*UNIVERSITY OF NOTTINGHAM*

Discussion Papers in Economics

Discussion Paper
No. 00/8

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March 2000 DP 00/8

ISSN 1360-2438

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March 2000

**Abstract:**

Cointegration analysis is used to investigate the short and long run dynamics of the relationship between the export prices of the EU wheat and of other major exporters in the world wheat market. The aim of this study is to determine whether long run relationships existed between EU prices and its major competitors. Based on monthly data from 1980 to 1998, the results show that most of the prices are cointegrated. Furthermore, the export prices of the major competitors were found to be weakly exogenous to the EU prices. The latter result may be an indication that the EU sets its export subsidies in relation to prices of competing wheat exporting countries.

**Acknowledgements:**

The authors are grateful to Ministry of Agriculture Fisheries and Food (MAFF) for funding research on this topic. We would like to thank the International Grains Council (IGC) for providing the data and the Home Grown Cereals Authority (HGCA) for useful information.

# I Introduction

Wheat exports account for a substantial volume of trade in agricultural commodities and emanate from the five principal exporters (USA, Canada, EU, Australia and Argentina) that together account for 90% of the wheat traded (Antle and Smith 1999). Policy regimes play a significant role in the production and export shares of these major players and the impact of the Common Agricultural Policy of the European Union is a case in point. For example during the 1980s the EU emerged as the second largest exporter of wheat, having previously been a net importer. However, wheat is far from the homogenous commodity it is typically believed to be. Variation according to location and numerous dimensions of quality may affect the pattern of trade and the end-uses to which the particular form of wheat may be put. Such differences demarcate markets and are likely to impact upon the linkages for what may often be imperfect substitutes.

In this paper we report a specific set results from a much broader study of price transmission in the world wheat market. Here, our attention focuses on the linkages between the price of the EU’s wheat exports (which are of a standard quality) and the prices of the other principal wheats traded internationally, taking in to account their location and quality. This perspective is motivated by policy considerations in that it is widely held that the EU sets the level of its export restitutions according to world prices implying that the EU acts as a ‘price follower’ (USDA 1998). This is a testable hypothesis for which we find empirical support. Furthermore, an understanding of price leadership is important in explaining the structure of the market and also helps researchers in specifying price linkage equations correctly. The statistical analysis, which is conducted in a vector autoregressive (VAR) framework, also sheds light on the evolution of wheat prices over both the long and short term. It also indicates that all wheat for human consumption embody a common price trend and that the majority of price shock are incorporated in to the EU export price instantaneously. Feed wheat are however characterised by a separate long term trends.

Section 2, describes the wheat classes used in this study, followed by a outline of the methodology in Section 3. Section 4 describes the data. Section 5 details the results of the analysis followed by a conclusion of the study in Section 6.

## II Wheat Characteristics

Many different varieties of wheat are produced commercially around the world although we confine our analysis to those of the major wheat exporting countries and Table 1 below summarises the various classes of wheat. Although a temperate product, wheat is grown in all hemispheres of the world and is thus planted and harvested at different times of the year. In the Northern hemisphere, the harvest occurs in June to October, whereas in the Southern Hemisphere, it is November to January. Spring wheats are generally harvested after the winter varieties and tend to be of lower yields. Both winter and spring wheat's produce grain that is red, white or amber in colour.

The principal criterion used for classifying wheat is ‘hardness’ which is a milling characteristic that is determined by protein content. ‘Hard’ wheats are characterised by a high protein content whereas softer varieties have a low protein content. Whereas the hardest varieties produce elastic dough suitable for the making of bread, those of medium hardness are used to make unleavened breads, Arabic and Indian-style flat breads and steamed breads. Soft wheat, with low protein content is milled into flour for cakes, cookies, pastries and crackers. Durum wheat produces a coarse flour with the highest protein content of all and is transformed into semolina for processing into pasta.

There are two other criteria that are commonly used in wheat classification, ‘test weight’ (which measures the density of wheat kernels and thus is an indicator of flour yield) and moisture content. The test weight of wheat is inversely related to the percentages of foreign material and shrunken/broken kernels present in the wheat, and low test weights (in lbs /bushel) are associated with wheat of low quality.

**Table 1.** Classes of wheat

| Types of wheat | Characteristics | Products | Consumers |
|---|---|---|---|
| Argentinean Trigo Pan wheat.<br>(ATP) | Semi-hard wheat<br>Protein (10%)<br>Moisture content (14%) | Bread | FSU, China, Peru, Bolivia and Iran. |
| Australian Standard wheat.<br>(ASW) | White wheat<br>Medium protein (10%) | Middle Eastern style flat bread and noodles | Mid and Far East |
| Canadian Western Red Spring wheat No1.<br>(C1) | Hard wheat<br>High protein 12.5% | Bread | Latin America and China |
| Canadian Western Red Spring wheat No3. C3 | High protein<br>No prescribed minimum | Feed wheat | * |
| US Dark Northern Spring wheat.<br>(USD) | Hard wheat<br>High protein 14% | Pasta products | Central America, Japan, Philippines and Russia |
| US Hard Red winter wheat.<br>(USH) | Hard wheat<br>High protein (12.5%) . | Bread rolls.<br>To a lesser extent sweet goods and all purpose flour | FSU, China, Japan, Morocco and Poland |
| US Soft Red Winter wheat.<br>(USS) | Weak wheat<br>Low protein (10%) | Biscuits, crackers, cakes and pastries | China, Egypt and Morocco. |
| US Western White wheat.<br>(USW) | Blend of soft white club and common wheat<br>Low protein (9%) | Biscuits, crackers cakes and pastries. | Far East Asian region. |
| European wheat.<br>(EUSW) | Soft winter wheat<br>Moderate protein content | Steam bread, flat bread and oriental noodles. | FSU, North and Sub-Saharan Africa |

Moisture content (expressed as % by weight) is a significant attribute in determining the quality of wheat. A higher moisture content is indicative of a lower amount of dry,

*

millable matter. Additionally, as the moisture content increases, the likelihood of damage during storage increases. Hence, with an increase in the moisture content the quality of wheat diminishes.

High protein wheat's include No.1 Canadian Western Red Spring (CWRS) and Dark Northern Spring and Hard Red Winter wheat from the U.S. The EU wheat along with Argentinean Trigo Pan and Australian Standard White fall under the category of medium protein wheat. Soft Red Winter wheat and Western White wheat from the U.S. are the low-protein wheat's. The Canadian Red Spring No.1 wheat has an average test weight of 58-60 lb per bushel. All the US wheat's which are of grade No.2 have a test weight of 57 lb per bushel. For Canadian wheat the minimum moisture level specification is 14.5%, for US wheat 16%, for Argentinean wheat 14%, and 12% for Australian wheat. The moisture content for the EU is based on contract specifications.

## III Methodology

In principle, the differences that exist between internationally traded wheats may be sufficient to divorce one market from another with the result that prices may evolve independently from one another. Alternatively, the wheats may be sufficiently differentiated to ensure that they have distinct behaviours but sufficiently substituable to ensure that their prices are tied together over the long term. When considering these long run relationships, it becomes necessary to consider the underlying properties of the processes that generate time series variables. That is, we must distinguish between stationary and non-stationary variables, since failure to do so can lead to a problem of ‘spurious regression’ (Granger and Newbold, 1974).

Accordingly, all of the price series used in this study are tested for their order of integration as a prelude to the examination of the relationships that exist between the price series. For *n* price series that are integrated of order one, {I(1)}, the existence of *n* distinct trends indicate the presence of *n* independent markets. At the other extreme, the existence of a single trend implies that all *n* prices co-move and that markets are perfectly integrated over the long run. In this case, all prices share a common trend. Clearly, however, intervening cases are possible and in general the number of common trends represents the number of separate markets.

In the analysis that follows, we bring cointegration techniques to bear on the issue of market integration in the world wheat market. It is well known (see *inter alia* Stock and Watson 1988) that there exists an relationship between the number of common I(1) trends and the number of distinct linear combinations of between $n$ I(1) series. Specifically, for $n$ I(1) series and $c$ common trends there exists $r = n - c$ distinct cointegrating relationships; that is, linear combinations of the I(1) series that are themselves I(0).

Testing for cointegration is conducted in a VAR($k$) model,

$$\mathbf{x_t} = \mathbf{\Pi}_1 \mathbf{x_{t-1}} + \cdots + \mathbf{\Pi}_k \mathbf{x_{t-\mathit{k}}} + \mathbf{u_t} \qquad \mathbf{u_t} \sim \text{n.i.d.}(0, \mathbf{\Sigma}) \qquad (1)$$

where $\mathbf{x_t}$ is a vector of the I(1) wheat prices, and each $\mathbf{\Pi}_i$ is a matrix of coefficients to be estimated using a $t$ = 1, . . .$T$ sample of data. Equation (1) depicts a reduced form representation of a general statistical system in which issues such as exogeneity may be subsequently tested using the data, rather than imposed *a priori*. With I(1) variables is useful to reformulate equation (1) as an error correction model

$$\Delta\mathbf{x_t} = \mathbf{\Gamma}_1 \mathbf{x_{t-1}} + \cdots + \mathbf{\Gamma}_{k-1} \Delta\mathbf{x_{t-\mathit{k}+1}} + \mathbf{\Pi}\mathbf{x_t} + \mathbf{u_t} \qquad \mathbf{u_t} \sim \text{n.i.d.}(0, \mathbf{\Sigma}) \qquad (2)$$

where $\mathbf{\Gamma}_i = (-\mathbf{I} + \mathbf{\Pi}_1 + \cdots + \mathbf{\Pi}_i)$, $(i = 1, \ldots k-1)$ captures the dynamic effects and $\mathbf{\Pi} = (-\mathbf{I} + \mathbf{\Pi}_1 + \cdots + \mathbf{\Pi}_k)$ defines the steady-state relationships among the variables in the system.

To avoid the problems associated with over-parameterisation of VAR models, $\mathbf{x_t}$ does not comprise all 13 of the wheat price series at our disposal, but is formed for the EU wheat price and each of the other 12 prices. Hence (2) is estimated for each the 12 pairings of EU and other wheat price series.

Following Johansen (1988), the rank of $\Pi$, denoted by *r*, corresponds to the number of linearly independent combinations of $\mathbf{x_t}$ that are I(0). These are the cointegrating relationships between the price series. The presence of cointegration is determined empirically using the maximum eigenvalue and trace test statistics. They are calculated as,

$$\lambda_{trace}(r) = -T \sum_{i=r+1}^{n} \log_e[1-\hat{\lambda}_i]$$

$$\lambda_{max}(r,r+1) = -T \log_e[1-\hat{\lambda}_{r+1}]$$

where $\hat{\lambda}_i$ is the estimated value of the characteristic roots obtained from the estimated $\Pi$ matrix. The null hypothesis is that there are no cointegrating vectors. The alternative hypothesis is that there is one cointegrating vector. In the trace statistic the further the eigenvalues are from zero, the more negative is $\log_e[1-\hat{\lambda}_i]$ and the larger the $\lambda_{trace}$ statistic becomes. Obviously $\lambda_{trace} = 0$ when all $\hat{\lambda}_i = 0$. The second statistic test the null that the number of cointegrating vectors is r against the alternative that it is r+1. If the estimated value of the characteristic root is close to zero $\lambda_{max}$ will be very small.

The critical values for both these tests are tabulated by Osterwald-Lenum (1992). The distribution of the statistics depends upon the number of non-stationary components under the null hypothesis (i.e. *n* - *r*) and whether or not a constant is included in the cointegrating vector.

Where $\Pi$ is of reduced rank $(r < n)$ there exist *r* linear combinations of the *n* I(1) variables in $\mathbf{x_t}$ that are I(0) and $\Pi$ may be expressed as the outer product of two $(r \times n)$ matrices $\Pi = \alpha\beta'$ where $\beta'$ is a matrix of cointegration (steady-state) vectors and $\alpha$ is a matrix of loading (or error correction coefficients). This decomposition delivers a neat interpretation to the model since $\alpha\beta'\mathbf{x_{t-k}}$ contains all information pertinent to the steady-state relationships; the only other observables being the lagged

$\Delta\mathbf{x}_t$ which assign short-run (or impact) information through the coefficients in the $\Gamma_i$ s. Given that $\mathbf{x}_t$ only comprises a pair of I(1) prices, $n = 2$, meaning that there can be at most a single cointegrating relationship between each price pair. Where this is so, the pair must share a common trend. So, if a single cointegrating relationship is found ($r = 1$) $\alpha$ and $\beta$ collapse to (2×1) vectors in which the elements of $\beta$ quantify the unique steady state relationship between the variables in the system and the elements of $\alpha$ load deviations from the long-run relationship (i.e. $\beta'\mathbf{x}_{t-k}$) in to each short-run equation for correction. The speed of the adjustment towards the long-run relationship is given by the size of the coefficients in $\alpha$.

The error correction coefficients can also be used in exogeneity inference. Johansen (1992) develops a test based on the notion that variables that do not respond to 'dis-equilibrium' in the system of which they are a part may be considered weakly exogenous to that system. Johansen's test of weak exogeneity (of the variables to the parameters of the long-run relation) is thus a test of the statistical significance of the error correction coefficients that comprise $\alpha$. This indicates which of the prices in each pair adjusts to maintain the cointegrating relationship, and thereby offers evidence of 'price leadership'. Specifically, where both elements of $\alpha$ are statistically different from zero, neither price is weakly exogenous to the other, but jointly determined and a price leader cannot be identified. An insignificant loading coefficient thus indicates the weakly exogenous price.

Weak exogeneity also simplifies the estimation since in the $n = 2$ case, it is legitimate to condition on the weakly exogenous variable in a single equation. Hence we may estimate

$$\Delta x_{1t} = \sum_{i=0}^{k} \phi_{1i} \Delta x_{1t-i} + \sum_{i=1}^{k} \phi_{2i} \Delta x_{1t-i} + \alpha \hat{z}_{t-1} + u_t \tag{3}$$

where $\hat{z}_{t-1}$ is the deviations about equilibrium and $u_t$ is a well behaved error term. Given that all terms are I(0) under cointegration, standard critical values may be applied in hypothesis testing of the estimated parameters in (3).

# IV Data

The data used for the analysis are monthly average export price quotations (FOB) prices from July 1980 to December 1998.[2] They include: Argentinean Trigo Pan Wheat (ATP); Australian Soft Wheat (ASW); Canadian Western Red Spring wheat No.1 from St. Lawrence port (C1L) and Pacific ports (C1P); Canadian Western Red Spring wheat No.3 from St. Lawrence port (C3L) and the Pacific ports (C3P); US Dark Northern Spring wheat from the Gulf port (USDG) and Pacific ports (USDP); US Hard Red Winter wheat from the Gulf ports (USHG); US Soft Red Winter wheat from the Gulf ports (USSG), US Western White wheat from the Pacific Ports (USWP), US Hard Winter wheat from the Pacific Port (USHP) and EC specified zones (EUSW) wheat. The data source was the World Grain Statistics, published by the International Grains Council. All prices are quoted in US dollars per tonne. The subsequent analysis of the data is carried out on the logarithm of prices. Figures 1 and 2, illustrate the hard and soft wheat export prices respectively. A number of features are apparent from an inspection of the data. The export price series for all wheat exhibit trending behaviour indicating they are I(1) processes Second, the prices tend to move together with time. Third, the EU prices are on average less than the other wheat export prices (see table below). In general, hard wheats command the highest prices. Fourth, all the wheat prices exhibit considerable month-to-month variability over time, with a coefficient of variation around 20%. Finally, the price distributions also tend to be skewed to the right and platykurtic (having fatter tails than the normal distribution), common features of non-stationary price series.

[2] With the exception of C3L and C3P which has monthly data from July 1986 to February 1997, USSG has data from July 1981 to December 1998, USHP from July 1986 to December 1988 and EU from July 1980 to November 1988.

Descriptive Statistics of Wheat Price Series

| Variable | Mean | Standard Deviation | Coefficient of Skewness | Coefficient of Excess Kurtosis |
|---|---|---|---|---|
| ATP: | 135.69 | 36.47 | 0.79 | 0.65 |
| ASW: | 160.59 | 29.28 | 0.68 | 1.35 |
| C1L: | 184.19 | 29.39 | 0.25 | 0.52 |
| C3L: | 169.41 | 35.74 | 0.33 | -0.26 |
| C1P: | 196.33 | 27.50 | 0.55 | 0.99 |
| C3P: | 184.16 | 34.21 | 0.50 | 0.02 |
| USDG: | 167.53 | 26.99 | 0.32 | 0.62 |
| USHG: | 151.88 | 26.71 | 0.66 | 1.34 |
| USSG: | 140.33 | 23.50 | 0.89 | 1.89 |
| USDP: | 173.13 | 27.61 | 0.41 | 0.68 |
| USWP: | 147.63 | 24.27 | 0.12 | -0.22 |
| USHP | 156.01 | 29.33 | 1.01 | 1.48 |
| EUSW: | 132.02 | 33.56 | 0.53 | 0.48 |

Furthermore, the influence of policy is also discernible. For example, the price decline of the 1980s coincides with the EU's most intensive phase of wheat export subsidisation, and the increased variability observed during the 1990s is commonly attributed to the prevailing policy environment.

## Results

### (a) **Testing for Unit Roots.**

The price series were initially tested for their order of integration. Table 2 presents the results of the Augmented Dickey Fuller unit root tests for each of the price series expressed in log-levels and in growth form (first difference of log-levels). The hypothesis tests are based on the comparison of calculated statistics with the McKinnon (1991) critical values. Lag length was determined in a general-to-specific modelling strategy according to the 10% critical value of the SBC. Given the monthly nature of the data, lag length was initially set at 25.

**Table 2.** ADF statistics for each price series.

| Variable | Levels | First Differences |
|---|---|---|
| LATP | -3.02 | -3.624** |
| LASW | -3.28 | -3.795** |
| LC1L: | -3.19 | -4.245** |
| LC3L | -2.70 | -3.264* |
| LC1P | -3.18 | -10.34** |
| LC3P | -2.95 | -7.756** |
| LUSDG | -2.53 | -4.411** |
| LUSHG | -2.75 | -3.927** |
| LUSSG | -2.78 | -3.93 |
| LUSDP | -2.51 | -3.928** |
| LUSWP | -2.97 | -9.63** |
| LUSHP | -2.74 | -2.98* |
| LEUSW | -2.15 | -4.55** |

The critical value calculated from McKinnon tables for levels with constant and trend at 5% significance is -3.45 and at 1% significance is 4.002. *Indicates rejection of null hypothesis of non-stationarity at 5% level and ** for rejection at 1% level. For differences with constant and without trend the 5% significance level is -2.89 and at 1% is 3.45.

For the results in the table it is clear that unit roots cannot be rejected for the price series in levels at the 5% significance level yet are rejected for all price series in growth form. We conclude that the log-level of each price series is integrated of order one, [I(1)].

## (b) Cointegration Results

As discussed in the previous section, the EU wheat export prices were paired with all other major wheat exporting countries' prices to see if any of the EU price forms a cointegrating relationship with any other price, in equation (2). The results of the cointegration tests using Johansen's maximum likelihood method are summarised in Table 3 below. Lag length (*k*) of the each bivariate VAR was determined using the 10% critical value of the SBC.

**Table 3.** The Maximum Eigenvalue and Trace Test Results for Pairwise Cointegration.

| Variables | Null | Alternative | Max Eigenvalue | Trace |
|---|---|---|---|---|
| LATP | $r=0$ | $r>0$ | 18.28* | 25.71** |
| | $r\leq 1$ | $r>1$ | 7.44 | 7.44 |
| LASW | $r=0$ | $r>0$ | 17.24* | 22.93* |
| | $r\leq 1$ | $r>1$ | 5.68 | 5.68 |
| LC1L | $r=0$ | $r>0$ | 18.55* | 27.32** |
| | $r\leq 1$ | $r>1$ | 8.77 | 8.77 |
| LC3L | $r=0$ | $r>0$ | 8.76 | 15.23 |
| | $r\leq 1$ | $r>1$ | 6.48 | 6.48 |
| LC1P | $r=0$ | $r>0$ | 20.04** | 28.66** |
| | $r\leq 1$ | $r>1$ | 8.62 | 8.62 |
| LC3P | $r=0$ | $r>0$ | 11.44 | 17.03 |
| | $r\leq 1$ | $r>1$ | 5.59 | 5.59 |
| LUSDG | $r=0$ | $r>0$ | 19.59* | 27.97** |
| | $r\leq 1$ | $r>1$ | 8.37 | 8.37 |
| LUSHG | $r=0$ | $r>0$ | 27.47** | 36.28** |
| | $r\leq 1$ | $r>1$ | 8.81 | 8.81 |
| LUSSG | $r=0$ | $r>0$ | 19.95** | 28.36** |
| | $r\leq 1$ | $r>1$ | 8.42 | 8.42 |
| LUSDP | $r=0$ | $r>0$ | 15.76* | 24.07* |
| | $r\leq 1$ | $r>1$ | 8.31 | 8.31 |
| LUSWP | $r=0$ | $r>0$ | 22.31** | 30.21** |
| | $r\leq 1$ | $r>1$ | 7.91 | 7.91 |
| LUSHP | $r=0$ | $r>0$ | 26.58** | 33.65** |
| | $r\leq 1$ | $r>1$ | 7.07 | 7.07 |

*Significant at 95%; **Significant at 99%

The results in Table 3 offer a very clear picture of the price relationships in the world wheat market, in that the price of EU standard wheat cointegrates with the prices of virtually all other wheats. Specifically, the null hypothesis of no cointegration is rejected for all EU price pairings with the exception of Canadian Western Red Spring wheat No.3 (from St. Lawrence and Gulf ports). Where cointegration is found the results are highly significant irrespective of whether it is the trace or maximum eigenvalue tests that is used to evalaute the null. In contrast, the test statistics for the pairings involving Canadian No.3 wheat are so low (rejection probabilities greater than 20%) that they seem unlikely to be the outcome of statistical fluke. The upshot is that Canadian No.3 wheat behaves quite differently from the other wheat types in the sample, following a long-run trend that is statistically distinct. As discussed in Section II however, this wheat is of low quality that is commonly used as animal feed whereas all the other 11 wheats in the sample are used almost exclusively for human consumption. Cointegration is thus a common, indeed typical, behaviour among the food wheats included in the sample.

A number of implications follow from these results. First, the price of EU wheat is characterised by the same underlying trend as the other 10 food wheats in the sample. Such evidence of market integration is reassuring although it is hardly surprising given the degree of price co-movement discernible in Figures 1 and 2. Second, with 13 wheat prices and 11 cointegrating relationships there is evidence for just two common trends. Whilst further testing (of all 78 pairwise combinations) would be required in order to determine whether these separate trends identify separate markets for feed and food wheats, the preliminary evidence provided above is consistent with market delineation according to quality. Importantly, the EU price did not cointegrate with the Canadian feed wheat from either the St. Lawrence or Gulf ports. This alone suggests that the price trends differ due to some inherent difference in wheat type rather than location. Third, in general, the failure of two prices to co-move, does not necessarily imply that the prices are independent since markets may be linked through a third (or more) factor(s), such as the prices of other substitutes. Hence, the markets for feed and food wheats may respond to price changes in the other, but not exclusively.

**(c) Weak Exogeneity Results**

Tests of weak exogeneity establish casual priority in regression models. With relatively high frequency data they can be usefully employed to indicate whether some variables 'lead' others, or indeed whether they are simultaneously determined. In the current empirical application, the concept of weak exogeneity is akin to the principle of price leadership. If, as is generally, believed the EU determines the price of its exports with reference to past and prevailing prices of other wheats it can be considered to be a price follower in the world market. Where this applies, the prices of other internationally traded wheats will be weakly exogenous to the EU export price and not *vice versa*. In short, weak exogeneity is indicative of price leadership, and results are reported in Table 4. The first subheading, $H_0 : \alpha_{21} = 0$ tests the null that EU price is weakly exogenous to the other price in the pair; $H_0 : \alpha_{11} = 0$ tests the null that the other price is weakly exogenous to the EU price. In cases where both nulls are rejected the prices are determined simultaneously.[1] The test statistics are distributed as $\chi^2$ (1) with [p-values].

Conducting inference at the 5% significance level, the test statistics under the $H_0 : a_{21} = 0$ subheading in Table 4 indicate the EU export price reacts to the prices of all but one of the other export prices. Test statistics under the $H_0 : a_{11} = 0$ sub-heading fail to reject the null at the 5% significance level, indicating that the prices of other wheats do not adjust to shocks in the EU price. This suggests that in general it is the EU export price that adjusts to maintain the cointergating relationships that manifests as price co-movement. As such, the EU can be thought of a price follower in the world wheat market.

This broad conclusion is complicated by some test statistics that lie close to conventional significance levels. This is particularly apparent under the $H_0 : a_{11} = 0$ sub-heading where there is some evidence to suggest that neither price is weakly exogenous to the other. There is some evidence supporting the simultaneous determination of prices in the Canadian No.1 and some of the American wheats (both hard and soft) pairings. Furthermore, US Soft Red Winter wheat from the Gulf port (USSG) – a wheat of very similar quality to EU standard wheat appears to behave as if the EU wheat price is weakly exogenous. A recent report by the USDA offers an explanation for this result in that,

> "When the EU emerged as as a net exporter of wheat, they targetted the Morrocan (which regularly bought 1 million tonnes or moree of Soft Red winter wheat in the early 1980s), as they could enjoy substantial freight advantages, in addition to receiving export subsidies, and EU soft wheat quickly replaced Soft Red winter wheat" USDA (1999)

On balance, however, the weight of evidence favours the view that the EU is a price follower in the world wheat market, although the presence of more complex interactions cannot be denied. On-going research in to all 78 price pairs, will provide clarification and depth to the preliminary findings presented here

[1] The theory of cointegration implies the existence of causality in at least one direction, hence the inability to reject both nulls should not occur. This is born-out in the results of Table 4.

A further restriction of interest is whether the long run price transmission elasticity coefficient ($\beta_2$) is unity since this would indicate proportionality in prices. This amounts to testing whether the cointegrating vector is (1, $-\beta_1$, -1). Given that price levels differ considerably (see Section IV) proportionality is unlikely for all wheats of different quality to the EU. The results, reported in Table 4, reject the null of unit elasticity for all wheat except Australian Standard Wheat (LASW) and Argentinian Trigo Pan.

**Table 4.** Summary of restrictions on the cointegrating vector and weak exogeneity.

| LEUSW paired with: | Proportionality $H_0:[-1, b_0, 1]$ | Casual Priority $H_0: a_{21}=0$ | Casual Priority $H_0: a_{11}=0$ |
|---|---|---|---|
| LATP | $\chi^2$ =0.96[0.32] | $\chi^2$ = 8.73[0.00] | $\chi^2$=0.06[0.80] |
| LASW | $\chi^2$ =10.2[0.31] | $\chi^2$ = 11.14[0.00] | $\chi^2$ =1.35[0.24] |
| LC1L | $\chi^2$ =4.01[0.04] | $\chi^2$ = 3.66[0.05] | $\chi^2$ =2.91[0.09] |
| LC1P | $\chi^2$ =6.34[0.01] | $\chi^2$ = 4.21[0.04] | $\chi^2$ =3.57[0.06] |
| USDG | $\chi^2$ =4.35[0.04] | $\chi^2$ = 4.34[0.03] | $\chi^2$ =3.14[0.07] |
| USHG | $\chi^2$ =8.56[0.00] | $\chi^2$ =7.60[0.00] | $\chi^2$ =2.56[0.11] |
| USSG | $\chi^2$ =8.47[0.00] | $\chi^2$ =1.93[0.16] | $\chi^2$ = 4.40[0.03] |
| USDP | $\chi^2$ =2.91[0.08] | $\chi^2$ = 3.98[0.04] | $\chi^2$ =2.09[0.15] |
| USWP | $\chi^2$ =6.82[0.00] | $\chi^2$ = 12.16[0.00] | $\chi^2$ =0.07[0.78] |
| USHP | $\chi^2$ =14.1[0.00] | $\chi^2$ = 9.94[0.00] | $\chi^2$ =1.01[0.32] |

### (c) <u>Modelling the Short Run</u>

The foregoing analysis sheds light on the long-run aspects of the relationships between the prices of EU and competitor wheats. Reformulating the model as equation (3), in which the error correction terms are explicitly included, allows the dynamics of these relationships to be evaluated. The results of the estimation of equation (3) for each pairing are given in the Table 6 below (error correction terms in bold).[2] Lag length is determined by 5% critical values of the SBC.

Two distinctive features emerge from the results of Table 5. First, the impact coefficients are all around 0.6. This implies that around 60% of changes in prices are incorporated in the EU price within a single period. Undershooting rather than overshooting is thus clearly the norm in EU price adjustment process. Second, the error correction terms are all in the region of 0.1 suggesting that deviations from the long-run relationships are corrected at a rate of around 10% per month, thus the speed of adjustment to long run changes in the variables is slow, but significant. Whilst there is some variation around this average, (6% for US dark winter Pacific wheat to 22% for US hard winter Pacific wheat) overall the results imply that the process of price adjustment is characterised by a large immediate response followed by a relatively sluggish one. At the averages reported above, 60% of equilibrium is corrected within one month, yet it takes nine months for a further 30% of the 'disequilibrium' to be being corrected.

[2] Results from extensive diagnostic testing indicates that the error terms are empirical white noise. Departures from normality are present in the LUSSG model; functional form mis-specification in the models involving  LATP and LUSDP. Details of these and all other test results are available from the

**Table 5.** OLS estimates of the conditional model; dependent variable being $\Delta LEUSW_t$

| Variable | Coefficient | t-values |
|---|---|---|
| $\Delta LEUSW_{t-1}$ | 0.25 | 3.93[0.00] |
| $\Delta LEUSW_{t-2}$ | -0.03 | -0.44[0.65] |
| $\Delta LEUSW_{t-3}$ | 0.13 | 1.98[0.05] |
| $\Delta LEUSW_{t-4}$ | -0.11 | -1.87[0.06] |
| **$\beta_1$'$z_{t-1}$** | **-0.11** | **-3.70[0.00]** |
| $\Delta LATP_t$ | 0.58 | 10.27[0.00] |
| $\Delta LATP_{t-1}$ | 0.02 | 0.28[0.77] |
| $\Delta LATP_{t-2}$ | -0.0007 | -0.01[0.99] |
| $\Delta LATP_{t-3}$ | -0.09 | -1.36[0.18] |
| $\Delta LATP_{t-4}$ | -0.11 | -1.62[0.11] |
| $\Delta LEUSW_{t-1}$ | 0.18 | 3.00[0.00] |
| **$\beta_2$'$z_{t-1}$** | **-0.11** | **-3.93[0.00]** |
| $\Delta LASW_t$ | 0.71 | 8.89[0.00] |
| $\Delta LASW_{t-1}$ | 0.34 | 3.44[0.00] |
| $\Delta LEUSW_{t-1}$ | 0.33 | 5.29[0.00] |
| **$\beta_3$'$z_{t-1}$** | **-0.09** | **3.83[0.00]** |
| $\Delta LC1L_t$ | 0.44 | 5.130.00] |
| $\Delta LC1L_{t-1}$ | 0.12 | 1.29[0.19] |
| $\Delta LEUSW_{t-1}$ | 0.32 | 6.07[0.00] |
| **$\beta_4$'$z_{t-1}$** | **-0.09** | **-4.62[0.00]** |
| $\Delta LC1P_t$ | 0.60 | 6.93[0.00] |
| $\Delta LC1P_{t-1}$ | -0.04 | -0.39[0.69] |
| $\Delta LEUSW_{t-1}$ | 0.30 | 5.72[0.00] |
| **$\beta_5$'$z_{t-1}$** | **-0.09** | **-4.10[0.00]** |
| $\Delta LUSDG_t$ | 0.48 | 6.85[0.00] |
| $\Delta LUSDG_{t-1}$ | 0.002 | -0.03[0.97] |
| $\Delta LEUSW_{t-1}$ | 0.24 | 3.98[0.00] |
| **$\beta_6$'$z_{t-1}$** | **-0.18** | **-5.46[0.00]** |
| $\Delta LUSHG_t$ | 0.63 | 8.67[0.00] |
| $\Delta LUSHG_{t-1}$ | 0.05 | 0.56[0.57] |
| $\Delta LEUSW_{t-1}$ | 0.33 | 5.91[0.00] |
| **$\beta_8$'$z_{t-1}$** | **-0.06** | **-3.36[0.00]** |
| $\Delta LUSDP_t$ | 0.38 | 4.76[0.00] |
| $\Delta LUSDP_{t-1}$ | -0.04 | -0.42[0.67] |
| $\Delta LEUSW_{t-1}$ | 0.27 | 4.04 [0.00] |

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| | | |
|---|---|---|
| $\Delta LEUSW_{t-2}$ | -0.05 | -0.77[0.44] |
| $\Delta LEUSW_{t-3}$ | 0.01 | 0.14[0.88] |
| $\Delta LEUSW_{t-4}$ | -0.18 | -2.97[0.00] |
| **$\beta_9' z_{t-1}$** | **-0.14** | **-3.93[0.00]** |
| $\Delta LUSWP_{t}$ | 0.61 | 7.44[0.00] |
| $\Delta LUSWP_{t-1}$ | 0.16 | 1.53[0.12] |
| $\Delta LUSWP_{t-2}$ | -0.09 | -0.85[0.39] |
| $\Delta LUSWP_{t-3}$ | 0.0002 | 0.002[0.99] |
| $\Delta LUSWP_{t-4}$ | 0.17 | 1.57[0.12] |
| $\Delta LEUSW_{t-1}$ | 0.24 | 3.62[0.00] |
| **$\beta_{10}' z_{t-1}$** | **-0.22** | **5.12[0.00]** |
| $\Delta LUSHP_{t}$ | 0.59 | 7.84[0.00] |
| $\Delta LUSHP_{t-1}$ | 0.14 | 1.47[0.14] |

## VI Conclusion

Intuition and empirical observation suggest that wheat is traded in a highly integrated world market, characterised by differentiated products and policy intervention. The statistical analysis of EU price pairs presented here provides strong evidence in favour of market integration among all 11 food wheats analysed irrespective of quality or location of export. Interestingly, the only two wheats that did not cointegrate with the EU wheat were feed wheats, possibly reflecting the distinct nature of their end uses.

Additional results indicate that in most cases the EU export price has been responding to price formation in the other principal wheat exporters, but not *vice versa.* This implies that following a price shock disequilibrium persists until EU prices adjust to restore the long-run relationship. The result of the adjustment process leads to the co-movement of prices that is observed over time. Such behaviour is also consistent with the view that the EU sets its export subsidies in relation to the price of wheat in competing exporters. The speed of adjustment of the EU export prices to price shocks is initially rapid but thereafter correction is slow, although statistically significant.

The results are however preliminary and highlight the need for a detailed examination of the relationships between all prices, not simply those pairs involving the EU. On-going research seeks to identify sub-markets according to wheat quality and cast light on the nature of price linkages that exist more generally in the world wheat market.

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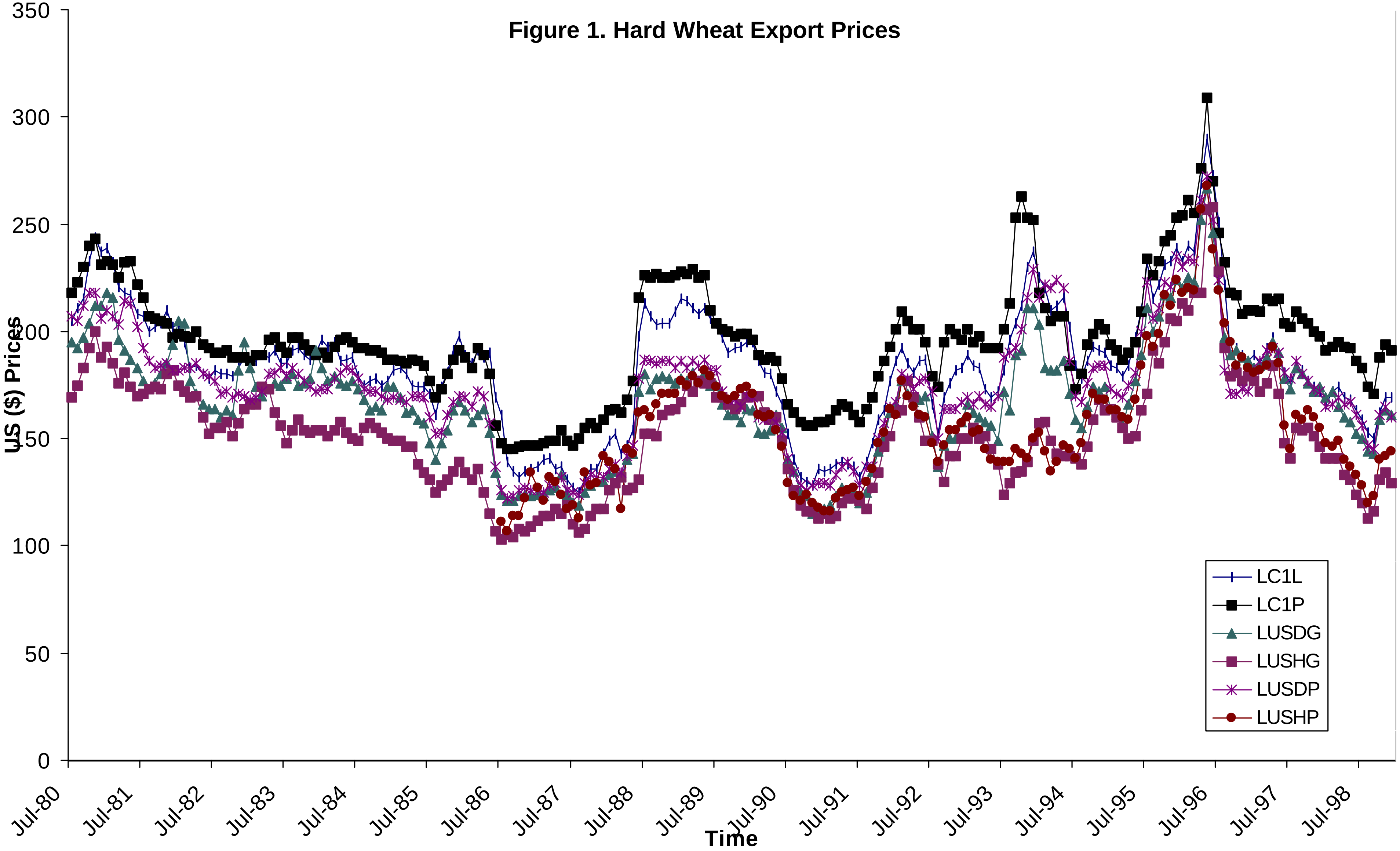

Figure 1. Hard Wheat Export Prices
US ($) Prices
Time
0
50
100
150
200
250
300
350
Jul-80
Jul-81
Jul-82
Jul-83
Jul-84
Jul-85
Jul-86
Jul-87
Jul-88
Jul-89
Jul-90
Jul-91
Jul-92
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LUSHG
LUSDP
LUSHP

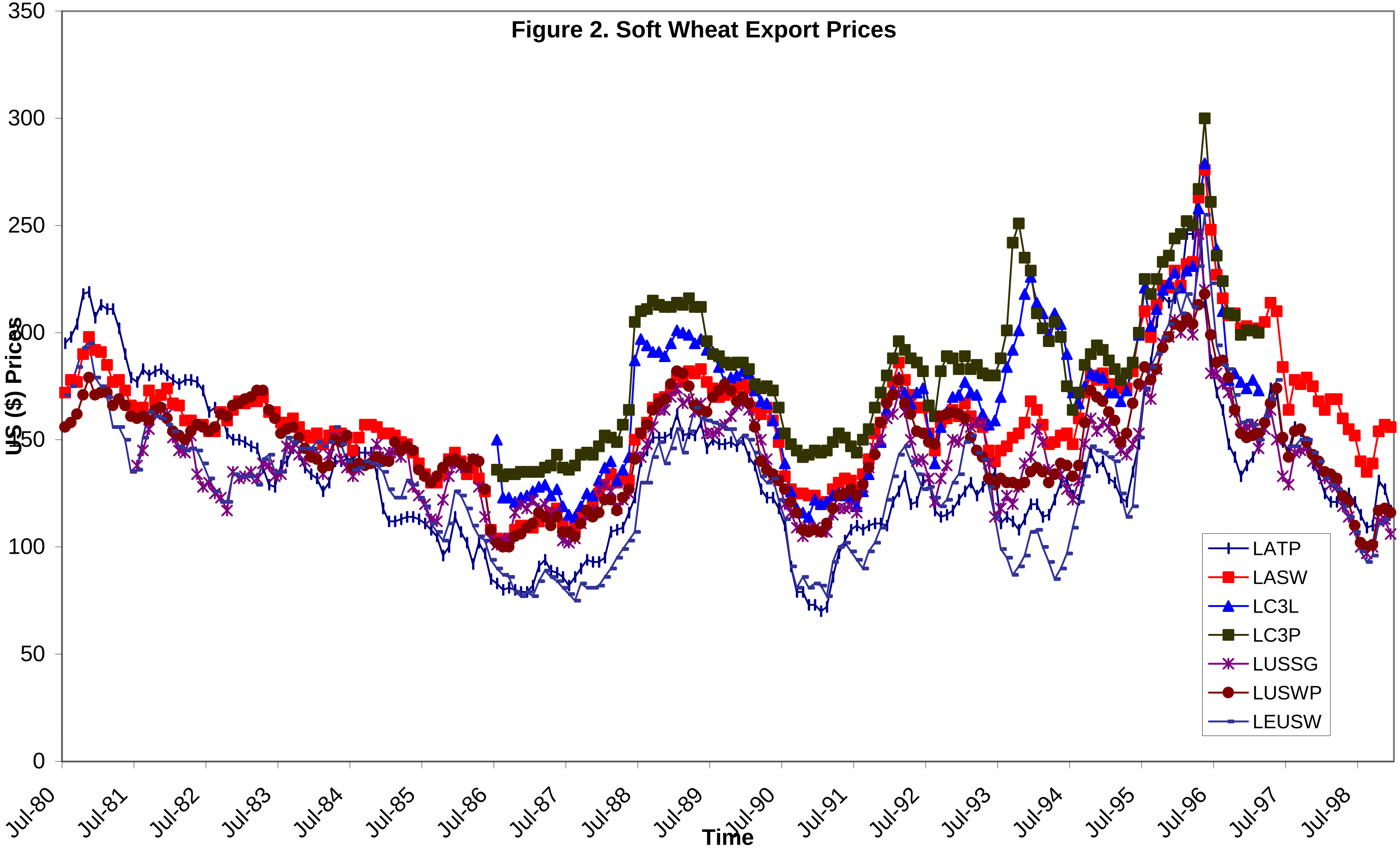

Figure 2. Soft Wheat Export Prices
US ($) Prices
350
300
250
200
150
100
50
0
Jul-80
Jul-81
Jul-82
Jul-83
Jul-84
Jul-85
Jul-86
Jul-87
Jul-88
Jul-89
Jul-90
Jul-91
Jul-92
Jul-93
Jul-94
Jul-95
Jul-96
Jul-97
Jul-98
Time
LATP
LASW
LC3L
LC3P
LUSSG
LUSWP
LEUSW