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Seasonality and spatial integration in agricultural (product) markets

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Abstract

The recent testing approaches of the 'Law of One Price' which are based on co-integration analysis are modified by incorporating the seasonal components of the agricultural price series into the testing procedure. Application of the modified testing approach to the soft wheat market of five European Union member states produces mixed results as some of the markets turn out to be integrated while in some cases a unified market cannot be assumed. These results differ in some cases from those obtained by co-integration tests which ignore seasonal unit roots.

Keywords: Seasonal co-integration; Market integration; Wheat; European Union

1. Introduction

Spatial market integration is closely linked to the behaviour of prices in the different markets. If trade exists between two markets, then it is expected that efficient commodity arbitrage will lead to an equilibrium where prices will differ only by the transport and other transfer costs between the two markets, assuming that no intramarket costs exist. The existence of such a spatial competitive equilibrium has given rise to the so-called Law of One Price (LOP) which in the case of agricultural markets presents an interest at both the international and regional/local level. In the first case, the existence of a single price (net of transportation and other transfer costs) in all markets is an essential part of international trade and exchange rate determination theories while at regional (and international in certain cases) level there is an interest in delineating the boundaries of the market and measuring the efficiency of arbitrage. The interest is enhanced by the fact that agricultural products are bulky and perishable while the areas of production and consumption are separated.

Contiguous international or regional agricultural markets present a further interest for two reasons. First, the existence of relatively lower transportation costs makes narrower the band within which prices may vary non-synchronously leading to over-rejection of the LOP in regression type tests (Goodwin et al., 1990). Second, price series in these markets may share common seasonal elements which may be important when investigating spatial market integration.

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Recently, co-integration analysis (Engle and Granger, 1987) has been used in the study of the LOP (for example, Ardeni, 1989; Baffes, 1991; Zanias, 1993). The contribution of co-integration analysis in this field is substantial since the price variables used in the study of the LOP usually exhibit a stochastic trend of the random walk type.

An important characteristic, however, of the agricultural price series used in the LOP studies has been neglected. Thus, these price series, usually monthly or quarterly, contain important seasonal components which may affect the LOP tests, while they may provide more information about market integration. Of the three types of seasonality – deterministic, stationary stochastic, and non-stationary stochastic due to seasonal unit roots – it is the last one which, if not accounted for, introduces the most troubling statistical problems (Beaulieu and Miron, 1993) to LOP tests based on co-integration analysis, leading to spurious results. This issue is tackled here using seasonal integration and co-integration. The methodology is applied to the soft wheat markets of five European Union member states. This application presents an interest of its own since, following nearly three decades of CAP (Common Agricultural Policy) operation, it would be interesting to test how common the so-called 'common market' is.

2. The LOP, co-integration and seasonality

Assuming a homogeneous product and no transportation costs or other obstacles to trade, the LOP, between two international markets, can be stated as: $P_1 = eP_2$, where e is the exchange rate and P_1, P_2, the corresponding prices in the two markets. The basic relationship used in studies of the LOP is the following:

$$p_{1t} = \alpha + \beta p_{2t} + u_t \qquad (1)$$

where p_1, p_2 are the logarithms of P_1 and eP_2, respectively. The LOP in its strict form requires that $\beta = 1$ and $\alpha = 0$. However, usually only $\beta = 1$ is tested and the constant term is left to account for transport and other transfer costs which are assumed to be constant or proportional to prices (when the logarithms of the price variables are used, which is the case here) during the sample period. The presence or not of the constant term does not affect the market integration test used here because, as will be shown later, it is based on the difference $p_1 - p_2$.

The existence of transport and other transfer costs which vary over time may seriously affect the market integration tests. Ideally, these costs should be subtracted from the prices before applying the testing procedure. However, this is not usually done because the relevant cost data are not available, which is the case here also. Some researchers, testing the LOP in international markets, have used proxy variables for transaction costs (Goodwin et al., 1990) or have tried to establish a link between some price differentials and transport costs by relating them in a co-integration framework (Baffes, 1991). In the case of the markets used here, the appropriate transport and other transfer cost data are not available, while using proxies may create more problems than it solves. In addition to this, it is expected that freight rates and other relevant costs are considerably less volatile in the EU than in international markets and therefore, their impact on the market integration tests may not be critical.

Deciding on the validity of the LOP on the basis of estimating relationship Eq. (1) has been criticised on several grounds.[1] One of the criticisms relates to the non-stationarity of the series used and it can be dealt with using co-integration analysis. Under this approach, two conditions must be satisfied for the LOP to hold. First, the two price variables must be co-integrated, which means that the least squares residuals of Eq. (1) are stationary. Second, it must hold that $\beta = 1$ and (possibly, if transportation and other transfer costs have been explicitly considered) $\alpha = 0$.

The work of Ardeni stops at the first condition and the rejection of non-co-integration is taken to imply the validity of the LOP, probably because of the well-known difficulties in testing $\beta = 1$ with the standard errors obtained from the co-integrating regression (Stock, 1987). This problem is overcome by Baffes who substituted the LOP restriction into the co-integrating relationship thus reducing the testing problem into a unit root test of a univariate series, which is the difference of the two price variables entering the co-integrating regression. Zanias, on the other hand, treats the two approaches as complementary, whereby

[1] For a short review see Sexton et al. (1991) and Baffes (1991).

a co-integration test in Eq. (1) precedes the application of Baffes's approach.[2]

However, all attempts so far to test the LOP as a co-integrating relationship, do so only at zero-frequency peak in the spectrum. This approach assumes the non-existence of other unit roots in the system, or disregards them. Agricultural price series, however, exhibit substantial seasonality which, following Pierce (1976), may have both deterministic and stochastic components:

$$p_t = x_t + \mu_t \tag{2}$$

where

$$\mu_t = \beta_0 + \sum_{j=1}^{q-1} \beta_{1j} S_{jt}$$

where S_{jt} are seasonal dummies and $q = 4$ in the case of quarterly data.

The stochastic component x_t can be generated by stationary or integrated seasonal processes. The interest here lies with the latter which exist if the series x_t has a seasonal unit root in its autoregressive representation. This can be denoted by

$$x_t \sim I_\theta(d)$$

where d is the order of integration and θ, the frequency. In the case of quarterly data, the unit roots for the stochastic component x_t can be identified using the familiar seasonal differencing operator $(1 - B^4)$ which can be expressed as:

$$\begin{aligned}(1 - B^4)x_t &= (1 - B)(1 + B + B^2 + B^3)x_t \\ &= (1 - B)(1 + B)(1 - \mathrm{i}B)(1 + \mathrm{i}B)x_t\end{aligned}$$

Thus, in the case of quarterly data, the unit roots are 1, −1, i and −i which correspond to one unit root at zero frequency, one at 2 cycles per year, and two complex pairs at 1 cycle per year. Such seasonally integrated series have properties similar to those of the ordinary integrated processes with shocks having a permanent impact (Fuller, 1976). Thus, following a shock to the process, the seasonal pattern may be altered.

While the existence of unit roots at the long-run frequency has a clear interpretation and its implications have been studied, seasonal unit roots lack strong support from economic theory. Thus, the economic mechanisms that give rise to seasonal unit roots need to be identified, especially because the power of unit root tests is never perfect (Beaulieu and Miron, 1993). In the case of agricultural prices, seasonality is mainly initiated by biological and other non-economic factors (production period) but the actual seasonal patterns are shaped by a number of economic factors. To single out one such economic factor, changes in storage costs are capable of altering the seasonal patterns which are in turn captured by seasonal unit roots. Other product-specific economic but also institutional factors may exist.

The presence of seasonal unit roots, apart from providing an opportunity for greater insight into the integration of agricultural markets, may create problems when ignored in integration and co-integration tests. In fact, Hylleberg et al. (1990) found that ignoring seasonal roots when using the (augmented) Dickey–Fuller test for a unit root at zero frequency results in test inconsistency and lack of power. In addition, the estimator of the co-integrating vector may be inconsistent (Engle et al., 1989), which constitutes a serious deviation from the 'super-consistency' obtained in the absence of seasonal unit roots. Furthermore, ignoring seasonal co-integration results in misspecified error correction models with inferior forecasts and long-run interpretation (Granger, 1991). Thus, given the seasonal patterns frequently existing in agricultural price series, there is a possibility of obtaining incorrect results when using co-integration to test the LOP, if seasonal unit roots do exist.

2.1. *Seasonal unit roots and the LOP testing procedure*

A useful test for seasonal unit roots was developed by Hylleberg et al., 1990 who also provide critical values for the case of quarterly data. The test involves the transformation of the original series and the creation of three new ones each of which eliminates all of the potential unit roots except one. Thus, in the case of

[2] Multivariate co-integration tests also exist but they do not seem to offer additional insight into the market integration process since market integration implies that efficient arbitrage eventually leads to the equalisation of prices between each pair of markets even if more than two markets are considered. Furthermore, the properties of these co-integration tests when seasonal unit roots are present have not been investigated yet.

a price series p_t the following variables are created:

$$y_{1t} = (1 + B + B^2 + B^3)p_t$$
$$y_{2t} = -(1 - B)(1 + B^2)p_t$$
$$y_{3t} = -(1 - B^2)p_t$$

where B is the lag operator. The first of these variables leaves the unit root at zero frequency, the second leaves the root at π frequency, and the third leaves the root at $\pi/2$ and $3\pi/2$ frequencies. Then, ordinary least squares is applied to the following auxiliary equation:

$$(1 - B^4)p_t = \pi_1 y_{1,t-1} + \pi_2 y_{2,t-1} + \pi_3 y_{3,t-2} + \pi_4 y_{3,t-1} + \sum \Phi_i (1 - B^4)p_{t-i} + \varepsilon_t \quad (3)$$

The deterministic seasonal component μ_t can be added to Eq. (3) where necessary. The t-values of the π's are then compared to the critical values provided by Hylleberg et al., 1990 which allow also for the presence of deterministic seasonality and trend. The p_t series has a unit root at zero frequency if $\pi_1 = 0$, at frequency π if $\pi_2 = 0$, at frequency $\pi/2$ if both π_3 and $\pi_4 = 0$. The last hypothesis can be tested either by a joint F-test or alternatively, which is used here, test the null hypothesis $\pi_4 = 0$ and if this is accepted, use an one tailed test for the hypothesis $\pi_3 = 0$ against the alternative $\pi_3 < 0$.

Once seasonal unit roots are detected, the interest could still be on co-integration at zero frequency but a modified test has to be used for the reasons explained above. Thus, detected seasonal roots can be filtered out and one can proceed with normal co-integration testing, using the pre-filtered variables and applying the Augmented Dickey–Fuller test.

Using pre-filtered variables, seasonal co-integration at 1/2 and 1/4 (and 3/4) frequencies can also be tested, but the testing equations are somewhat different. More specifically, and when testing for co-integration at frequency 1/2, the residuals, υ_t, from the co-integrating regression (of the pre-filtered variables y^1_{2t} on y^2_{2t}, corresponding to p_1 and p_2) are used in the testing equation:

$$(\upsilon_t + \upsilon_{t-1}) = \pi_2(-\upsilon_{t-1}) + \sum_{j=1}^{k} b_j(\upsilon_{t-j} + \upsilon_{t-j-1}) + e_t \quad (4)$$

Non-co-integration in this case means $\pi_2 = 0$ which can be tested by forming the t_{π_2} ratio and comparing it to the critical values found in Engle and Yoo (1987).

To test for co-integration at frequency 1/4 (and 3/4) the residuals υ_t from the co-integrating regression of the pre-filtered variables y^1_{3t} on y^2_{3t} and $y^2_{3,t-1}$ (see Engle et al., 1993) are substituted in the following testing equation:

$$(\upsilon_t + \upsilon_{t-2}) = \pi_3(-\upsilon_{T-2}) + \pi_4(-\upsilon_{t-1}) + \sum_{j=1}^{k} b_j(\upsilon_{t-j} + \upsilon_{t-j-2}) + e_{1t} \quad (5)$$

If both $\pi_3 = 0$ and $\pi_4 = 0$, no co-integration at this frequency exists. In this case the critical values for t_{π_3} and t_{π_4} provided by Engle et al., 1989, 1993 have to be used.

If co-integration cannot be rejected, the validity of the LOP further requires the existence of a co-integrating vector of $(1, -1)$ at the frequencies of interest. This can be tested by substituting the co-integrating vector $(1, -1)$, common to all frequencies, into the price series to produce the following variable:

$$x_t = p_{1t} - p_{2t} \quad (6)$$

which is the difference of the two price series. In this way, the problem of seasonal co-integration is transformed into a seasonal integration test of a univariate series. Thus, if this difference is stationary, the LOP restriction is a valid co-integrating vector. In this case the Hylleberg et al., 1990 seasonal integration test is applied.

When the price series exhibit seasonal unit roots, market integration requires that the LOP is valid at all frequencies where unit roots exist. The validity of the LOP at the long-run frequency indicates a long-run co-movement in the non-stationary series p_{1t} and p_{2t} where the price changes, due to the succession of seasons and other reasons, are fully transmitted between the two markets in the long-run. The validity of the LOP at the seasonal frequencies implies a co-movement of the seasonal patterns, of the two series, which are variable because of the existence of seasonal unit roots.

This co-movement in the seasonal patterns is not captured by co-integration at the long-run frequency since the average annual price may not change. But even if the average annual price changes, it has nothing to say about the role of arbitrage in changing intrayear (seasonal) supply availability in integrated markets so that changes in seasonal patterns are transmitted among integrated markets.

Suppose that in one market a rise in storage costs occurs. As a result, seasonal patterns will change with the price during harvest time tending to be lower (supply availability will increase since it will cost more to transfer part of it to another season), and in another quarter will tend to be higher (because supply availability will be reduced). Average annual price may not be affected but supply transfers will have taken place showing that the markets are integrated. Therefore, if two markets are integrated, efficient arbitrage will make sure that not only average annual prices are equalised but their variability also among the different seasons is the same, otherwise obstacles to integration exist (seasonal, all year round, or both).

The above framework is applied here to investigate the degree of market integration in the European Union soft wheat market. The frequently used Augmented Dickey–Fuller (ADF) test for co-integration is also applied and the results compared.

3. The integration of the European Union agricultural markets and the soft wheat price series

Since its creation, the European Union has been aiming at establishing an integrated market. In the case of agricultural markets this effort is assisted by the existence of the CAP, the backbone of which has been a common price policy. An impetus was also given by the Single European Act, which became operative in 1992 and entailed the creation of a truly integrated single market. Serious doubts, however, have been cast on whether the EU agricultural markets have been as unified as envisaged by the CAP proponents. It is not surprising that more than a third of the European Commission's regulations (Commission of the European Communities) amendments required for achieving the removal of trade obstructions under the '1992 ideal' affect directly the agriculture and food sector. Sanitary and phytosanitary restrictions, and the monetary compensatory amounts (MCAs) have been among the factors responsible for this criticism.

The degree of integration in the EU agricultural product markets attracted recently the interest of at least two researchers. Tangerman (1992) used regressions between pairs of price series in the levels and their first differences (and not co-integration analysis) to test the LOP for wheat, pig carcases, barley and butter in Belgium, Denmark, Germany, Italy and the U.K.. According to his findings, "it is surprising how weak the links among prices for the same agricultural products are across Member States in the Community". Zanias (1993) applied co-integration analysis to test the LOP for soft wheat, milk, pig carcases and potatoes in Belgium, Denmark, France, Germany, Italy and UK. He found that although "the integration of the agricultural product markets does not live up to the ideal of a truly common market", the "non-integrated markets seem to be in the minority."

The present study concentrates on a product which has been researched by both authors above: soft wheat. Quarterly price series for soft wheat from five EU member states, Belgium, France, Germany, Italy, United Kingdom, are used.[3] The original data were obtained from the Eurostat Agricultural Prices publications. All prices are nominal, in ECU terms converted by the market exchange rates, they refer to the producer level and cover the period 1975.IV–1991.IV.

The EU soft wheat market is strongly supported by the CAP with prices strongly influenced by intervention prices (especially before the 1992 CAP reform). Soft wheat prices have, especially, in the past been maintained at different levels among the EU member states because of MCAs. During this period, very high MCAs were recorded, exceeding in certain cases even 30 percentage points, while there has been a great variability in their magnitude. For this reason the MCAs were calculated and deducted from the original series. This treatment was thought necessary because

[3] The existence of trade between these markets constitutes a necessary economic condition for the application of market integration tests and especially those based on co-integration analysis. Thus, the relevant Eurostat data were checked which showed that regular trade in soft wheat exists between these markets which makes the market integration tests that follow to be applicable.

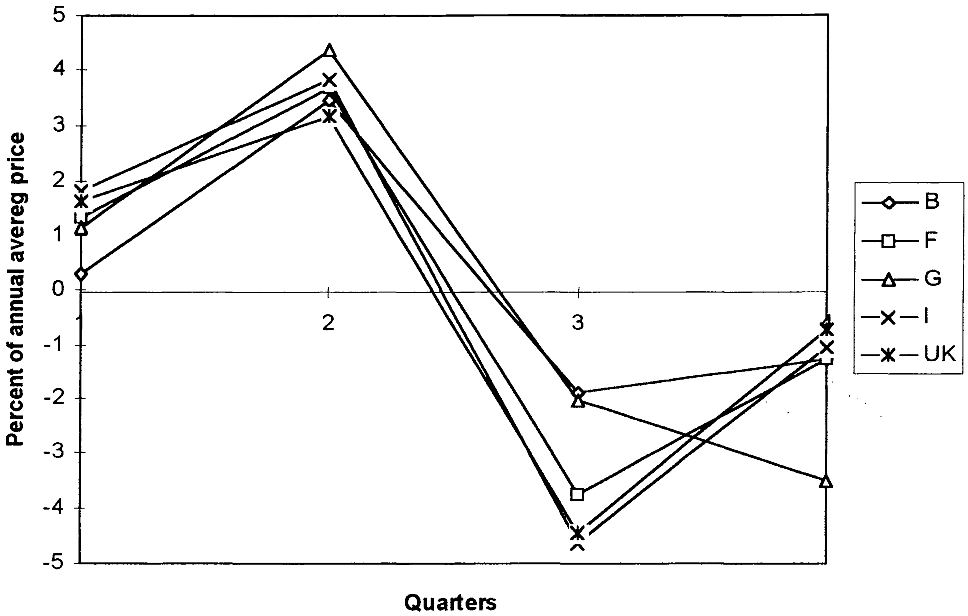

Fig. 1. Seasonal pattern of soft wheat prices.

otherwise the LOP test would have been influenced, probably, towards no integration.[4]

To show the seasonal pattern exhibited by the (modified) soft wheat price series, the percentage deviation of the soft wheat price in each quarter (1–4) from the annual average was calculated and averaged over all sample years. The result is presented in Fig. 1 which shows the existence of a distinct seasonal pattern for all member states analysed. The seasonal pattern is also very similar among the member states and it is the one generally expected for soft wheat. Prices are low at harvest time, they rise as a result of storage costs and reach a peak in the second quarter of the year.

The source of this pattern could be both deterministic and stochastic seasonality. The existence of non-stationary seasonality due to seasonal unit roots means that seasonal patterns tend to change as shocks have a permanent effect on the seasonality of the series. Changing seasonal patterns can be due to a number of factors which may be applicable for short or long time periods. For example, changes in storage costs (as argued also in an earlier section) and production technology can be two factors for changing seasonal patterns in a number of products. For soft wheat prices in particular, changes in price interventions under the CAP may play an important role. Thus, changes in the seasonal patterns of soft wheat prices in the EU can be attributed to factors like the new definition of the crop year, a reduced period for, or changes in triggering, intervention buying (Tangerman). The potential link of these with the existence of seasonal unit roots is explored in the next section.

4. Empirical results and implications

First, the soft wheat price series are transformed into logarithms and tested for seasonal unit roots using the seasonal integration test. The second column of Table 1 shows that the unit root at zero-frequency hypothesis cannot be rejected in all five series. The same result is found using the familiar ADF test (sixth column). There is no reason, of course, for a disagree-

[4]Negative MCAs operate as taxes on exports and subsidies on imports while positive MCAs constitute subsidies on exports and tariffs on imports. These trade impediments account for part of the price differences among the EU member states and therefore, should be subtracted before testing for market integration. MCAs would not have to be subtracted if they could be adequately represented by the constant term but they fluctuated, dramatically in some cases, during the sample period.

Table 1
Testing for seasonal unit roots in the price series

Variables	$t(\pi_1)$	$t(\pi_2)$	$t(\pi_3)$	$t(\pi_4)$	ADF	F
LWF (*C*, *S*, 1, 2)	−1.62	−1.57	−3.19	−1.04	−1.55(5)	6.18**
LWI (*C*, *S*, 1, 2)	−2.44	−2.24	−3.65**	−2.08**	−2.10(5)	7.38**
LWB (*C*, *S*, 0)	−1.99	4.49**	−4.49**	−3.24**	−1.85(4)	14.64**
LWG (*C*, *S*, 0)	−1.76	−5.12**	−4.54**	−2.87**	−1.69(4)	11.83**
LWU (*C*, *S*, 2)	−2.09	−3.37**	−4.55**	−2.78**	−1.96(4)	8.64**
Critical values (5%)					−2.91	2.76
(*C*, *S*)	−3.08	−3.04	−3.61	−1.98		
(*C*, *S*, *T*)	−3.71	−3.08	−3.66	−1.91		

(*C*, *S*): the testing equation includes a constant and seasonal dummies.
(*C*, *S*, *T*): the testing equation includes a constant, seasonal dummies and a trend.
In this and all subsequent tables, one asterisk (*) next to a statistic value means rejection of the null hypotheses at 10% level of significance and (**) rejection at 5%.
The critical ADF values are taken from MacKinnon (1991).
Next to the ADF statistic values the number of augmentation lags appears. The lags in the seasonal unit roots tests appear in the bracket next to the variable. In the latter case, 'holes' have been allowed in the lag structure in order to obtain a white noise error term with the smallest possible number of augmentation parameters (Engle et al., 1989, 1993).
LWF: logarithm of soft wheat price in France; LWI: logarithm of soft wheat price in Italy; LWB: logarithm of soft wheat price in Belgium; LWG: logarithm of soft wheat price in Germany; LWU: logarithm of soft wheat price in UK.

ment between the two test results in the case of the last three series which are found to have no unit roots in frequencies other than zero. However, the French soft wheat price is found to have unit roots at all frequencies and the Italian series at zero frequency as well as at two cycles per year.

The absence of integrated seasonal processes at all frequencies in the soft wheat prices of Belgium, Germany and the United Kingdom, and at some seasonal frequencies in the case of Italy, does not mean that these series do not exhibit seasonality since deterministic seasonality exists in all of them, as it is indicated by an F-test of the statistical significance of the seasonal dummies (last column) included in the unit root testing equations. Also, stochastic seasonality may exist but with all roots outside the unit circle.

The interesting result here is that, contrary to what is usually assumed, in two of the five series, the hypothesis of unit roots existing at seasonal frequencies also cannot be rejected. Thus, the usual co-integration tests can be used to test the LOP among the EU member states Belgium, Germany and UK, while the LOP between France and Italy needs to be tested using the seasonal co-integration test. In the first case, the LOP is tested using the Augmented Dickey–Fuller (ADF) test. The results of these tests (Table 2) show that the three EU soft wheat markets are integrated. More specifically, the LOP hypothesis in its unrestricted version (ADF1 – see footnote to Table 2) is in five cases significant at 5% and in one at 10%. All restricted version cases (ADF2) are significant at 5%. ADF1 is applied to both directions of the co-integrating regression since no direction of causality is implied or tested. The results, however, are very similar.

The LOP between the French and Italian soft wheat markets is tested using the seasonal co-integration test.

Table 2
Testing zero-frequency co-integration

Trade partners		ADF1	ADF2
Belgium	Germany	−3.43(4)**	−2.94(4)**
	UK	−3.65(4)**	−5.70(1)**
Germany	Belgium	−3.26(4)*	–
	UK	−3.80(4)**	−6.02(1)**
UK	Belgium	−5.73(1)**	–
	Germany	−3.47(5)**	–
Critical values		−3.44 (5%)	−1.95 (5%)
		−3.12 (10%)	−1.62 (10%)

ADF1: unrestricted version of the test (least squares estimation of the co-integrating vector).
ADF2: restricted version of the test (LOP restriction imposed).

Table 3
Testing zero-frequency and seasonal co-integration

Trade partners		t (π_1)	t (π_2)	t (π_3)	t (π_4)	ADF
France	Italy (*C*, *S*, *T*, 0)	−2.97	−5.96**	−4.42**	−2.18**	−3.45* (*C*, *T*, 4)
	Belgium (*C*, *S*, 1)	−2.32	−2.09	−2.14	−1.89*	−2.57 (*C*, 4)
	Germany (*C*, *S*, 1)	−1.99	−2.11	−3.43*	−0.84	−2.23 (*C*, 4)
	UK (*C*, 1, 3)	−1.86	−3.61**	−3.48*	−0.38	−3.79** (*C*, 0)
Italy	Belgium (*C*, *S*, 1, 2)	−1.07	−2.13	−3.73**	−1.86*	−3.17* (*C*, *T*, 4)
	Germany (*C*, *S*, 3)	−0.64	−2.89*	−3.98*	−1.03	−3.38* (*C*, *T*, 4)
	UK (*C*, *S*, 3)	−1.55	−2.82*	−3.93**	−1.07	−2.28 (*C*, 5)
Critical values	(5%) *C*, *S*, *T* or *C*, *T* *C*, *S* or *C*	−3.71	−3.08	−3.66	−1.91	−3.49
		−3.08	−3.04	−3.61	−1.98	−2.91
	(10%) *C*, *S*, *T* or *C*, *T* *C*, *S* or *C*	−3.37	−2.73	−3.28	−1.48	−3.17
		−2.72	−2.69	−3.24	−1.53	−2.59

See footnotes of Table 1.

First, co-integration is tested without imposing the LOP restriction, and then it is tested whether the LOP restriction constitutes a valid co-integrating vector. Because the Italian price series has unit roots only at 0 and 1/2 frequencies, the LOP is tested only for these frequencies. The first (unrestricted) test involves filtering out seasonal unit roots but the one of interest, and test for co-integration using the pre-filtered variables. Applying the testing procedures presented earlier, the calculated '*t*' statistics have as follows: −3.11, −2.99 for 0, 1/2 frequency co-integration, respectively. Comparing these '*t*' values to the critical values (taken from Engle and Yoo, 1987) it is found that the non-co-integration hypothesis is rejected at 10% percent level of significance for both frequencies. Next, it is tested whether the restriction (1, −1) is a valid co-integrating vector.

The test results (Table 3) show that in the case of the French and Italian soft wheat markets the non-co-integration hypothesis at the long-run (zero) frequency cannot be rejected at the conventional levels when the co-integrated vector is restricted to unity with the '*t*' value being quite close to the 10% critical value. The ADF test statistic, however, is almost equal to the 5% critical value indicating the existence of co-integration and hence the validity of the LOP at the long-run frequency.[5] This difference in the test results is apparently due to the existence of co-integration at the short-run biannual frequency. Thus, it seems that the LOP between the French and Italian soft wheat markets holds at the biannual frequency showing the existence of a 'parallel' movement in the corresponding seasonal components of the French and Italian soft wheat price series. However, accepting a level of significance close to 10%, integration between the French and the Italian soft wheat markets can be established at both the long-run and the biannual frequency.

The restricted seasonal co-integration test is also applied to test the market integration between the French and Italian soft wheat markets, which have unit roots at the long-run and certain seasonal frequencies, and the Belgian, German and UK markets which have unit roots only at the long-run frequency. In this case, however, co-integration only at zero frequency is relevant, although seasonal co-integration testing results are also given in Table 3. From these results, the following observations can be made: first, the seasonal co-integration test shows that the soft wheat price series between the two groups of countries are not co-integrated (the respective markets are not integrated) at the long-run frequency. This is confirmed by the ADF test in half of the cases (in two cases at 10% and in one at 5% level of significance). Second, in some cases seasonal non-co-integration cannot be rejected. This, however, constitutes a failure of the test since the Belgian, German and the United Kingdom price series are not integrated at the seasonal frequencies (the same applies to the Italian series at

[5]The existence of co-integration between these two price series was also found by Zanias using a shorter sample period.

1/4 and 3/4 frequencies). This theoretical conflict can happen with finite samples, but it points also to the relatively low power of the co-integration tests in general.

The testing results separate the five member states into two groups: France–Italy and Belgium–Germany–UK. Within each group the LOP holds mostly at the 5% level of significance. However, this is not the case between the two groups of EU member states.[6] The results show that the soft wheat market in the five member states cannot be considered as a unified market. This is an interesting finding which, however, requires further investigation in a number of directions to identify the reasons for lack of market integration. One possible reason is apparently the lack of efficient arbitrage or the existence of imperfect competition which makes price discrimination possible. The possible existence of variable transport and transaction costs may also be responsible in certain cases. It is also possible that this result may be due to testing weaknesses which have not been properly investigated yet. In particular, the test used may not be so powerful when testing co-integration between variables which have seasonal unit roots and those with unit roots at the zero frequency only. On the other hand, application of the ADF test for zero-frequency co-integration is not very convincing either.

With regard to the testing procedure itself, it appears that application of zero-frequency integration and co-integration tests when seasonal unit roots exist may produce misleading results. More specifically, although most of the time both tests pointed in the same direction, there was a tendency for the ADF test to accept the existence of zero-frequency unit roots or co-integration, when seasonal unit roots were present, more readily than seasonal integration and co-integration tests. It is very likely that in more marginal cases this difference may be decisive. For this reason the strong seasonal elements of agricultural price series should be taken into account when testing the LOP using co-integration analysis. Otherwise incorrect results may be obtained.

[6] Less than full transmission, however, of price changes may exist.

5. Concluding remarks

This article introduces the seasonal characteristics of agricultural price series into the LOP tests which are based on co-integration analysis. The methodology is applied to the European Union soft wheat market, for which mixed results are found. France and Italy seem to form an integrated market. The same applies to Belgium, Germany and UK. There is no indication of market integration between the two groups of countries. It is also found that the presence of seasonal unit roots does affect integration and co-integration, and hence the LOP testing results.

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