde{\omega}_{ir}(\tau_{ir})$ and factor content of trade $\tilde{A}_{iod}(\tau_{io})$, as these variables are different between CF and IF.

Combining equations (14) and (27) yields the transaction cost hypothesis with respect to the Ricardian technology differences:

$$\tilde{R}_{od}(\tau_o) - R_{od} \geq 0 \tag{30}$$

Hypothesis (30) says that if farm (re)organisation, input use and productivity are constrained by transaction costs, then weighting factor input and farm output shares according to the farm-type productivity differences should improve factor allocation efficiency and hence increase the match between exporter's actual production cost and importer's hypothetical production cost. Note that hypothesis (30) holds for country o exporting good i. However, the transaction cost hypothesis cannot be tested for the aggregate trade, as the results would be biased by country specialisation effects.

Analogously, combining equations (20) and (29) yields the transaction cost hypothesis with respect to the relative factor abundance:

$$\widetilde{HO}_{od}(\tau_o) - HO_{od} \geq 0 \tag{31}$$

The transaction cost hypothesis (30) and (31) says that if markets are perfect, then productivities ω_{ir}^C and ω_{ir}^I should not differ significantly for the same sector i in region/country r, $\lim\limits_{t_{ir}\to 1} \omega_{ir}^I/\omega_{ir}^C = 1$ between different types of farms, implying that the measured factor content of trade, A_{iod}, should be close or equal to the predicted factor content of exports, $\tilde{A}_{iod}(\tau_{io})$, from region r in sector i. However, if farm (re)organisation, input use and productivity is constrained by transaction costs, then weighting factor input and farm output shares according to the farm-type productivity differences should improve the factor allocation efficiency and hence performance of the Ricardo and Heckscher-Ohlin tests of factor content of bilateral trade.

5 Empirical results

We test empirically the three hypothesis derived in section 4: (i) the role of Ricardian technology differences in the bilateral trade of agricultural goods; (ii) the Heckscher-Ohlin endowment hypothesis; and (iii) the role of transaction costs in the factor content of bilateral trade in the CEE. More precisely, by comparing two trade equilibriums - the observed equilibrium computed using the actual transaction costs with a hypothetical trade equilibrium computed using reduced transaction costs - we are able to assess the importance of transaction costs of farm (re)organisation and hence the distortions of the factor content of agricultural trade.

Following *Lai* and *Zhu* (2007), all three hypothesis are tested by performing a sign test for four different sets of countries. The full sample (EU-25) examines exporter's actual production cost versus importer's hypothetical production cost in bilateral trade of all EU 25 member states. There are 300 unique bilateral trade flows in 2004. The sub-sample EU-15 consists of relatively capital abundant old EU member states and contains 105 unique bilateral trade flows.[17] The sub-sample CEE consists of relatively labour abundant new EU member states and contains 45 unique bilateral trade flows. Finally, we examine factor content of bilateral trade between EU-15 and the CEE. This sub-sample consists of 75 unique bilateral trade flows. As explained, we test the impact of transaction costs only for the CEE.[18]

[17] The results reported in *Kancs*, *Ciaian* and *Pokrivcak* (2008) confirm that EU-15 is relatively capital-abundant whereas the CEE is relatively labour abundant, capital is relatively expensive in the CEE whereas labour is relatively expensive in EU-15.

[18] Given that in most EU-15 countries with well functioning markets transaction costs are low and the CF share is negligible, $\alpha_{ir}^q < 0.01$, we expect most of the adjustments to occur in the eight post-communist transition countries, where market imperfections are significant and the average share of CF is 44% (see Table 1).

5.1 Ricardian technology differences

In this section we empirically test hypothesis (14), which says that, on average, a country imports the services of those factors that are cheaper in its trading partner and exports the services of those factors that are more expensive for its trading partner. In order to empirically test the role of Ricardian technological differences, two variables need to be calculated and compared: (i) the importer d's hypothetical unit cost of production; and (ii) the exporter o's actual unit cost of production. The former can be calculated using the importer d's factor prices and exporter o's factor usage. The latter can be calculated using the actual exporter o's factor prices and factor usage. The data sources for all variables are summarised in Table 10 in the Appendix. In addition, the productivity parameter ω_{ir} is required. Productivity parameter is obtained from the TFP estimates, which is described in the Appendix.

We test hypothesis (14) by performing sign test for bilateral trade flows with agricultural goods in 2004. Column 1 in Table 4 reports the obtained sign statistics for factor content of aggregate agricultural trade, which are defined as the percentage of country pairs that satisfy $R_{od} \geq 1$.

Table 4: Ricardian technology differences and factor content of bilateral trade

	$R_{od} \geq 1$	Obs	$R_{iod} \geq 1$	Obs
	(1)	(2)	(3)	(4)
EU-25 (full sample)	0.72	300	0.54	2400
	(0.01)		(0.01)	
EU-15 (capital-abundant)	0.78	105	0.53	840
	(0.01)		(0.01)	
CEE (labour-abundant)	0.47	45	0.45	360
	(0.03)		(0.03)	
EU-15 - CEE	0.74	75	0.57	600
	(0.02)		(0.04)	

Notes: Sign test results based on equations (14) - column (1) and (15) - column (3); p-values in parenthesis. $R_{od} \geq 1$ refers to countries; $R_{iod} \geq 1$ refers to sectors.

The sign statistics reported in Table 4 suggest that for EU-25 $R_{od} \geq 1$ is satisfied for 72% of bilateral trade flows between EU-25 countries. The $p-$value of the sign test is below 0.01, which means that the probability of having $R_{od} \geq 1$ for more than 72% of the time is less than 1%. Thus, the hypothesis $R_{od} \geq 1$ performs rather well for EU-25 country pairs. According to Table 4, the test statistics is even higher for EU-15 - the hypothesis $R_{od} \geq 1$ is satisfied for 78% of bilateral trade flows of agricultural goods. Again, the hypothesis $R_{od} \geq 1$ cannot be rejected at the 1% significance level. The test performance is considerably lower for the CEE, where the hypothesis $R_{od} \geq 1$ is satisfied for 47% of bilateral trade flows. Moreover, the results are less significant. The sign statistics reported in Table 4 also suggest that the test performance is rather good (74%) for bilateral trade between capital-abundant EU-15 and labour-abundant the CEE countries.

As a robustness check, in addition to the total agricultural trade, we also test the activity-level version of the Ricardian technological difference hypothesis, which is given in equation (15).[19] The obtained test statistics for the activity-level technology differences is reported in column 3 of Table 4. The activity-level test statistics suggest that the hypothesis $R_{iod} \geq 1$ performs rather poor both for the full sample of EU-25 as well as for different sub-sets of country pairs. This result is in line with our expectations, as specialisation adjustments at the agricultural activity-level are constrained by agronomic reasons, such as crop rotation. As for the total agricultural trade, the highest success rate is for bilateral trade between EU-15 countries and the CEE countries.

One general conclusion that we can draw from the Ricardian sign statistics is that the factor content of bilateral trade between the old EU member states (EU-15) reflects cross-country technology differences considerably better than agricultural trade between the new EU member states (the CEE). Second, compared to the aggregate trade (manufacturing + agriculture) (not reported), the $R_{iod} \geq 1$ test performance is lower at the agricultural sector level, and yet poorer at the sub-sectoral (agricultural activity) level. These results are in line with previous studies analysing factor content of bilateral trade, e.g. *Choi* and *Krishna* (2004); *Lai* and *Zhu* (2007), who report sign test statistics between 0.82 and 0.96 for the aggregate trade.

5.2 Relative factor abundance

In this section we empirically test hypothesis (20), which says that exports by capital-abundant countries embody a higher capital labour ratio than exports by labour abundant countries. In order to empirically test the role of Heckscher-Ohlin endowment differences, empirical data for factor prices and and factor use is required. More precisely: (i) labour wages and capital rental rates for each country; and (ii) the amount of capital and labour embodied in each country's exports. The data sources are summarised in Table 10 in the Appendix.

We test the relative factor abundance hypothesis $HO_{od} \geq 0$ for two factors: labour and capital.[20] Column 1 in Table 5 reports the obtained sign statistics for factor content of bilateral trade, which is defined as the percentage of country pairs that satisfy $HO_{od} \geq 0$.

The sign statistics reported in Table 5 suggests that for EU-25 the hypothesis $HO_{od} \geq 0$ is satisfied for 79% of bilateral trade flows between EU-25 countries. The $p-$value of the sign test is below 0.01, which means that the probability of having

[19]The eight agricultural activities (sub-sectors) are described in Table 9 in the Appendix.

[20]Empirical analysis of *Kancs*, *Ciaian* and *Pokrivcak* (2008) extends the canonical two factor version of the HO model by introducing land in addition to the tradition factors labour and capital.

Table 5: Relative factor abundance and factor content of bilateral trade

	$HO_{od} \geq 0$	Obs	$HO_{iod} \geq 0$	Obs
	(1)	(2)	(3)	(4)
EU-25 (full sample)	0.79	300	0.72	2400
	(0.01)		(0.01)	
EU-15 (capital-abundant)	0.81	105	0.77	840
	(0.02)		(0.02)	
CEE (labour abundant)	0.56	45	0.63	360
	(0.14)		(0.17)	
EU-15 - CEE	0.85	75	0.70	600
	(0.02)		(0.06)	

Notes: Sign test results based on equations (20); p-values in parenthesis. $HO_{od} \geq 0$refers to countries; $HO_{iod} \geq 0$ refers to sectors.

$HO_{od} \geq 0$ for more than 79% of the time is less than 1%. Thus, the hypothesis $HO_{od} \geq 0$ performs rather well for EU-25 country pairs. According to column 1, row 3 in Table 5, the test statistics is even higher for EU-15, where the hypothesis $HO_{od} \geq 0$ is satisfied for 81% of bilateral trade flows of agricultural goods. The hypothesis $HO_{od} \geq 0$ cannot be rejected at the 2% significance level. The test performance is considerably lower for the CEE, where the hypothesis $HO_{od} \geq 0$ is satisfied only for 56% of bilateral trade flows. Moreover, the results are considerably less significant. The sign statistics reported in Table 5 also suggests that the test performance is quite good (85%) for bilateral trade between capital-abundant EU-15 and labour-abundant the CEE countries.

Similar to section 5.1, in addition to the total agricultural trade, we also test the match between wage-rental ratio and capital-labour ratio in trade at the agricultural activity-level. The obtained test statistics for the relative factor abundance at the activity-level is reported in column 3 of Table 5. The disaggregated results suggest that the hypothesis $HO_{iod} \geq 0$ performs rather poor both for the full sample of EU-25 as well as for the sub-sets of country pairs involving the CEE. In line with the results for the total agricultural trade, the highest success rate is estimated for bilateral trade between EU-15 and the CEE country pairs.

The results reported in Table 5 allow us to draw similar conclusions as in section 5.1. First, the factor content of bilateral trade between the old EU member states (EU-15) reflects country relative factor abundance considerably better than agricultural trade between the new EU member states (the CEE). Again, the $HO_{iod} \geq 0$ test performance is lower at the agricultural sector level, and yet poorer at the sub-sectoral (agricultural activity) level. Again, these results are in line with previous studies analysing factor content of bilateral trade, e.g. *Choi* and *Krishna* (2004); *Lai* and *Zhu* (2007).

5.3 Transaction costs and market imperfections

In this section we examine the role of transaction costs and market imperfections in factor content of agricultural trade in the CEE. In particular, we focus on transaction costs which farms incur when reorganising their production from CF to IF and vice versa. First, we re-examine equations (27) and (29) by performing a sign test for the same four sub-sets of countries as in sections 5.1 and 5.2. In a second step, we evaluate the empirical evidence of transaction costs on the basis of equations (30) and (31).

We start with re-examining the Ricardian technology differences in the presence of transaction costs. Column 1 in Table 6 reports the obtained sign statistics for factor content of aggregate agricultural trade using the hypothetical output shares from equations (24) and (25).

Table 6: Ricardian technology differences and factor content of bilateral trade

	$\tilde{R}_{od}(\tau_o) \geq 1$	Obs	$\tilde{R}_{iod}(\tau_{io}) \geq 1$	Obs
	(1)	(2)	(3)	(4)
EU-25 (full sample)	0.77	300	0.54	2400
	(0.01)		(0.02)	
EU-15 (capital abundant)	0.78	105	0.53	840
	(0.01)		(0.02)	
CEE (labour abundant)	0.71	45	0.46	360
	(0.02)		(0.03)	
EU-15 - CEE	0.78	75	0.57	600
	(0.03)		(0.04)	

Notes: Sign test results based on equations (27); p-values in parenthesis. $\tilde{R}_{od} \geq 1$ refers to countries; $\tilde{R}_{iod} \geq 1$ refers to sectors.

The sign statistics reported in Table 6 suggest that for EU-25 $\tilde{R}_{od}(\tau_o) \geq 1$ is satisfied for 77% of bilateral trade flows between EU-25 countries. The $p-$value of the sign test is below 0.01, hence the probability of having $\tilde{R}_{od}(\tau_o) \geq 1$ for more than 77% of the time is less than 1%. Thus, the hypothesis $\tilde{R}_{od}(\tau_o) \geq 1$ performs quite well for EU-25 country pairs. The test performance is even better for EU-15, where the hypothesis $\tilde{R}_{od}(\tau_o) \geq 1$ is satisfied for 78% of bilateral trade flows of agricultural goods. Again, the hypothesis $\tilde{R}_{od}(\tau_o) \geq 1$ cannot be rejected at the 1% significance level. The test performance is slightly lower for the CEE, where the hypothesis $\tilde{R}_{od}(\tau_o) \geq 1$ is satisfied for 71% of bilateral trade flows. The sign statistics reported in bottom row of column 1 in Table 6 also suggest that the test performance is quite good (78%) for bilateral trade between capital-abundant EU-15 and labour-abundant the CEE countries.

As in section 5.1, we also test the agricultural activity-level version of the Ricardian technological differences hypothesis, which is analogue to equation (15). The obtained sign statistics for the activity-level technology differences is reported in column 3 of Table 6. The activity-level test statistics suggest that the hypothesis $\tilde{R}_{iod}(\tau_{io}) \geq 1$ performs rather poor both for the full sample of EU-25 as well as different sub-sets of country pairs. Similar to the total agricultural trade, the highest success rate is for bilateral trade between EU-15 countries and the CEE countries.

The second step involves the empirical evaluation of the transaction cost hypothesis (30). Compared to Table 4, the sign statistics reported in Table 6 suggest that the Ricardo test performance has not changed for EU-15. This result is due to the fact that we do not test the transaction cost hypothesis for EU-15. Comparing Tables 4 and 6 we also note that the sign statistics has improved considerably for the CEE - from 47% to 71%, and slightly for bilateral trade between EU-15 and the CEE - from 74% to 78%. According to the hypothesis (30), these results indicate presence of market imperfections. Our interpretation of these market imperfections are transaction costs related to adjusting farm organisation and hence input use.

The sign test results at the sub-sectoral level are rather similar to those reported in Table 4, i.e. the productivity-weighted adjustments in $\tilde{\alpha}_{ir}^{q}$ have not improved the Ricardo test performance at the sub-sectoral level. In contrast to the aggregate agricultural trade, the test performance has not improved significantly for factor content of the CEE's bilateral trade at activity-level. These results may suggest that either transaction costs of farm re-specialisation are less important in the CEE compared to transaction costs of farm (re)organisation; or it is not a good measure at the activity-level due to agronomic reasons, such as crop rotation.

Next, we re-examine the relative factor abundance hypothesis in the presence of transaction costs and market imperfections. The obtained sign statistics for factor content of aggregate agricultural trade using the hypothetical output shares from equations (24) and (25) are reported in Table 7 (column 1 for aggregate agricultural trade and column 3 for activity-level trade).

The results reported for the full sample (row 1, column 1) suggest that the hypothesis $\widetilde{HO}_{od}(\tau_o) \geq 0$ is satisfied for 81% of bilateral trade flows between EU-25 countries. As above, the $p-$value of the sign test is 0.01. According to Table 7, the test statistics has the same magnitude for EU-15. The hypothesis $\widetilde{HO}_{od}(\tau_o) \geq 0$ cannot be rejected at the 2% significance level. We also note that the test performance is rather good for the CEE, where the hypothesis $\widetilde{HO}_{od}(\tau_o) \geq 0$ is satisfied for 78% of bilateral trade flows in agriculture. However, the results are less significant. The sign statistics reported in Table 7 also suggests that the best test performance (83%) is estimated for bilateral trade between capital-abundant EU-15 and labour-abundant the CEE countries.

The results for the activity-level version of the Heckscher-Ohlin relative factor endowment hypothesis is reported in column 3 of Table 7. The activity-level test

Table 7: Relative factor abundance and factor content of bilateral trade

	$\widetilde{HO}_{od}(\tau_o) \geq 0$	Obs	$\widetilde{HO}_{iod}(\tau_{io}) \geq 0$	Obs
	(1)	(2)	(3)	(4)
EU-25 (full sample)	0.81	300	0.72	2400
	(0.01)		(0.01)	
EU-15 (capital abundant)	0.81	105	0.77	840
	(0.02)		(0.03)	
CEE (labour abundant)	0.78	45	0.68	360
	(0.03)		(0.05)	
EU-15 - CEE	0.83	75	0.69	600
	(0.04)		(0.09)	

Notes: Sign test results based on equations (29); p-values in parenthesis. $\tilde{HO}_{od} \geq 0$ refers to countries; $\tilde{HO}_{iod} \geq 0$ refers to sectors.

statistics suggest that the hypothesis $\widetilde{HO}_{iod}(\tau_{io}) \geq 0$ performs rather good both for the bilateral trade between EU-25 country pairs and EU-15 country pairs as well as for the sub-set of country pairs involving only the CEE. Again, the highest success rate is estimated for bilateral trade between EU-15 country pairs.

The second step of the transaction cost analysis involves the empirical evaluation of equation (31). For this purpose we compare Tables 5 and 7. Comparing the two Tables suggests that the transaction cost hypothesis (31) yields zero values, both for the aggregate agricultural trade and the activity-level trade for EU-15. For the CEE the test results yield positive and significant values (+0.22), implying that the $\widetilde{HO}_{iod}(\tau_{io})$ test performance is by 22% better that the $HO_{od} \geq 0$ test performance. The opposite holds for the bilateral trade between EU-15 and the CEE countries, where the success rate has slightly decreased (by 2%). However, these results are the least significant.

One general conclusion we can draw from evaluating the full (EU-25) sample performance, is that the sign statistics has improved solely for the aggregate agricultural trade, but not for the activity-level trade. These results may suggest that transaction costs of farm (re)organisation are more significant than transaction costs of farm re-specialisation. A second conclusion we may draw in light of these results is that weighting factor input and farm output shares according to farm-type productivity differences (the more productive type of farms have larger weight) considerably improves performance of the Heckscher-Ohlin relative factor endowment hypothesis. According to hypothesis (31), these results suggest presence of market imperfections. According to the transaction cost hypothesis these market imperfections are transaction costs related to transforming CF into IF and vice versa.

6 Conclusions

In this paper we study the determinants of factor content of the CEE agricultural trade. Compared to studies of factor content of the developed country trade, which usually rely on the HOV model, our analysis is considerably complicated by the fact that the CEEs are characterised by sizeable differences in technology and factor prices both compared to their main trading partner - EU and within the CEE. Given that these differences strongly violate the key assumptions of the HOV theorem, the traditional HOV model would yield biased results in the present study.

In order to get around these issues, we build our theoretical framework on the previous work of *Helpman* (1984) and *Staiger* (1986), who consider a trade equilibrium in which factor prices are allowed to differ across countries and *Lai* and *Zhu* (2007), who account for international technology differences. In the absence of factor price equalisation, we are able to predict the factor content of trade from the post-trade data without restricting preferences, and this can be done for bilateral trade patterns. Hence, our approach is less restrictive and more consistent with the empirical evidence than the HOV model.

In the empirical analysis we examine three hypothesis. First, the exporter's actual unit cost of production cannot be greater than the importer's hypothetical unit cost of production. This hypothesis was first examined by *Choi* and *Krishna* (2004) under the assumption of identical technology across countries. Second, exports by capital-abundant countries embody a higher capital-labour ratio than the exports by labour-abundant countries. This hypothesis was first examined by *Lai* and *Zhu* (2007). Our third hypothesis relates the factor content of trade to transaction costs and market imperfections. This hypothesis has not been examined in the literature before.

In contrast to most of the previous studies, which usually have been confined to either aggregate or manufacturing trade of developed countries, our empirical analysis focuses on the agricultural trade in the CEE transition economies. We find that the hypotheses of technological differences and relative factor abundance are confirmed by the majority of developed country pairs (EU-15). These results are in line with previous studies analysing factor content of bilateral trade, e.g. *Choi* and *Krishna* (2004); *Lai* and *Zhu* (2007). In contrast, both hypotheses are rejected by roughly one half of the CEE transition country pairs. However, when accounting for transaction costs of farm (re)organisation, which are assumed to be proportional to productivity differences between different types of farms, both hypotheses of technological differences and relative factor abundance are confirmed by the majority of the CEE country pairs. According to our transaction cost hypothesis, these findings provide empirical evidence of market imperfections, which we interpret as transaction costs. These results are robust to various alternative specifications.

Based on findings from the transaction cost analysis we can draw several implications for agricultural policies in the CEE. First, differentiated findings for EU-15 and the CEE suggest that agricultural policy in the CEE transition economies need to be different from the developed market economies, where transaction costs and market imperfections are low. Second, our empirical findings suggest that adjustments in farm organisation would increase the allocation efficiency of production factors, raise the employment of technological and relative factor endowment advantages and hence increase factor rewards. Increased farmer income would in turn reduce the need for agricultural support policies. Hence, policies addressing transaction costs and market imperfections in the CEE have the potential to increase farmer income without market-distorting side-effects. Therefore, agricultural policies in the CEE need to be aimed at decreasing transaction costs rather than fixing prices and distorting agricultural markets or supporting farmers through direct farm payments. The current CAP subsidy system either reduce incentives to re-organise farms or create distorted institutions.

References

[1] Allen, A. and Lueck, D. (1998), The nature of the farm. Journal of Law and Economics 41: 343-386.

[2] Brecher, R.A. and Choudri, E.U.(1988), The Factor Content of Consumption in Canada and the United States : A Two-Country Test of the Heckscher-Ohlin-Vanek Model. in : Feenstra, R. C. (ed.), Empirical Methods for International Trade, MIT Press, Cambridge.

[3] Ciaian, P. and J.F.M. Swinnen, (2006), Land Market Imperfections and Agricultural Policy Impacts in the New EU Member States. American Journal of Agricultural Economics, 88: 799-815.

[4] Ciaian, P. and J.F.M. Swinnen, (2009), Credit Market Imperfections and the Distribution of Policy Rents, American Journal of Agricultural Economics, forthcoming.

[5] Choi, Y., Krishna, P. (2004), The factor content of bilateral trade: an empirical test. Journal of Political Economy 112: 887–914.

[6] Davis, Donald R. and David E. Weinstein (2001), An Account of Global Factor Trade. American Economic Review, 91 (5): 1423-1453.

[7] Debaere, P. (2003), Relative Factor Abundance and Trade, Journal of Political Economy, 111 (3): 589-610.

[8] Eurostat (2007), Intra- and extra-EU trade - Annual data, CN - Supplement 2/2007, (DVD-ROM), Luxembourg.

[9] Eurostat (2009), Europe in figures - Eurostat statistical yearbook 2008, Luxembourg.

[10] Helpman, E. (1984), The factor content of foreign trade. Economic Journal 94: 84–94.

[11] Jensen, M. and Meckling, W. (1976), Theory of the firm: Managerial behavior, agency costs and ownership structure. Journal of Financial Economics 3: 305-360.

[12] Kancs, D. (2007), Trade Growth in a Heterogeneous Firm Model: Evidence from South Eastern Europe, The World Economy, 30 (7): 1139-1169.

[13] Kancs, D., Ciaian, P. and Pokrivcak, J. (2008), Comparative Advantages, Transaction Costs and Factor Content of Agricultural Trade: Empirical Evidence from the CEE, EERI Research Paper 08/11, Economics and Econometrics Research Institute.

[14] Lai, H, and Zhu, S (2007), Technology, endowments, and the factor content of bilateral trade, Journal of International Economics, 71: 389–409.

[15] Leamer, E. Levinsohn, J. (1995), International Trade Theory: the Evidence, Chapter 3 In Handbook of International Economics, volume 3, Amsterdam North Holland.

[16] Melitz, M. J. (2003), "The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity," Econometrica, 71: 1695-1725.

[17] Olley, S. G. and Pakes, A. (1996) The dynamics of productivity in the telecommunications equipment industry. Econometrica 64: 1263-1297.

[18] Pollak, R. A., (1985), A transaction costs approach to families and households, Journal of Economic Literature, 23: 581-608.

[19] Prosterman, R.L., Rolfes, L. (Jr.)., (1999), Review of the Legal Basis for Agricultural Land Markets in Lithuania, Poland and Romania, in Csaki and Lerman eds., Structural Changes in the Farming Sectors in the CEE: Lessons for EU Accession.

[20] Schmitt, G., (1991), Why is the Agriculture of Advanced Western Countries still Organised by Family Farms? Will this continue to be so in the Future? European Review of Agricultural Economics 18: 443-458.

[21] Staiger, R.W. (1986), Measurement of the factor content of foreign trade with traded intermediate goods. Journal of International Economics 21: 361–368.

[22] Trefler, D. (1995), The case of the Missing Trade and Other Mysteries, The American Economic Review, 85: 1029-46.

[23] Yasar, M., Raciborski, R. and B. Poi (2008), Production function estimation in Stata using the Olley and Pakes method, Stata Journal 8 (2): 221-231.

7 Appendix

7.1 Productivity estimates

The TFP estimates are based on a two year (2004 and 2005) firm-level panel data from the Farm Accountancy Data Network (FADN). 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. In the present study we make use of a panel data for 25 EU economies covering two years - 2004 and 2005. The unbalanced panel contains 151,434 observations: 38,981 for the new EU member states (CEE) and 112,454 for the old EU member states (EU-15).

In order to estimate the TFP using a panel of firm-level data several issues need to be addressed. In particular, simultaneity and selection bias need to be addressed (*Yasar et al* 2008). Given that productivity is known to the profit maximising firms (but not to the econometrician) when they choose their input levels, the problem of simultaneity may arise. As a result of positive productivity shocks, firms will increase their use of inputs (*Marschak* and *Andrews* 1944). Given that OLS does not account for the unobserved productivity shocks, the obtained estimates of production function parameters would be biased. If we are willing to assume that the unobserved firm-specific productivity is time-invariant, a fixed effect estimator would solve the simultaneity problem.[21]

Second, selection bias need to be addressed when estimating production function parameters. Selection bias result from the relationship between productivity shocks and the probability of exit from the market (*Yasar et al* 2008). If a firm's profitability is positively related to its capital stock, then a firm with a larger capital stock is more likely to stay in the market despite a low productivity shock than a firm with a smaller capital stock because the firm with more capital can be expected to produce greater future profits. Without controlling for firm selection, the negative correlation between capital stock and probability of exit for a given productivity shock would bias downward the coefficient on the capital variable.

When these biases are not controlled for, the coefficients associated with variable inputs (e.g. labor and materials) are expected to have an upward bias and the co-

[21] Other methods, including instrumental variables approaches, have also been proposed to control for this bias when estimating the parameters of production functions (*Yasar et al* 2008).

efficients associated with quasi-fixed inputs (e.g. capital) are expected to be biased downwards (*Olley* and *Pakes* 1996). In order to address these issues, we adopt the *Olley* and *Pakes* (1996) estimator, which allows to address the simultaneity and selection problems when estimating the production function parameters and firm-level productivity. The simultaneity problems are addressed by using investment to proxy for an unobserved time-varying productivity shock, and the selection problems are addressed by using survival probabilities.

In our dataset the variable $\ln q$ represents log output, $exit$ is a dummy variably, one indicating the firm exited in the current period and zero otherwise, t is the trend, and $\ln capital$, $\ln labour$, $\ln materials$ and $\ln investm$ are the logs of capital, materials, labour, and investment, respectively. We treat $\ln capital$ as a state variable, $\ln labour$ and $\ln materials$ as freely variable inputs, and $\ln investm$ as the proxy variable. All these variables are extracted from the FADN data base.

We estimate production function for each country, each farm type and each agricultural activity. As a result, we obtain 8×2×25=400 sets of production function parameters. However, given that there are only few CF in EU-15, Cyprus and Malta, it is impossible to obtain statistically significant and economically meaningful CF estimates for EU-15. Therefore, for EU-15, Cyprus and Malta we do not distinguish between CF and IF. This reduces the number of production function parameter estimates to 8×2×8+8×1×17=264, which we use in the empirical analysis. For illustrative purposes in Table 8 we report production function parameters for agriculture as a whole sector for EU-25.

Table 8: Olley-Pakes production function estimates for EU-25

	Coefficient	Std. Err.
$\ln capital$	0.103**	0.017
$\ln labour$	0.120***	0.002
$\ln materials$	0.722***	0.005
t	-0.038***	0.005
No	151434	

Notes: Dependent variable: log of output. Standard errors are bootstrapped using 500 replications. ***significant at 1% level.

According to Table 8, all three inputs (labour, materials and capital) have positive and significant coefficients. Variable capital inputs, $\ln materials$, have the highest elasticity, which is in line with literature. The magnitude of the estimated input coefficients is of the same order of magnitude for capital and land. Trend variable, t, has a negative coefficient indicating productivity growth over time.

7.2 Countries, sectors and data sources

The full sample containing all EU-25 countries consists of two sub-samples: CEE (new EU member states) and EU-15 (old EU member states). CEE: Czech Republic, Cyprus, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, and Slovenia. EU-15: Belgium, Denmark, Germany, Greece, Spain, France, Ireland, Italy, Luxembourg, Netherlands, Austria, Portugal, Finland, Sweden,United Kingdom.

Table 9: Sectoral classification and concordance with FADN sectors

Sectors	FADN classification
Cereals, oilseed and protein crops	Specialist cereals, oilseed, protein crops
Root crops and technical crops	Specialist root crops
	Cereals and root crops combined
	Specialist field vegetables
	Various field crops
Horticulture	Specialist market garden vegetables
	Specialist flowers and ornementals
	General market garden cropping
Permanent crops	Specialist vineyards
	Specialist fruit and citrus fruit
	Specialist olives
Milk	Specialist dairying
Grazing livestock	Specialist cattle-rearing and fattening
	Cattle-dairying, rearing and fattening
	Sheep, goats and other grazing livestock
Pigs and poultry	Specialist granivores (pigs and poultry)
Rest of agriculture	Rest of agricultural activities*

Notes: *Rest of agricultural activities capture also mixed (non-specialist) farming.

Table 10: Key variables and the employed data sources

	Variable	Dimension	Source
w_r^L	Wage rate	$(r \times 1) \times h$	FADN
w_r^K	Capital rental rate	$(r \times 1) \times h$	FADN
a_{ir}	Factor input per output unit	$(r \times i) \times h$	GTAP/FADN
ω_{ir}	Productivity	$(r \times i) \times h$	EUROSTAT/FADN*
E_{iod}	Gross exports	$r \times (r-1)/2 \times i$	COMEXT/GTAP
A_{iod}^L	Labour input in exports	$(r \times (r-1)/2 \times i) \times h$	COMEXT/FADN
A_{iod}^K	Capital input in exports	$(r \times (r-1)/2 \times i) \times h$	COMEXT/FADN

Notes: i - number of industries; h - number of farm types (only for the CEE-8); r - number of regions/countries; $r \times (r-1)/2$ - number of non-duplicate country pairs. *own estimations based on firm-level panel data from FADN.