The Law of One Price and the Czech Cereal Market Integration into the EU Common Agricultural Market[1]

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Abstract

The Czech cereal market integration into the common agricultural market (EU) between 1993 – 2010 is studied using monthly price data for wheat and barley in Belgium, Germany, Austria and the Czech Republic. Stability in the law of one price (LOP) equation is studied through multiple structural breaks within the equation. Results indicate that the integration of the Czech Republic into EU cereal markets is more unstable than that of Austria (a fourth enlargement country), although there is empirical support for the LOP when structural breaks are taken into account. Structural change also occurred in the old EU LOP equation between Belgium and Germany.

Keywords: *law of one price, time series analysis, structural change, commodity markets, Czech Republic, common agricultural market*

JEL Classification: C01, C32, E30, E31, Q11, Q13

Introduction

Agriculture is one of the key determinants of sustainable development in a modern society. Even though the share of agriculture out of the total economic output of individual countries has been declining, particularly in developed countries, it continues to be an integral part of societal development. The policies

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of the European Union also respect the key role of agriculture within countries' economies. By the end of the 1950s, the EC countries had formulated a Common Agricultural Policy (CAP) wherein some main goals were set, such as stabilisation of the agricultural and food products markets, food security, rural development as well as stabilization of the prices of agri-food products.

While the CAP protects the domestic EU market, markets are competitive inside the EU due to the free movement of goods and services and also the lack of trade restrictions within the region (Burianová and Belová, 2012). This implies that countries within the EU trading zone must be competitive with other regions within the zone. This has created a relatively stable agricultural trading zone among EU trading partners, which can operate within the restrictions imposed by the CAP and provide consumers with the benefits of intra-regional competition.

The issue that is studied in this research is how well the EU trading zone integrates new members into the EU agricultural trading region. This has been particularly important during the last two decades. The recent expansion of the EU agricultural trading area included the entry of Finland, Sweden and Austria (the so-called fourth enlargement) in 1995 and the former command economies of Eastern Europe (including the Czech Republic, Slovakia, Poland and Hungary) in 2004. This study addresses a question related to the stability of agricultural markets that resulted from the addition of the countries of the fourth enlargement and from the entry of the former command economies of Eastern Europe to the EU trading zone. This could have led to disruptions in markets, both in the agricultural economies that entered the EU trading region and in those industries already in the trading zone. Market integration within the region is further complicated by the general volatility in agricultural markets (Rumánková, 2012) that resulted from the commodity boom beginning in 2007 and the crash of the general economy resulting from the financial crisis of 2008. The implication is that all of these events could have resulted in repeated structural changes in EU agricultural markets which could have hampered overall market integration over the last two decades.

This paper examines the process of convergence in the agrarian sector that has resulted from the changes in and expansion of the EU trading area over the last two decades. The mechanism used to study market integration is the law of one price (LOP). Our interest lies in not only how well markets in new member states (i.e. the Czech Republic) adapted to rapid and continuous shocks to trading relationships, but also how these changes could have disrupted markets in existing member states. To this end, the analysis includes prices of two commodities (wheat and barley) as well as the process of market integration in Central Europe, using Germany as the base country, Belgium for an established EU country, a country from the fourth expansion in 1995 (Austria) and a country from the

former Eastern Bloc countries (the Czech Republic). Germany is among the states with the largest agricultural economy in the European Union; the other three, Belgium, Austria and the Czech Republic, are located geographically next to Germany and therefore their integration with the German agricultural economy ought to be economically important. These countries are for that reason good candidates for this study.

The Czech Republic is an example of a new EU country from the former Eastern Bloc that gained complete access to the EU only recently in 2004. The agrarian market in the Czech Republic is heavily influenced by its close proximity to Germany. On the other hand, Austria and Belgium, being of a similar size to the Czech Republic in terms of population, are representatives of the older EU countries. While Belgium and Austria have similar populations, they also have significant differences that make them an interesting choice for study in this paper. Austria became a full member of the EU agricultural trading area in 1995, whereas Belgium has been part of the EU agricultural trading area since 1957. Furthermore, both countries border Germany, and like the Czech Republic, should also be heavily influenced by the German economy. Therefore, all three economies may differ in their historical development in terms of the speed and level of price convergence during the last two decades. It was decided to apply the theory of LOP to two commodities (wheat and barley), since these commodities can be regarded as homogenous in all markets. Moreover, these commodities are traded in the markets of the analysed countries and constitute a portion of their mutual foreign trade.

The literature on market integration is extensive. The introduction of the European Single Market in 1992 brought the expectation that markets become more efficient and prices would converge within the European Union then only price differences between member countries would simply reflect transactional costs or differing value added taxes (Cecchini, Catinat and Jacquemin, 1988). Similar expectations emerged when the European Monetary Union started (Mongelli, 2008). The early empirical studies seemed to confirm the expectation of declining price differences between countries (Barro and Sala I. Martin, 1995; Carree and Klomp, 1997; Egger and Pfaffermayr, 2009; Wolszczak-Derlacz and De Blander, 2009; Parsley and Wei, 2008; Fischer, 2009; Funke and Koske, 2008).

On the other hand, the price level differences among the EU countries are still substantial. Price levels are, in general, lower in countries with a low per capita income such as Central and Eastern European transition countries (Lindenblatt and Feuerstein, 2014). Dreger et al. (2008) emphasize two countervailing effects on the price indices of these countries. The integration into the internal market will increase competition and thereby lower prices, while the process of catching up increases prices due to the Balassa-Samuelson effect, i.e. due to rising wages.

When the second effect dominates, rising labour costs lead to rising prices. Price differences within the EU become smaller and thus price convergence is observed.

Considering market efficiency in terms of market integration the authors usually test for law of one price. Empirical studies show that the law of one price has little evidence to support it. Large price differences for identical products are observed which cannot be explained by cost differences (see e.g. Cumby, 1996; Haskel and Wolf, 2001; Goldberg and Verboven, 2004; Egger and Pfaffermayr, 2009; Wolszczak-Derlacz and De Blander, 2009; Parsley and Wei, 2008; Fischer, 2009; Funke and Koske, 2008; Dreger et al., 2008).

The specific area of price development and price transmission is represented by the EU agricultural market (Listorti and Esposti, 2012). Continuing to this day are significant price differences among individual EU countries even in the case of such a homogenous commodity group as cereals (Roche and McQuinn, 2003). The European price of wheat and barley differs across the EU. The wheat and barley market price formation over Europe is the object of a couple of studies published during the last few years (Bakucs et al., 2012; Dawson, Sanjuan and White, 2006; Viju, Nolan and Kerr, 2006 etc.). The published results provide quite significant differences across the European countries. Wheat price seems to be much more homogenous across Europe but on the other hand the level of price transmission in the case of barley is much lower (Bubáková, 2015). There are significant barley price differences among individual EU countries (Gil, Angulob and Zapatac, 2008). Barley and wheat markets provide a unique case study of market integration for several reasons. First, the introduction of Monetary Compensatory Amounts which operated for more than twenty years as a means to tax/subsidize exports have compensated for currency fluctuations and therefore have facilitated agricultural trade among the EU countries. Secondly, there is a considerable degree of self-sufficiency among the main producing countries with intra-trade flows that fluctuate between 20% to 50% of total trade for barley and 35% to 60% for wheat. Lastly, the existence of the CAP may help to create a more ideal market environment for arbitrage activities. Therefore, the study of market integration and price dynamics is timely and will provide price information useful to market agents involved in the barley and wheat trade (Gil, Angulob and Zapatac, 2008).

1. The Evolution of Market Integration in Central Europe and Neighbouring Countries

The agricultural commodity market in Central Europe between 1993 – 2010 can be characterized by rapid changes, particularly for the countries from the former Eastern Bloc. Before 1989, prices were determined within a centrally-planned

economy. After 1989, the introduction of market-based principles, deregulation and liberalization led to a system where decentralized market mechanisms determined prices. A good example of this process is the events that have occurred in the Czech Republic since the so-called "Velvet Revolution" of 1989. While the former Eastern Bloc countries are the most obvious examples of economies that have had to adjust over the last two decades, other countries within the region were also subject to changes in policy regimes. These include the countries of the fourth enlargement (Sweden, Austria and Finland). These countries did not have centrally-planned economies but did not join the EU agricultural trading region until 1995.

The fourth enlargement of 1995 meant that these economies had to integrate within the much larger economy of the founding EU member states, due to the adoption of a common currency and adherence to Maastricht criteria. In the absence of trade restrictions, prices of agricultural commodities in Central European countries should be similar due to their geographic proximity and similar climatic conditions.

However, the process of integration through price adjustments has been disrupted by periodic economic, legal and political events that may have led to structural changes within markets during the last two decades.

Furthermore, global events have occurred since 1995 that have affected Central European agricultural markets. These include the implementation of obligations arising from the Uruguay Round of GATT as well as the ongoing discussions of the Doha round of the World Trade Organization (WTO). The signing of other important documents, liberalizing bilateral trade among countries and the EU, may have influenced market integration in the region (examples for the Czech Republic include „double profit" and „double zero", which extended association agreement from 1991).

The cereals price development at the level of individual EU countries was seriously affected by the set of reforms related to the character of the EU agricultural market. EU CAP was heavily influenced by MacSharry reform and Agenda 2000. The Mid-term review and Health check recorded only a limited impact on CAP character. The current CAP is running under the last and reform CAP 2014 – 2020. All of those reforms made the EU agricultural market more homogenous. Many constraints, limits and imperfections affecting the EU agricultural market structure development were removed and also the significant impact on the EU internal market food price formation is evident. Food price differences existing among individual countries are slowly disappearing. However, they are still significant especially if we compare them between the south of Europe and the northern part of the EU.

The period between 1998 – 2004 was marked by a series of trade-liberalizing events in the Czech Republic's agricultural markets which then intensified during the lead-in to full entry into the EU agricultural trading region in May 2004. While official entry was in May 2004, an intense process of legal and economic adjustments for final EU entry began to be implemented as early as 1998. The process was one of gradual market liberalization which was accompanied by the transformation of agricultural production. All of these events could have led to structural changes within agricultural markets over the last two decades and especially during the period between 1998 to 2004.

Finally, the rapid rise in prices beginning in 2007 could also have disrupted agricultural markets within the EU agricultural trading area and thus this is the next candidate for structural break. Changes in global economic conditions (Goswami and Nag, 2012; Junková and Matoušková, 2011), especially the rapid rise in demand from emerging economies like China, India and the rise of cereals use for the non-food processing industry, led to a dramatic rise in the prices of agricultural commodities. Between 2007 and 2008, prices of major food commodities more than doubled, with the largest increase occurring in the prices of rice, wheat and soybeans. Finally, the meltdown of financial markets in October 2008, which resulted from the collapse of housing prices in the US, led to a global recession; this could have had a spill-over effect in Central European commodity markets, which experienced a decline in prices. Then have agricultural commodity markets begun to recover. Drought and other weather-related events in 2010, especially in Russia, also disrupted the EU's agricultural markets resulting in another price fluctuations.

In this study, agricultural market stability in Central Europe will be studied by examining prices within the region. In the next section, theoretical and econometric aspects of pricing within the region will be presented. This is followed by a presentation of results. The final section concludes with a discussion of the implications of this study.

2. Materials and Methods

2.1. Market Integration, Structural Change and the Law of One Price

Market integration in the Central European agricultural economy is a trade problem. How well these markets are integrated is often measured and tested by examining the law of one price. The LOP states that, at equilibrium:

$$P_{it} - TC_{ijt} - P_{jt} = 0 \tag{1}$$

where

P_{it} – the price in the *ith* market at time *t*,

P_{jt} – the price in the *jth* market at time *t*,

TC_{ijt} – the transaction costs associated with trade.

The transaction costs of trade include transportation costs, tariffs as well as non-tariff barriers, effects that reduce or enhance trade due to the implementation of trade agreements and any other significant trade-related disruptions (including weather, global economic conditions, etc.). Equation (1) is assumed to hold when trade takes place and if trade flows from the *ith* market to the *jth* market, then the *ith* market is the exporting country and the *jth* market is the importing country.

From the LOP equation (1), it is evident that the nature and properties of the transaction costs of trade, TC_{ijt} , is critical to the nature and properties of the LOP. Often, it is assumed that $TC_{ijt} = \mu_i + \varepsilon_{it}$, where μ_i is a constant and ε_{it} is an error term. In that case

$$P_{it} = \mu_i + \beta_i P_{jt} + \varepsilon_{it} \tag{2}$$

where $\beta_i = 1$ if LOP holds. Equation (2) is the specification of the LOP that is often estimated in literature (e.g. Goodwin and Piggott, 2001; Goodwin and Schroeder, 1991). Less often, transportation costs are collected and entered into the estimating equation as a separate regressor (e.g. Baulch, 1997). Barret and Li (1996) examine regime-switching regressions, assuming data are stationary and variable returns to arbitrage that lead to positive or zero trades.

Goodwin (1992) develops a general set of restrictions for the LOP using equation (2) under general equilibrium with a single commodity market. He finds that if there are k markets, then the LOP implies that there ought to be $k - 1$ co-integrating vectors. The finding that there are $k - 1$ co-integrating vectors is a necessary but not a sufficient condition for the LOP to hold. The sufficient condition is that all slope terms are as follows: $\beta_i = 1$, $i = 1, \ldots, k - 1$. These over-identifying restrictions can also be tested using maximum likelihood, employing the methodology developed by Pesaran and Pesaran (1997).

A problem with the use of the maximum likelihood general equilibrium approach is that it may not lead to uniquely identifiable violations in the LOP. Infrequent but significant changes in the TC_{ijt} term in equation (1) resulting from changes in trading regimes cannot be incorporated into the Johansen approach (1991), where constant intercepts of a type characterized by equation (2) are assumed. Violations resulting from non-constant intercept terms due to structural change because of infrequent changes in the TC_{ijt} term in equation (1) could result in rejection of the LOP when in fact it holds true.

This is because equation (2), with infrequent changes in policy regimes, more accurately reflects the true trading regime in agricultural markets in Central Europe during the last two decades.

2.2. Parameter Stability and the Law of One Price

Violations in the LOP could result from parameter instability in equation (1). The kinds of changes that could be important include time-specific, one-time changes in the constant due to structural change resulting from euro zone entry by countries of the fourth expansion in 1995, or due to entry by the former Eastern European countries in 2004. Other potentially significant events that could possibly have influenced the intercept term in equation (2) because of infrequent changes in TC_{ijt} include the commodity boom of 2007 – 2008 and the financial crisis of 2008. There are several methods by which parameter instability can be examined with an econometric relationship. Early examples include Chow (1960) and Quandt (1960). Hansen (1992) extends the tests to include cases where the break point is unknown (to avoid data snooping) and the regressors are I(1). Other methods that detect parameter instability include threshold estimation methods (e.g. Hansen, 2002; Caner and Hansen, 2001).

A maintained hypothesis used in this study is that the LOP can be well approximated by a single structural change in the model and that all variables are I(1). Models that can capture infrequent but multiple structural changes in the TC_{ijt} term in equation (2), such as in the LOP equation of the type discussed in the previous section, include Bai and Perron (1998), Kejriwal and Perron (2010) and Garcia and Perron (1996). Kerjiwal and Perron (2010) provide the most general case, in which model regressors can be both stationary I(0) and non-stationary I(1) stochastic processes with multiple regime shifts.

The use of the Kejriwal and Perron (2010) approach requires the selection of a numeraire price and individual pairwise comparisons. In this study, the German price is chosen as the numeraire (regressor) price since Germany is the largest agricultural economy of the region. A disadvantage of this approach over the Johansen approach (1991) is in the selection of the numeraire price and it is inherently limited (rather than full) information in nature.

Kejriwal and Perron (2010) outline a procedure that can be used to test for multiple structural breaks within a co-integrating relationship. Variables included within the model can be either stationary I(0), non-stationary I(1) or trending variables. Since the prices examined in this study are determined to be non-stationary I(1) variables, (see Table 1 below), the rest of this section will outline the Kejriwal and Perron (2010) results for the case of a pure I(1) process. Furthermore,

the discussion in a previous section indicated a strong likelihood that structural changes in Central European agricultural markets would result in a changing intercept in the LOP equation. This particular case is labelled case 2(a) in Kejriwal and Perron (2010).

Implementation of the Kejriwal and Perron (2010) procedure utilizes the dynamic programming algorithm developed by Bai and Perron (2003) to find the least squares estimates of parameters of equations with multiple breaks. Following the suggestion of Kejriwal and Perron (2010), the estimator used is the leads and lags (dynamic OLS) estimator of Saikkonen (1991) to correct for possible endogeneity in I(1) regressors.

Other parameters that need to be specified for unique critical values associated with hypotheses to be deduced for the Kejriwal and Perron (2010) approach include the: (1) maximum number of structural breaks considered (m = 4); (2) trimming factor (ε = 0.15); (3) number of leads and lags considered (l_t = 6 months); and (4) minimum length of structural break (h = 18 months).[2] Three tests of structural change have been developed by Kejriwal and Perron (2010). The first is a test of $k = 0$ against $k = j$, $j = 1, \ldots, m$. This tests the null of no structural breaks against k structural breaks, up to a maximum number of m breaks considered. Rejection of this test would indicate that the data are consistent with at least $0 < k \leq m$ structural breaks in the estimated relationship. The second test is a sequential test of k structural breaks against the alternative of $k + 1$ structural breaks. The third, called UDmax, is the maximum of the sequence of the first test from $j = 1, \ldots, m$, and tests the null hypothesis of no structural breaks against the alternative of some unspecified number of breaks, greater than zero but less than or equal to m structural breaks. This test would lead to a conclusion similar to that of the first test but was determined by Kejriwal and Perron (2010) to have the highest monotonic power properties of all the tests considered. The algorithm used to calculate the tests is the dynamic programming algorithm outlined in Bai and Perron (2003).

Critical values of tests 1 and 2 for a trimming factor of $\varepsilon = 0.15$ and $m = 4$ for the first and third tests are listed in Table 1, category (a), case 2 of Kejriwal and Perron (2010). Critical values of the sequential (second) test are listed in Table 3, category (a), case 2 of Kejriwal and Perron (2010).

A final test of the LOP equation given by equation (2) tests H_0: $\beta = 1$ versus H_a : $\beta \neq 1$, after appropriate adjustments in intercept due to structural change

[2] The maximum number of structural breaks $m = 4$ was determined with respect to the fact that the maximum number of break $m = 5$ provided by Kejriwal and Perron (2010) produced inconsistent results. The values of trimming factor and minimum length of structural break follow Kejriwal and Perron (2010) as well as their generated critical values of the test. Number of leads and lags correct for possible endogeneity in I(1) regressors was determined according to Saikkonen (1991).

testing are made. Assuming that the estimated relationships represent co-integrated relationships adjusted for structural change, the leads and lags estimator can be used to test whether $\beta = 1$ using a regular t-test. Since serial correlation cannot be ruled out, the leads and lags estimator is adjusted by a Cochrane-Orcutt serial correlation correction to avoid over-rejection of null hypotheses when errors are serially correlated.

3. Data and Results

3.1. Data

Two commodities were chosen for the study: soft wheat (food quality) and barley (food quality). All data are measured in EUR per tonne and represents producer price level. The data is monthly data and the time period concerned is from January 1993 to June 2010 (Figures are provided in the Appendix). Data for this time period was collected for four European countries: Germany, Belgium, Austria and the Czech Republic. These represent a good cross section of countries to use to study the LOP in Central Europe. Germany is the largest economy in the EU and is geographically in a central position within the EU. The data on Germany and Belgium were collected from Eurostat (2010). Belgium is not located in Central Europe but it is a member of the original EU membership that borders Germany and therefore is a good example of how the entry of other countries into the EU can affect stability within the original member states. Austria also borders Germany and is a member of the fourth enlargement, namely those countries that entered in 1995. Austrian data was collected using the Eurostat (2010) – during the period from July 1995 till June 2010 – and BOKU database (BOKU, 2010) – during the period from January 1993 till June 1995. Finally, the fourth country in this study is the Czech Republic, which also borders Germany and is a former command economy that entered the EU in 2004. The data on the Czech Republic was collected from Eurostat (2010) – during the period from May 2004 till June 2010 – and the Ministry of Agriculture of the Czech Republic (2010) during the period from January 1993 till April 2004.

3.2. Results

Table 1 presents the results of Dickey-Fuller (1979) unit root tests (constant, no trend and constant, trend) for the series. The table indicates that a unit root in the soft wheat price series cannot be rejected for any of the countries studied. For barley, a unit root cannot be rejected for Belgium, Germany and the Czech Republic. For Austria, the results are ambiguous, with a unit root rejected for

constant trend in Austria and not rejected for constant, no trend. From these results, we can conclude that the weight of the evidence favours a unit root in soft wheat and barley prices.

T a b l e 1

Dickey-Fuller Tests on Price Series

	Prices in levels		**Prices in first differences**	
	Deterministic variables entered into the Dickey-Fuller regression		Deterministic variables entered into the Dickey-Fuller regression	
Series	Constant	Constant, trend	Constant	Constant, trend
1) Barley				
Austria	–2.86 (12)	–3.95 (12)	–3.82 (11)	–3.84 (11)
Germany	–2.17 (12)	–2.89 (12)	–3.90 (12)	–3.89 (12)
Belgium	–2.88 (5)	–3.31 (5)	–9.66 (0)	–9.64 (0)
Czech Republic	–1.98 (11)	–2.34 (11)	–5.49 (9)	–5.47 (9)
2) Soft wheat				
Austria	–2.22 (9)	–3.06 (9)	–4.60 (8)	–4.65 (8)
Germany	–1.55 (11)	–2.99 (11)	–4.67 (9)	–4.66 (9)
Belgium	–2.19 (10)	–3.06 (10)	–4.50 (12)	–4.49 (12)
Czech Republic	–1.92 (10)	–2.24 (10)	–3.97 (12)	–3.98 (12)

Notes: The lag length of the first differences included in the Dickey-Fuller regression is presented in the parentheses. It is the highest significant (0.05 level significance) based on a lag length t-test (maximum 12 lags).

Source: Own calculations: 5% critical value for constant, no trend $n = 100$, is –2.89, and 5% critical value for constant trend is –3.45; Fuller (1976), p. 373.

Table 2 presents the results of tests for structural breaks in the LOP equations completed using the Kejriwal and Perron (2010) approach. The table indicates that all of the LOP equations are consistent with at least one structural break during the last two decades. In all cases, the test of no structural break against $m = 1, 2, 3, 4$ and the UDmax test are rejected at a 1% level of significance. Therefore, intercept instability characterizes this data.

For barley, the Czech Republic LOP equation and the Austrian LOP equation indicates that four structural breaks (the maximum number considered) are consistent with the data, using the results of the sequential structural break test. While this result is consistent with four breaks, Kerjriwal and Perron (2010) argue that finding the maximum number of breaks considered is also consistent with the rejection of a co-integrating relationship. For the Belgian LOP equation, the data indicates that there is one structural break based on conclusions coming from the sequential test (using a significance level of 5%).

For wheat, the conclusions using the sequential test indicates three structural breaks in the sample period in the Czech Republic, one structural break in the Austrian LOP equation and one structural break in the Belgian LOP equation (using a significance level of 5%). In general, the wheat LOP equations exhibit

much less instability than the barley LOP equations, even to the extent that the instability in the barley equations could indicate the lack of a co-integrating relationship.

T a b l e 2

Tests for Multiple Structural Breaks

Region/Crops	Breaks under the null	Breaks under the alternative	Test	UDmax
Czech Republic Barley	0	1	140.86 ***	
	0	2	106.42 ***	
	0	3	102.08 ***	
	0	4	81.87 ***	140.86 ***
	1	2	28.46 ***	
	2	3	19.95 ***	
	3	4	17.51 ***	
Czech Republic Wheat	0	1	80.23 ***	
	0	2	44.79 ***	
	0	3	31.32 ***	
	0	4	34.25 ***	80.23 ***
	1	2	14.54 ***	
	2	3	13.74 **	
	3	4	10.28 *	
Austria Barley	0	1	252.94 ***	
	0	2	214.55 ***	
	0	3	152.22 ***	
	0	4	186.48 ***	252.94 ***
	1	2	138.79 ***	
	2	3	44.80 ***	
	3	4	29.66 ***	
Austria Wheat	0	1	213.60 ***	
	0	2	109.86 ***	
	0	3	79.94 ***	
	0	4	57.08 ***	213.60 ***
	1	2	9.79 *	
Belgium Barley	0	1	29.71 ***	
	0	2	27.94 ***	
	0	3	22.97 ***	
	0	4	30.45 ***	30.45 ***
	1	2	9.04 *	
Belgium Wheat	0	1	56.22 ***	
	0	2	26.78 ***	
	0	3	25.77 ***	
	0	4	26.04 ***	56.22 ***
	1	2	4.94	

Notes: Three tests of structural change are presented in the table. The first is a test of $k = 0$ against $k = j$, $j = 1, \ldots, m$. This tests the null of no structural breaks against k structural breaks, up to a maximum number of m breaks considered. Rejection of this test would indicate that the data are consistent with at least $0 < k \leq m$ structural breaks in the estimated relationship. The second test is a sequential test of k structural breaks against the alternative of $k + 1$ structural breaks. The third, called UDmax, is the maximum of the sequence of the first test from $j = 1, \ldots, m$, and tests the null hypothesis of no structural breaks against the alternative of some unspecified number of breaks, greater than zero but less than or equal to m structural breaks.

Source: Own calculations. *, **, ***, are 10%, 5% and 1% levels of significance, respectively. Critical values of test statistics are taken from Kerjriwal and Perron (2010), Table 1, category (a), case 2, $\varepsilon = 0.15$ and Table 3, category (a), $\varepsilon = 0.15$.

T a b l e 3

Estimated Law of One Price Equations for Central European Countries (1993:01 – 2010:06)

Time period	Intercept estimate		Slope estimate	Time period	Intercept estimate		Slope estimate
1 Czech Republic a) Barley (4 structural breaks)				b) Wheat (3 structural breaks)			
1993:01 – 1995:12	–70.61 (15.53)		1.068 (0.11)	1993:01 – 1995:12	–39.44 (16.67)		0.94 (0.10)
1996:01 – 2000:12	–39.61 (13.31)	t-test	0.64	1996:01 – 2001:06	–6.83 (16.03)	t-test	0.51
2001:01 – 2003:06	–22.65 (13.65)			2001:07 – 2003:11	–29.22 (15.74)		
2003:07 – 2005:12	–43.55 (14.02)			2003:12 – 2010:06	–4.31 (15.78)		
2006:01 – 2010:06	–32.60 (15.02)						
2 Austria a) Barley (4 structural breaks)				b) Wheat (1 structural break)			
1993:01 – 1995:01	11.59 (23.91)		1.10 (0.14)	1993:01 – 1995:01	83.31 (9.19)		1.16 (0.06)
1995:02 – 2000:06	20.06 (23.44)	t-test	0.64	1995:02 – 2010:06	–19.07 (16.03)	t-test	2.69
2000:07 – 2004:07	21.30 (22.95)						
2004:08 – 2006:01	34.49 (22.70)						
2006:02 – 2010:06	–22.17 (22.54)						
3 Belgium a) Barley (1 structural break)				b) Wheat (1 structural break)			
1993:01 – 2006:04	30.25 (23.91)		0.75 (0.14)	1993:01 – 2004:02	1.95 (3.93)		0.97 (0.03)
2006:05 – 2010:06	48.24 (9.59)	t-test	–3.94	2004:03 – 2010:06	8.85 (1.97)	t-test	–1.00

Notes: Values in parentheses are standard errors. T-test refers to t-statistic associated with test that slope parameter = 1.

Source: Own calculations.

Further econometric results coming from the LOP equations are presented in Table 3. The table lists the estimated intercept terms for the structural breaks, the time periods of the structural breaks, the estimates of the slope coefficient and standard error in each LOP as well as a t-test indicating that the slope coefficient is unity.

For the Czech Republic, the period between 1993 – 2010 was characterized by instability in both the barley and wheat markets. The first break for both commodities was at the end of 1995, which corresponded with the volume growth of export licenses and the dropping of trade barriers (import quotas) and import tariffs to 23% (see Novak, 1999; Kren, 1996). The time of the break can

also be connected with the fourth enlargement and the entry of Austria, Sweden and Finland as full members into the EU agricultural market trading region, which was a significant institutional change in the region and affected the markets. Thus, the first break can be viewed as a result of both trade liberalizing events coming from the GATT Uruguay Round agreement and the integration processes in the analysed region. The second break occurred at the end of December 2000 for barley and six months later in June 2001 for wheat. This break can be attributed to the Double zero agreement (see Ministry of Agriculture of the Czech Republic, 2000) and the change in interventional prices. The Double zero agreement meant duty-free quotas for cereals.

Moreover, the import and export quotas significantly increased. The State Agricultural Intervention Fund (SAIF) of the Czech Republic changed the interventional price in 2001, from more than 4 000 CZK/t to only 3 300 CZK/t (see SAIF CR, 2001). The next break in wheat occurred with the entry of the Czech Republic into the EU agricultural trading region in 2004. This was the final break in the wheat LOP equation. For barley, the break associated with full membership occurred sooner, in the middle of 2003, i.e., 10 months before the EU accession. The presence of the break shows that the market anticipated the entrance (one reason for this is the high number of future contracts – FAO (2006). The final break in the Czech Republic barley LOP equation in July 2006 is connected with an overall increase in commodity prices, or anticipation of the commodity boom in 2007, as the case may be. For both the wheat and barley LOP equations, the hypothesis that the slope coefficient is unity is not rejected, which is consistent with the LOP holding in both markets, despite the fact that the time period was associated with several structural breaks. This suggests that the wheat market is integrated. Since the Czech Republic and German barley prices may not be co-integrated, market integration is questionable.

For Austria, the structural change tests indicate that the promotion of Austria to full EU agricultural market trading status in 1995, together with the trade liberalization events (the impact of the Uruguay Round Agreement), was associated with a structural break in both the barley and wheat markets. No further structural breaks occurred in the wheat market. For barley, additional structural breaks occurred in mid-2000, August 2004 and at the beginning of 2006. That is to say that the results of the test for barley are similar to the results for the Czech Republic. The second break can be associated with subsequent trade liberalization events in the trade region. Trade liberalization resulted in the barley stock being highly volatile (see Faostat, 2010). The occurrence of the third break may indicate spill-over effects associated with the promotion of the former Eastern European command economies, such as the Czech Republic, to full EU agricultural

trading status in 2004. The last break effects can be associated with the commodity boom in 2007. For barley, the hypothesis that the slope coefficient is unity is not rejected, unlike for wheat, where it is rejected.

For Belgium, the data indicate one structural break in the Belgian/German LOP equation. The break times are somewhat different, with the barley structural break in mid-2006 and the wheat structural break somewhat earlier coming in early 2004. Thus, for barley, only the break associated with the commodity boom in 2007 is significant. For wheat, this is the time when the former Eastern European command economies entered the EU. The t-test that the barley slope coefficient is unity is rejected for barley but not rejected for wheat.

4. Discussion and Conclusion

This study examines the law of one price (LOP) equations for wheat and barley agricultural markets in Central Europe between 1993 – 2010. The time period is characterized by several events that could have disrupted agricultural markets, including trade liberalization events resulting from the GATT Uruguay Round agreement, the fourth enlargement of 1995 when Sweden, Austria and Finland joined the EU agricultural trading region, the promotion of the former command economies of Eastern Europe to full agricultural trading status in 2004, the commodity boom of 2006 – 2007 and the global recession that began in 2008.

The study uses a method developed by Kejriwal and Perron (2010) to measure and test for parameter instability in LOP equations. This method can identify up to eight structural breaks in the data and applies methods that can be used if data are either I(1) or I(0).

The results indicate that the barley market in Central Europe is much more unstable than the wheat market, even to the point where Czech Republic and German barley prices as well as Austrian and German barley prices may not be co-integrated. In line with findings from Backus et al. (2014) for different agricultural markets, the reason can be found in the trade frequency and market interventions. The wheat LOP equations were much more stable, with co-integration found among all Czech Republic/German wheat prices, Austrian/German wheat prices and Belgian/German wheat prices. This could indicate that the Central European barley market is much less integrated than the Central European wheat market.

The Belgian/German market was found to be the most stable and integrated of the three markets; however, even for this „old" EU market, one structural break was found: in 2006 in the barley market and in 2004 in the wheat market. Also, for the barley market the coefficient on price was statistically different for

unity, which is in violation of one of the requirements of the LOP theory. The reason is the different specialisations of Belgian farmers (barley for feeding and malting barley).

The Austrian/German market was of intermediate stability, with the barley LOP equation consisting of four structural breaks (or the lack of a co-integrating relationship) and the wheat LOP equation consistent with one structural break. The breaks in the barley LOP equation occurred with the entry of Austria into full EU agricultural trading membership in 1995, another break in mid-2000, a third break in mid-2004 and a final break beginning in 2006. For wheat, a single structural break occurred when Austria was promoted to full agricultural trading status in 1995. Afterwards, stability characterized the wheat market. The hypothesis that the coefficient on German price was equal to unity was rejected for wheat and not rejected for barley.

The Czech Republic/German LOP equation was found to be the most unstable of the three LOP country equations studied, with three structural breaks for wheat and four (or perhaps the lack of a co-integrating relationship) for barley. The time periods of the breaks roughly mirrored each other in both markets. The test that the coefficient on German price was equal to unity was not rejected for wheat or barley.

These results indicate that the trade liberalization events and accession of the former command economies in Eastern Europe into the EU agricultural trading region could be accompanied by a high degree of market instability. Transactions costs of trading between these nations and others seems to be highly volatile and susceptible to both internal changes in trade relationships between them and other nations within the EU as well as to external global market changes, like the trade liberalization and commodity boom of 2006 – 2007.

The addition of nations that have a long history of market economies seems to be much more stable, especially for wheat. Shocks to transactions costs beyond the initial entry into the EU trading region are much less prevalent in the Austrian/German LOP equations than in the Czech Republic/German LOP equations. The least susceptibility to trade disruptions was shown in the LOP equations among the old EU countries of Belgium and Germany, although significant structural breaks still occurred. For both wheat and barley, a single structural break occurred; in the case of barley, this break occurred at the beginning of 2006, associated with the commodity boom in 2007; in the case of wheat, the break occurred at the beginning of 2004, which was connected to the EU enlargement in 2004. The coefficient for the German price in the Belgian/ German LOP equation was statistically different from unity, whereas for wheat it was not.

The results provide the evidence of the market integration in European cereal markets, especially soft wheat markets, as opposed to Bakucs et al. (2012), Viju and Kerr (2009), Viju, Nolan and Kerr (2006) and others who reject the validity of law of one price. The reason can be found in the employed methodology. The standard co-integration tests may reject the co-integrating relationship if the structural break is present in the data.

However, the time series may be co-integrated with a structural break. That is, using a test for multiple structural changes in co-integrated regression models may provide more relevant results. This is especially true in the analysis with long time series which are more likely to be affected by structural breaks (Kejriwal and Perron, 2010). On the other hand, our findings are in line with other studies on agricultural market integration which found the evidence for law of one price, e.g. Bubáková (2015) and for some commodities and countries also Bakucs et al. (2014).

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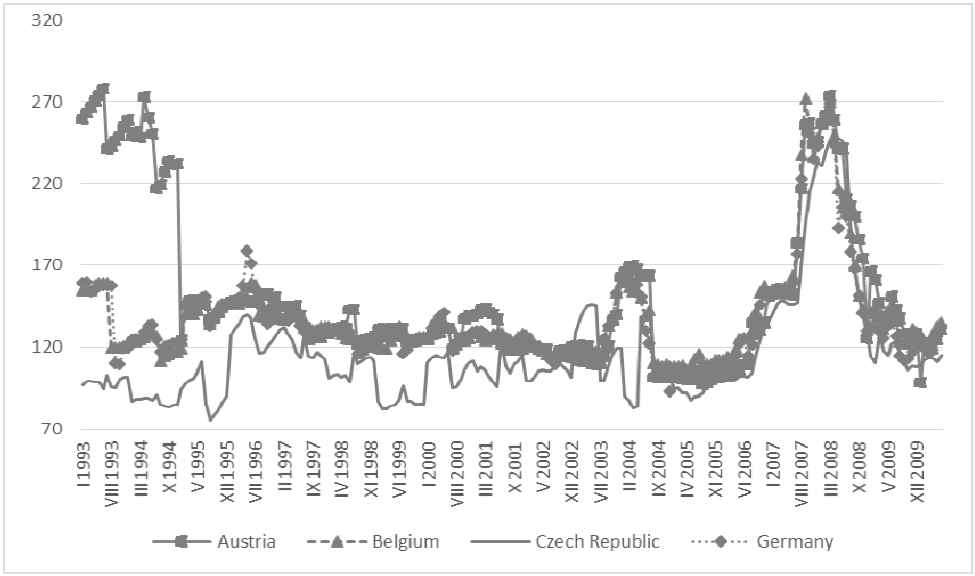
Appendix

Figure A1

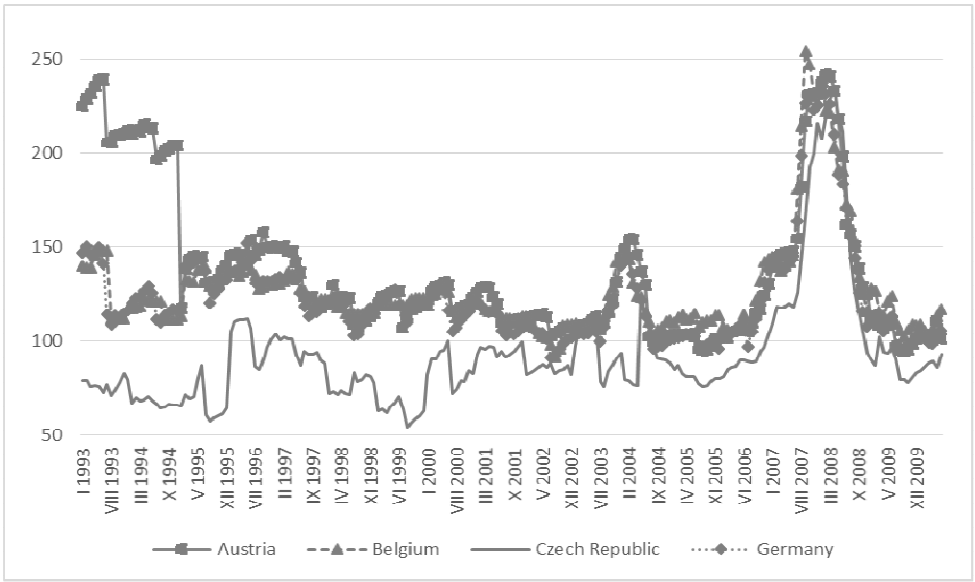
Soft Wheat Prices



Source: Eurostat (2010); BOKU database (2010); Ministry of Agriculture of the CR (2010).

Figure A2

Barley Prices



Source: Eurostat (2010); BOKU database (2010); Ministry of Agriculture of the CR (2010).