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Allister Keller and Ron McIver

Suggested citation format:

Keller, A. and R. McIver. 2012. "Foreign Exchange Pass-Through and the Potential Use of Grain Export-Denominated Trade Weighted Indices." Proceedings of the NCCC-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management. St. Louis, MO. [http://www.farmdoc.illinois.edu/nccc134].

Foreign Exchange Pass-Through and the Potential Use of Grain Export-Denominated Trade Weighted Indices

Allister Keller[#] and Ron McIver[^]

PAPER PREPARED FOR:

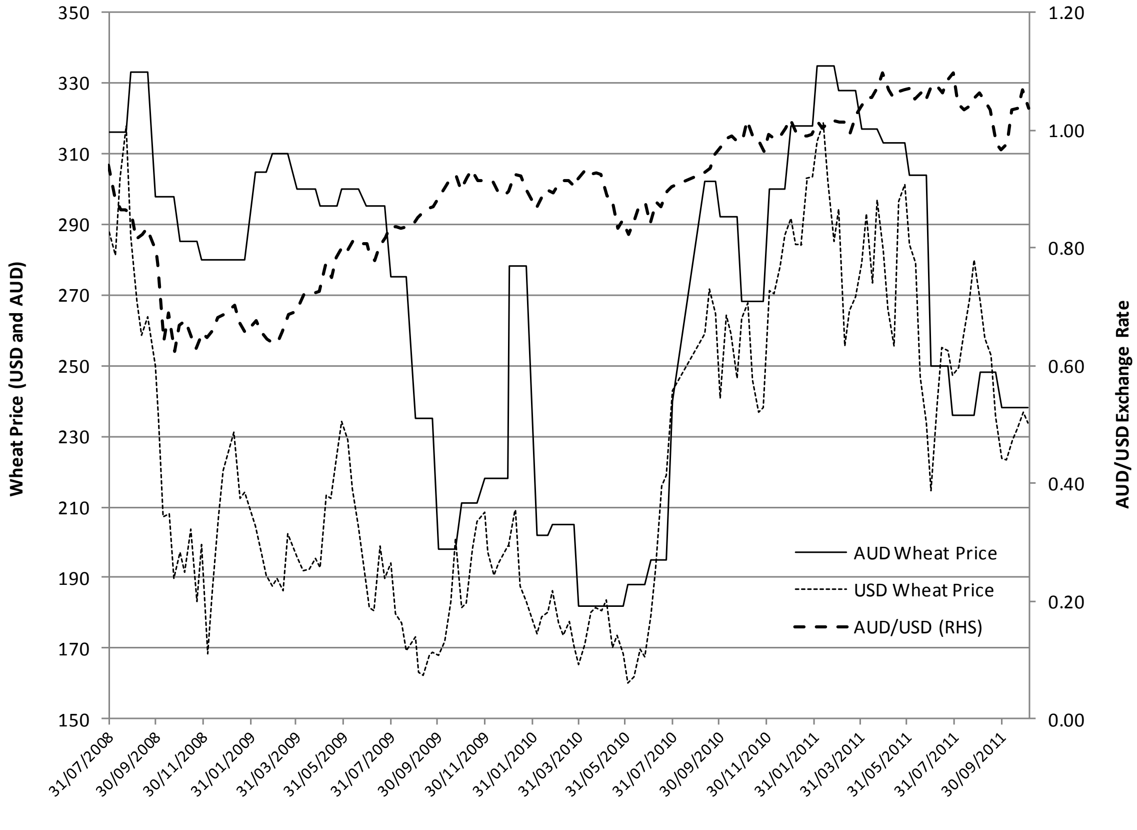
2012 NCCC-134 Applied Commodity Price Analysis, Forecasting and Market Risk Management

[#] Corresponding author: Risk Manager, Viterra Ltd.
[^] Lecturer in Financial Economics, Centre for Applied Financial Studies (CAFS), School of Commerce, University of South Australia

Introduction

International grain marketers (traders) trade grain in markets for which the trades are dominated by a few currencies, including the USD. Thus, the volatility in the USD value of these dominant currencies constitutes a source of at least part of the volatility exhibited by grain prices when expressed in the domestic (or base) currency (Figure 1).

Figure 1: USD and AUD Wheat Prices and the AUD/USD rate 31 July 2008 to 4 November 2011



Source: Viterra Ltd., Australian Bureau of Statistics, Thomson Reuters and Authors' calculations.

As a small, open economy, Australia is a net exporter of grain for which both grain prices and quantities are susceptible to USD price volatility. This reflects that foreign demand is, in part, a function of the purchasing power provided by the home currencies of each importer of grain and the global USD pricing of the commodity. As South Australia is effectively an export-only origin of grain, with no material domestic market, South Australian farmers and marketers are potentially even more susceptible to the world (USD) price of grain and exchange rate variability. However, while the USD/AUD rate dominates in determining the

AUD received per unit by Australian (including South Australian) marketers,[1] it provides little information as to the quantity response of grain exports to changes in USD prices. Furthermore, it may not accurately reflect likely AUD price changes, where the AUD and USD prices are not perfectly correlated. This is especially likely to be the case where the customers are not AUD based, and so are also responding to changes in the value of their currencies against the USD.

Historically, it has been assumed that the Australian Dollar's (AUD) variability against the United States dollar (USD) was the most relevant variable for the practice of hedging. In turn this meant that international grain marketers who hedge foreign exchange risk tended to hedge the AUD/USD rate. Recent turbulence in foreign exchange (FX) markets has led to increased scrutiny of the efficacy of FX hedging programmes for international marketers.

Adding to this variability was the removal of the monopoly of the Australian Wheat Board (AWB) which controlled what was known as the 'single desk.' All wheat that was exported from Australia had to be handled through the AWB who in effect controlled the prices received by marketers and farmers. While Australian wheat prices were still susceptible to changes in the world price, the hedging practices of the wheat board imparted influence on the domestic price of wheat. With the removal of the single desk, and the introduction of competition in the sector in 2007, the dominance of the AWB was also removed and price variability due to FX movements became more pertinent to industry players.

The above noted, a focus on the AUD/USD rate may ignore the true driver of demand for Australian grain—namely the strength of South Australia's trading partner's currency fluctuations against the USD. That this is a core issue is reinforced by the fact that grain exports form only a minor component of Australian exports.[2] Approximately 85 per cent of grain produced in South Australia is exported. Of this, 52 per cent is wheat.

To determine if this is the case we propose the development of a Grain Export Trade Weighted Index (GETWI) of the value of the USD in terms of the currencies of those countries to which Australian-originated grain is exported. The GETWI is representative of the trade-weighted foreign currency price of Australian Grain, given the USD contract price provides the global basis for pricing of this commodity. The GETWI is calculated daily against the USD and the trade weights rebalanced monthly.

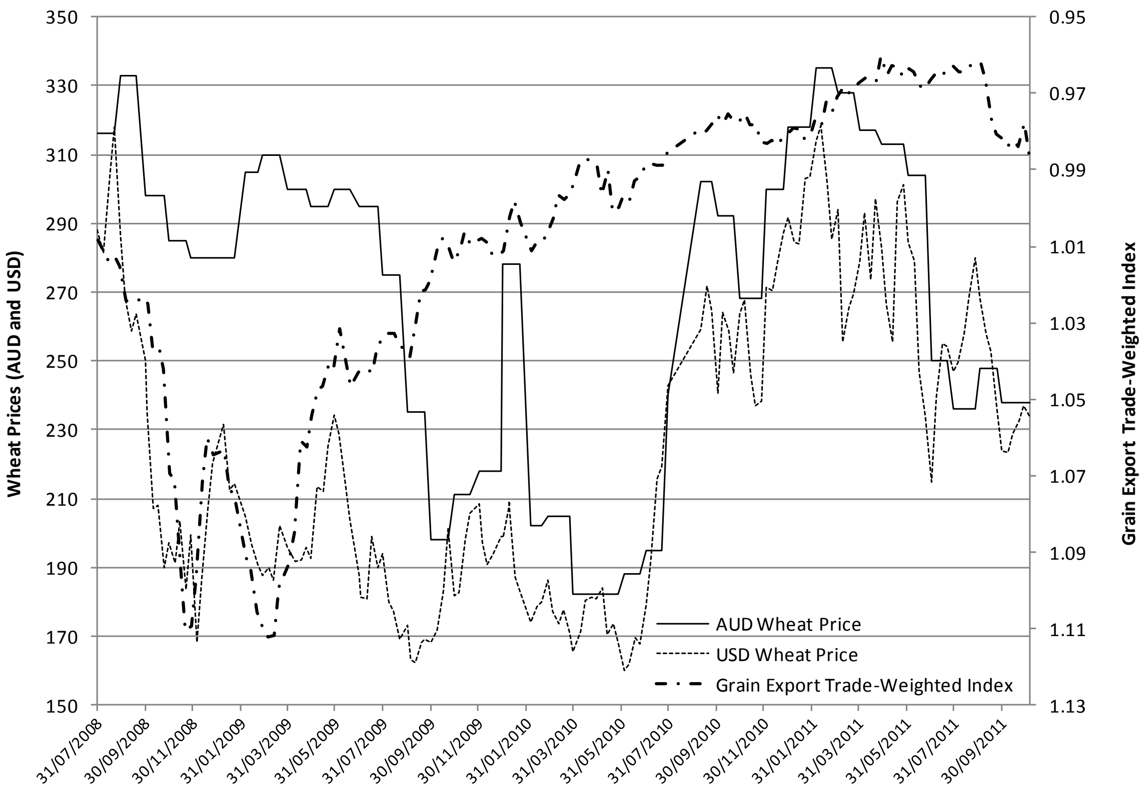
The core objective of this paper is to refine the understanding of the contributors to export price and quantity volatility for South Australian exporters. The sensitivity of grain export prices to exchange rate changes in a grain export-based TWI is used as a starting point for this process. This would reflect the quantum of trade to export markets and the currencies of these export markets against the USD. Changes in this rate would, in all likelihood, provide more (or additional) information about potential export quantity changes than changes in the USD/AUD directly. Consequently this may assist with the management of dynamic FX

[1] The correlation between the actual AUD price and the price implied by the USD contract and AUD/USD exchange rate (the implied AUD wheat export price) is slightly less than 80 per cent.

[2] In each of the years from 2005 to 2011, cereals and cereal preparations have represented only two or three per cent of total exports of goods and services (Australian Bureau of Statistics, International Trade in Goods and Services, Cat. No. 5368.0 (various issues); and authors' calculations).

hedging for Australia's international grain marketers, or in pricing decisions. By defining the variability in the Australian export wheat price attributable to an appropriate measure of FX movements, this allows a better understanding of the remaining contributors to price and quantity variability and it then becomes simpler to determine appropriate hedging ratios. This is particularly important as most liquid derivative markets are located in significantly different geographic regions to exporting nations such as Australia. Risk management practices relating to basis price risk management can then be refined.

Figure 2: USD and AUD Wheat Prices and the Grain Export Trade-Weighted Index 31 July 2008 to 4 November 2011



Source: Viterra Ltd., Australian Bureau of Statistics, Thomson Reuters and Authors' calculations.

The study proceeds in two stages: Development of a grain-export-based trade-weighted index of the exchange rate (GETWI) and the assessment of whether this index provides, statistically, alternative (or greater) information on AUD export pricing shifts than the USD/AUD rate. It is expected that the responsiveness of Australian grain prices to a grain TWI would be statistically stronger than that to the AUD/USD rate.

Literature Review

Of the literature, there is limited application to Australian and international wheat price composition. Goodwin (1991, 1992) uses multivariate co-integration procedures and Vector auto-regression models to evaluate the law of one price (LOP) for prices in five international wheat markets. Efficient arbitrage and trade activities should ensure that individual wheat prices in spatially separated markets are linked through a common long-run equilibrium. The results indicate that the LOP fails as a long-run equilibrium relationship when transportation costs are ignored. However, if wheat prices are adjusted for freight rates, the LOP is fully supported. This forms the basis for our assertion that South Australian Wheat prices are formed in a small open economy where marketers and growers are assumed to be price takes. This view is also supported by discussion with marketers who state emphatically that domestic prices are set in this way. It is important to note that this research, while informative, was carried out during a period of monopoly control of wheat exports. Bond (1985) for instance, does not focus on exchange rate movements in their analysis. It also predates the removal of the single desk.

Exchange rate pass through in agricultural markets is not a common theme explored in the literature. In fact, the majority of the literature dedicated to Australian commodity prices was published prior to the floating of the Australian dollar in 1983.

The Basis of the Model

At its simplest level, the domestic currency price of export wheat for a small, open economy such as Australia, should reflect the world price of wheat (in this case in USD), and the exchange rate linking the currency in which the world price is denominated to the local currency (in this case the AUD/USD rate). This reflects the assumption of a simple relationship of the type implied by the model of purchasing power parity (PPP) introduced in most elementary courses in international finance, but recognising the specific inability of the small economy to significantly impact the global price of the commodity being traded. Thus, at its most basic level, we would assume a relationship as follows:

$$AP = ER \times GP \quad (1)$$

Here AP is the Australian price of the commodity being traded expressed in AUD, ER is the relevant exchange rate showing the price in terms of the AUD value of the currency used to price contracts on the commodity, and GP is the world price for the commodity expressed in the contract currency.

However, given taxes, transport costs and other distortions, it is more usual to think in terms of a relative PPP model based on changes (Δ) in each of the above variables, or even rates of change:

$$\Delta AP = \Delta ER + \Delta GP \quad (2)$$

Empirically, we could generalise the relationship between AP and ER and GP as being a dependency relationship (based on the small economy assumption (as supported by Goodwin 1991 and 1992)), and thus consider the following simple representation of the reduced form function for AP as:

$$AP = f\,(\overset{+}{ER}, \overset{+}{GP}) \qquad (3).$$

Clearly, the sign on most variables can be specified fairly easily *a priori* using economic theory. Thus we would expect increases in global contract price for the commodity to have a positive (and approximately one-to-one) effect on the AUD export price and increases in the level of the foreign currency/AUD exchange rate to have a positive (and, again, approximately one-to-one) effect on the AUD export price.[3]

Data

Data for the study has been obtained from three main sources: Viterra Ltd maintains a data base of core commodity prices including Australian Premium White[4] (APW) wheat at several pricing points including FOB from Port Adelaide out of South Australia which is used in this analysis. Port Adelaide handles a large proportion of South Australian wheat exports. While other ports handle large tonnages the correlation of these pricing points is very strong. The period being studied relates to that following the abandonment of the monopoly “single desk” Australian Wheat Board and introduction of a competitive market. This implies that the hedging strategies of the single exporter would not bias the relation between foreign currency and domestic wheat prices.

Foreign exchange rates are obtained from Thomson Reuters and relate to the midpoint at the end of the day.

Monthly wheat export volumes are obtained from the Australia Bureau of Agriculture and Resource Economics (ABARES) and pertain to individual export country destinations for Australian wheat.

Daily and weekly data were run through various models but the stability of both the coefficients of the variables and the residuals were unstable in the case of the daily data. To rectify this we have chosen to use data that better coincides with the monthly frequency of the export data. The impact was increased stability in both the coefficients and residuals. Problems with autocorrelation also lessened as demonstrated in the form of a higher Durbin-Watson statistic.

[3] Where the exchange rate is expressed as units of the foreign currency per unit of AUD (e.g., as in the AUD/USD case), the opposite holds and a negative relationship would be expected
[4] This type is used to produce Middle Eastern and Indian breads as well as Asian baked goods and noodles. Please notice that this physical price data is proprietary and is available only upon request from the corresponding author.

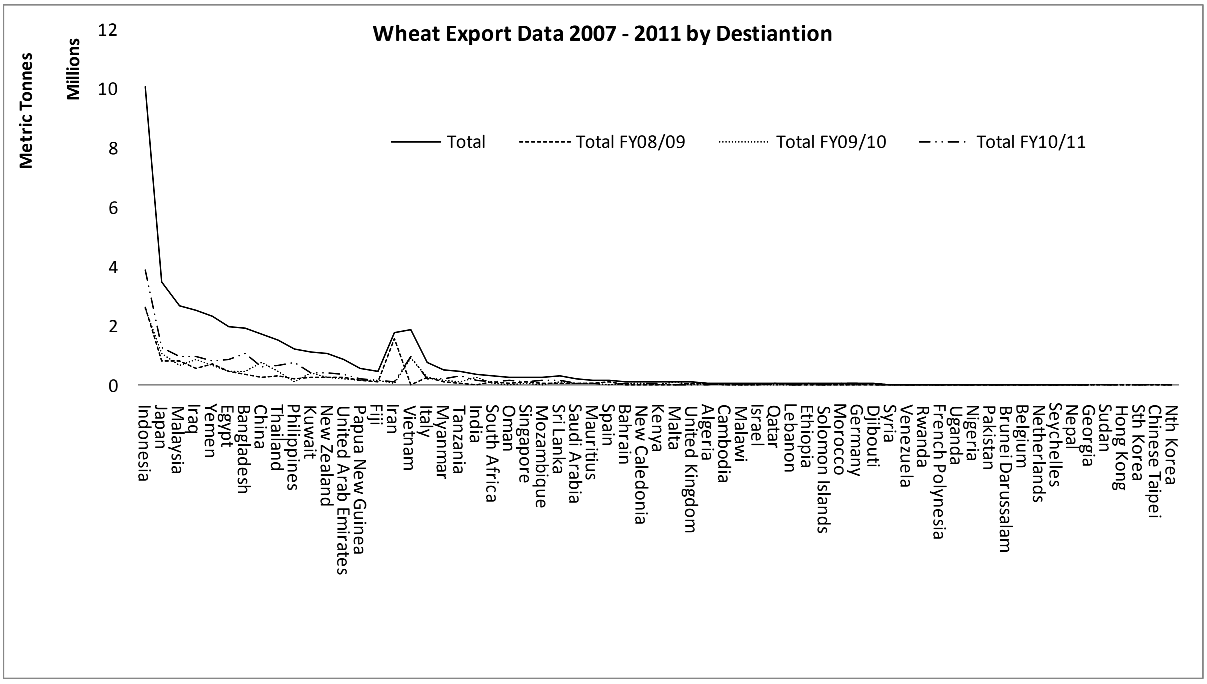
Trade Weighted Index Construction

The construction of the wheat-export trade-weighted index (GETWI) is based upon the standard TWI method used by the Australian Bureau of Statistics. The inclusion of the nation weights was based upon several criteria. These are the:

- Total size of export tonnes over a three year period.
- Ranking of the size of exports compared to others over time. This means that to be included an export destination country must have been materially relevant reasonably consistently over time.

As the units for each currency vary widely all are rebased to 1 at the beginning period. Subsequent relative changes in currency are then incorporated. The weight in the TWI is then determined by the relative size of exports to that country compared to the others. For instance, at time 0, the TWI has a value of 1 with Indonesia comprising exactly .2396 of that. This meat that a destination such as Vietnam has been excluded from the TWI as it received large shipments but only infrequently.

Figure 3: Australian Wheat Exports (2008 to 2011)



Source: Australian Bureau of Statistics, Thomson Reuters and Authors' calculations.

Export Data

Australia wheat exports are calculated and published by ABARES on a monthly basis. Data for this study date back to July 2007. See Figure 3. South Australia has disproportionately small domestic use of wheat with the vast majority of state level production being dedicated to exports. In a normal year approximately 86.5 per cent of grain production in SA is exported of which 52 per cent is wheat. The proportion of wheat exported is similar to that of other grains.

Figure 3 shows the level of total exports of Australian wheat over the study period and for each annual period (Australian harvest and exporting periods run over multiple years as summer runs from December through to February).

Prices

The price of both Australia APW wheat and CBOT futures were particularly volatile and this in an investment class notorious for its volatility. Australian APW was chosen as a price series as it exhibits the characteristics of both milling and feed wheats. In turn, as it has generic uses it is generally accepted that its price path will at least approximately follow that of the world price of export grains. The nearby CBOT futures price is used as a proxy for the world price of wheat. These prices are easily obtainable from Thomson Reuters and have been shown to be highly correlated with various US physical wheat prices (over a range of geographic locations).

Methodology

This paper uses a general-to-specific modelling approach and co-integrating regression (CR) techniques so as to incorporate an error-correction mechanism (ECM) into an otherwise fairly standard model of pass-through from USD-denominated wheat prices and each of the measures of the exchange rate—the USD/AUD exchange rate and the GETWI. This is to allow for the separation of both long-run and short-run effects, in particular the impact of exchange rate and contract price variability. The methodology also allows for the presence of coefficients on variables of different signs at different lags, through the use of lagged difference terms, while the CR eliminates the necessity of finding relationships involving lags in the levels variables.[5]

When performed correctly, this econometric methodology also overcomes problems associated with potential non-stationarity in the residuals. In the case of the CR technique, stationarity of the error term from the first regression in the two stage Engle-Granger estimation process is necessary to provide the ECM; regressions not having this property are "spurious".[6]

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[5]If two time series x_t and y_t are co-integrated, then x_t and y_{t-k} will also be co-integrated for any lag k (Granger, 1991, p 69). This property simplifies the modelling strategy, as arbitrary searches for appropriate lag structures between levels in variables is not required.

[6]The CR technique is also preferred by some to the Box-Jenkins (B-J) methodology, which also requires stationarity in variable to perform a relevant analysis, due to the retention of information about long-run relationships between variables.

Unit Roots

In this section the order of integration of the time series used is tested to determine whether the possibility of co-integration between the series exists.[7] Time series that are integrated of a different order will not provide the basis for a co-integrating vector, leading to the possibility that regression results may be spurious, and thus questioning the usefulness of any relationships identified in the hedging process.

Table 1: Autocorrelation functions in levels and first differences (1st Diff.)

	LNAPW		LNAUD		LNGETWI		LNW1	
	Level	*1st Diff.*	*Level*	*1st Diff.*	*Level*	*1st Diff.*	*Level*	*1st Diff.*
1	0.956	0.107	0.978	-0.168	0.988	0.275	0.949	-0.008
2	0.904	-0.001	0.962	0.232	0.969	0.221	0.899	0.089
3	0.852	-0.026	0.939	-0.102	0.945	0.137	0.838	-0.127
4	0.802	-0.126	0.920	0.044	0.919	-0.129	0.786	0.021
5	0.760	0.086	0.902	0.020	0.895	-0.053	0.737	-0.084
6	0.711	-0.001	0.885	0.109	0.873	-0.243	0.699	-0.007
7	0.663	-0.044	0.863	0.011	0.855	-0.093	0.663	0.047
8	0.618	0.041	0.837	0.133	0.840	-0.004	0.620	0.051
9	0.574	0.008	0.808	-0.008	0.823	-0.135	0.576	-0.064
10	0.528	-0.001	0.778	-0.100	0.809	0.052	0.539	-0.154
11	0.482	-0.005	0.756	0.037	0.794	0.043	0.522	-0.049
12	0.437	-0.025	0.731	-0.047	0.777	0.171	0.510	0.001
13	0.393	-0.107	0.710	0.008	0.758	0.094	0.502	-0.041
14	0.359	-0.003	0.687	0.092	0.736	0.121	0.496	0.063
15	0.325	0.002	0.659	-0.058	0.711	0.150	0.486	0.031
16	0.292	0.025	0.633	0.032	0.683	0.014	0.471	0.038
17	0.257	0.059	0.608	0.053	0.654	0.055	0.457	0.078
18	0.218	-0.159	0.579	0.020	0.624	-0.106	0.432	0.100
19	0.192	0.001	0.550	-0.032	0.597	-0.074	0.408	-0.104
20	0.168	-0.010	0.523	0.052	0.572	-0.012	0.388	0.100
21	0.146	0.020	0.493	-0.088	0.546	-0.125	0.353	-0.029
22	0.122	0.116	0.466	0.067	0.523	0.075	0.317	-0.036
23	0.089	0.009	0.435	-0.035	0.498	-0.025	0.281	-0.064
24	0.056	-0.003	0.407	-0.013	0.474	-0.087	0.255	0.036
25	0.023	-0.086	0.379	-0.058	0.452	0.033	0.225	0.008
26	-0.006	-0.136	0.354	0.023	0.428	-0.046	0.198	-0.092
27	-0.025	-0.010	0.327	-0.106	0.406	-0.008	0.181	-0.116
28	-0.042	-0.030	0.303	0.041	0.383	-0.021	0.176	0.028
29	-0.057	0.119	0.279	-0.061	0.362	-0.036	0.168	0.017
30	-0.082	0.068	0.258	-0.010	0.341	0.035	0.159	-0.001
31	-0.112	0.029	0.236	-0.029	0.319	-0.085	0.150	-0.028
32	-0.145	-0.003	0.216	-0.149	0.300	-0.088	0.140	0.134
33	-0.175	0.004	0.201	0.016	0.282	-0.037	0.121	-0.069
34	-0.206	-0.019	0.186	-0.018	0.265	-0.103	0.109	-0.045
35	-0.235	0.046	0.170	-0.062	0.250	-0.060	0.101	0.011
36	-0.268	0.020	0.157	0.055	0.236	0.021	0.090	0.086

[7] The order of integration of the measures of exchange rate variability will be considered in a latter section prior to testing for co-integration between sets of time series.

Four weekly time series are tested, covering the period 31 July 2008 to 4 November 2011:

- LNAPW, the log of the Australian wheat price (in AUD);
- LNAUD, the log of the AUD/USD exchange rate (the USD cost of 1 AUD);
- LNGETWI, the log of an index of the grain export trade-weighted exchange rates (price of 1 USD) of Australia's main export destinations; and
- LNW1, the log of the price, in USD, of the closest-dated wheat contract provided by the Chicago Board of Trade.

As a preliminary examination for the presence of unit roots in a time series, it is useful to examine the sample autocorrelation function (ACF) of each series. Series for which a unit root is present will be characterised by an ACF which takes a high initial value then decays slowly and smoothly. Table 1 (above) reports the value of the sample ACFs for each of the above series in level and first difference forms.

From Table 1 it is apparent that the log levels of the time series have ACFs which decay slowly and smoothly from their initial as the lag is increased. This pattern is similar to that of a non-stationary time series with a root at or near the unit value.[8]

Having shown that preliminary tests of each of the time series are, in most cases, suggestive of non-stationarity, it is now time to turn to more formal testing of the time-series properties of each series based on unit root tests. In order to allow a test of whether the series are trend-stationary processes as opposed to difference-stationary processes, augmented Dickey-Fuller tests for the presence of unit roots in the individual time series are derived from the following equation:

$$y_t = \mu + \beta\tau + \alpha_1 y_{t-1} + \sum_{i=1}^{k} \alpha_{i+1} \Delta y_{t-i} + \varepsilon_i\,, \quad (2)$$

where y_t is the variable to be tested, τ is a time trend and *k*, initially, is set equal to four.[9],[10]

The tests are conducted in the following order:

I. Φ_1, H_0: $(\mu, \beta, \alpha_1) = (0, 0, 1)$.

II. Φ_2, H_0: $(\mu, \beta, \alpha_1) = (\mu, 0, 1)$.

III. Φ_3, H_0: $(\mu, \beta, \alpha_1) = (\mu, \beta, 1)$.[11]

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[8]An examination of the partial autocorrelation functions (PACFs) for all variables is consistent with the idea that all of the time series are non-stationary. All four time-series display a significant PACF at lag one, with all other PACFs, to lag 10, being insignificantly different from zero.

[9]The inclusion of the lagged difference terms allows for the presence of serial correlation in the residuals. In the absence of their inclusion, the presence of serial correlation will affect the asymptotic distribution of the test statistics used to determine whether the individual time series are integrated of order one. See MacKinnon (1991, p 270).

[10]In those cases where the t-score on the coefficient of a lagged difference term was insignificant at the five per cent level (two-tailed), the term was usually dropped from the regression. The Durbin-Watson statistic for each regression was also used to guide the decision on whether to retain particular sets of lagged difference terms. As noted by MacKinnon (1991, p 270), the essential criterion is that sufficient lagged difference terms should be added to ensure that the residuals from the test regression appear to be generated by a white noise process.

The results of unit root tests I to III are reported in Table 2 for the levels and differences of each of the four time series tested.[12]

For each of the log-level series, it is not possible to reject the joint hypothesis of a unit root with no drift or trend at the five per cent level using the Φ_1, Φ_2 or the Φ_3 tests.

An examination of the results of the tests for unit roots on the first differences of each of the four variables, leads to the conclusion that the null hypothesis can be rejected for all of Tests I to III. Thus, the tentative conclusion is that the series LNAPW, LNAUD, LNGETWI and LNW1 are all integrated of order one. This indicates that either or both of LNAPW, LNAUD and LNW1 or LNAPW, LNGETWI and LNW1 could constitute elements of co-integrating vectors.

Table 2: Augmented Dickey-Fuller tests in levels and first differences

Variable	$\boldsymbol{\Phi_1}$	$\boldsymbol{\Phi_2}$	$\boldsymbol{\Phi_3}$
LNAPW	-0.4884	-1.8918	-1.8918
ΔLNAPW	-11.3100***	-11.2860***	-11.2860***
LNAUD	-0.9442	-1.0035	-3.9479**
ΔLNAUD	-15.0907***	-15.0626***	-15.0626***
LNGETWI	-1.4522	-1.4319	-1.4319
ΔLNGETWI	-9.4095***	-9.3844***	-9.3844***
LNW1	-0.3604	-2.1689	-2.1689
ΔLNW1	-12.7068***	-12.6718***	-12.6718***

Note: *** indicates significance at the one per cent level
** indicates significance at the five per cent level.

Testing for the Co-integrating Vector

Given the tentative conclusions regarding the time-series properties of the variables established to this point, Engle-Granger and Johansen co-integration tests were performed on the two sets of variables that potentially provide co-integrating vectors:

- LNAPW, LNAUD and LNW1; and
- LNAPW, LNGETWI and LNW1

The results of the Engle-Granger co-integration tests, which use LNAPW as the dependent variable, are reported as equations (4) and (5):[13]

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[11]The inclusion of the constant and trend in the equation used to calculate the value of the ADF statistic means that the estimated t-statistic on y_{t-1} (α_1) in equation (2) is independent of μ, although it does assume that $\beta = 0$ (MacKinnon, 1991, p 270).

[12]When the tests are done in the order indicated, a rejection of H_0 in Test I (the Φ_2 test) and a failure to reject H_0 in Test II (the Φ_3 test) suggests that the time series being tested is difference stationary with drift rather than trend stationary.

[13]It is possible to estimate a number of co-integrating relationships, with different coefficients, by normalising on different variables. Following Maddala (1992, pp 594 & 596), it is to be expected that not all of these equations would provide for easy economic interpretation. This is due to the fact that co-integration is a

$$LNAPW = -0.1707 - 0.8084LNAUD + 1.0453LNW1$$
$$(-0.4109)\ (-8.5448^{***})\qquad (13.7829^{***}) \tag{4}$$
$$Adj-R^2 = 0.6463 \qquad ADF = -4.2828^{***}$$

$$LNAPW = -0.0597 + 3.3403LNGETWI + 1.0386LNW1$$
$$(-0.1489)\ (9.2499^{***})\qquad (14.0286^{***}) \tag{5}$$
$$Adj-R^2 = 0.7040 \qquad ADF = -4.9782^{***}$$

Note: *** denotes significance at the one per cent level.

Equations (4) and (5) have several elements in common. Each equation displays a high value for the R^2 statistic, high absolute *t*-test results for each of the exchange rate and wheat contract price variables indicating significance at the one per cent level, and with each having a co-integrating ADF test statistic that exceeds the critical value at the one per cent significance level.[14] Additionally, the signs and general orders of magnitude of the coefficients on the common variables are similar across equations. Although biased in small samples, these parameter estimates are "super consistent"; that is, they converge to the true parameter values much more rapidly than suggested by the results of the classical econometric model when all of the classical assumptions have been met (Maddala, 1991, pp 591-592; Thomas, 1993, pp 166-167).[15] This result holds even though the equation may clearly be misspecified due to a lack of dynamics. A further evaluation of the co-integrating regressions and individual coefficients within each is not generally recommended, however, due to the lack of consistency in the OLS estimates of the standard error for each coefficient (Engle and Granger, 1991, p 10; Charemza and Deadman, 1992, pp 156-157).[16,17]

A Dynamic Model of Australian Export Wheat Price Changes

A dynamic generalised model of Australian export wheat price changes relates the one-week change in the log-level of the Australian wheat export price (ΔLNAPW) to its own lags and current and lagged values of the one-week changes in the log-levels of our measures of the

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statistical property. Thus it appears sensible to choose the normalisation that is economically relevant in terms of an initially specified general model. Additionally, the Johansen tests for each of the sets of variables support this normalisation, as each identifies that there is only one co-integrating equation, with LNAPW as the variable with a coefficient of one in each case.

[14]Following Thomas (1993, p 166) we use the co-integrating ADF test (on the equation residuals) as a test for co-integration in the variable set. As this test indicates stationarity in the residuals, which are the long-run component of our later models, we accept co-integration.

[15]In fact, at the rate given by T^{-1} rather than $T^{-½}$ (Engle and Granger, 1991, p 9).

[16]It should be noted that combinations of subsets of the variables included in equations (4) and (5) do not produce co-integrating vectors. The variables included in equation in each of equations (4) and (5) provide the minimum set before co-integration is indicated.

[17]It would, however, be possible to construct *t* scores with normal limiting distributions using a maximum likelihood technique (Engle and Granger, 1991, p 10) but may not be worthwhile for the sample of 161 observations used in this analysis.

relevant exchange rate (ΔLNAUD or (ΔLNGETWI) and changes in the global USD contract price of wheat (ΔLNW1). Four lags of each of these variables are included in the initial equation. Additionally, the one-week lagged value of the residuals from the co-integrating regression is included in the model. This allows a modelling of the error-correction mechanism (ECM), the long-run component of the model. Given the results of equations (4) and (5), the following general models were tested for the sample period:[18]

$$\Delta LNAPW_i = \alpha + \beta\, ECM1_{-1} + \sum_{j=1}^{4} \chi_j\, \Delta LNAPW_j + \sum_{j=0}^{4} \delta_j\, \Delta LNAUD_j + \sum_{j=0}^{4} \gamma_j\, \Delta LNW1_j + \varepsilon_i \tag{6}$$

$$\Delta LNAPW_i = \alpha + \beta\, ECM2_{-1} + \sum_{j=1}^{4} \chi_j\, \Delta LNAPW_j + \sum_{j=0}^{4} \delta_j\, \Delta LNGETWI_j + \sum_{j=0}^{4} \gamma_j\, \Delta LNW1_j + \varepsilon_i \tag{7}$$

In equation (6) $ECM1_{-1}$ corresponds to the one-week lagged residuals from equation (4), while in (7) $ECM2_{-1}$ corresponds to the one-week lagged residuals from equation (5).

In order to produce more parsimonious models a simple search procedure was undertaken on each of equations (6) and (7). Variables were tested for significance within the regression through the use of a likelihood-ratio (LR) test based on the differences between the residual sum of squares in a restricted and an unrestricted regression.[19,20] The final results of the search procedure, along with the diagnostics for the final equations[21], are presented as equations (8) and (9), with the *t*-scores reported in parentheses under each coefficient:

$$\begin{aligned} \Delta LNAPW &= -0.0002 - 0.2128\, ECM1_{-1} + 0.1549\, \Delta LNW1 \\ &\quad (-0.0588)(-6.3182^{***}) \qquad (2.4162^{***}) \\ Adj-R^2 &= 0.2132 \quad DW = 1.8531 \quad F-statistic = 22.5412^{***} \end{aligned} \tag{8}$$

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[18]The choice of lags of four periods is dictated by considerations of the adjustment time for Australian export wheat prices.

[19]As one restriction was being tested, the appropriate LR statistic has an asymptotic chi-square distribution with one degree of freedom.

[20]Reference was also made to the *t*-scores of individual coefficients as well as their associated variance inflation factors (VIF) in order to determine significance. As the search procedure continued, increasingly stringent requirements were set, in terms of level of significance, for those variables to be included in the regression.

[21]Some authors may question the presentation of a set of final equations rather than the presentation of the single 'best' equation. However, this approach is consistent with the use of a LSE style of econometric methodology. Under this approach the econometrician seeks to develop a statistically acceptable representation of the *data generation process*. This representation need not be considered to be either unique or invariant with respect to time. It may also be expected that a number of acceptable representations of the data generation process would be possible, given slight changes in the measurement or representation of some variables.

$$\Delta LNAPW = -0.0006 - 0.2415\,ECM2_{-1} + 0.1771\,\Delta LNW1$$
$$\qquad (-0.1697)(-6.5734^{***}) \qquad (2.7764^{***}) \qquad (9)$$
$$Adj-R^2 = 0.2261 \quad DW = 1.8201 \quad F-statistic = 24.2296^{***}$$

Note: *** denotes significance at the five per cent level.

Discussion

The econometric results produced during this study have a number of potentially interesting implications for the analysis and modelling of changes in the Australian wheat export price, and through this, perhaps, risk management and pricing.

The co-integrating vectors in equations (4) and (5) represent estimates of the long-run path of LNAPW;[22] as a function of exchange rates (LNAUD or LNGETWI) and the global USD wheat price (LNW1). An examination of equations (4) and (5) reveals that all coefficients for which it was possible to suggest a sign a priori, are significant and have estimated signs consistent with theory. Note also that the rough order of magnitude for the coefficients of each of the variables that are common to each of the equations are similar for equations (4) and (5). It is also clear that the explanatory power of each of equations (4) and (5) is similar in terms of adjusted R^2. Thus, the trade-weighted grain export price may provide a possible alternative to the AUD/USD rate in modelling changes in the Australian wheat export price.

The results of equations (4) and (5) indicate an elasticity of Australian wheat export prices with respect to the global USD wheat contract price of 1.04 and 1.05, respectively. Thus, there is an approximate 100 per cent flow-through of changes in the global USD price of wheat to the Australian export wheat price.

Equations (4) and (5) also provide estimates on the elasticity of the Australian wheat export price with respect to both a trade-weighted measure of the exchange rate of its major trading partners and the AUD/USD exchange rate. For equation (4) this takes the value of 3.34, while for equation (5) the respective value is -0.81. The difference in sign on the coefficients reflects that the AUD/USD rate is a direct quote from a US perspective while that for GETWI is an indirect quote reflecting its use of foreign currency to USD exchange rates in its construction. What is apparent, however, is that the elasticity of the Australian wheat export price is higher with respect to the currencies of our major export markets than to the AUD/USD rate. Additionally, it is clear that there is not a 100 per cent pass-through from changes in the AUD/USD exchange rate to Australian wheat export prices, and that this is the likely source of the lack imperfect correlation between the actual and implied Australian wheat export (i.e., exchange rate adjusted USD wheat contract) prices.

[22]As indicated above, the co-integrating vectors chosen need not represent unique summaries of the relationship between the chosen variables. This is due to the possibility of normalising on one of the other variables.

Much as equations (4) and (5) provide an indication of the long-run determinants and progress of the Australian wheat export price, the dynamic models in equations (8) and (9) provide models of the short-run adjustments made in the Australian wheat export price as it moves towards a new long-run equilibrium level following changes in its determinants. In each of equations (8) and (9), the lagged ECM is highly significant. This is indicated by the levels of the respective *t*-statistics, and the appropriate negative signs, which indicate stability in the adjustment process. Additionally, the coefficient on the lagged ECM in each equation is roughly of the same order of magnitude. Finally, the explanatory power of each model, as reflected in the value for adjusted R^2, is of a similar order of magnitude (as with equations (4) and (5)). This confirms that GETWI may have a role as an alternative to the AUD/USD rate in explaining movements in the Australian wheat export price.

Equations (8) and (9) suggest that LNAPW will change over a week by between 0.21 and 0.24 per cent, respectively, for each one per cent by which it deviates from its long-run equilibrium value. Values above the long-run equilibrium level will lead to falls in the Australian wheat export price, while values below the long-run equilibrium will lead to an increase in the Australian wheat export price (as expected). The pace with which equations (8) and (9) suggest that any disequilibrium in the level of real exports is corrected may seem surprising. However, a consideration of the Australian wheat export price data, and the frequency with which adjustment in the export price occurs, suggests this outcome.

Conclusions

This study has used a well-defined methodological approach, based on co-integration techniques and using an error-correction modelling process, to explore whether an alternative to the use of the AUD/USD exchange rate may prove useful in modelling changes in the Australian wheat export price. The alternative proposed has consisted of a trade-weighted average of the value of the USD in the currencies of those countries that are the major export markets for Australian grain. The justification for choice of this variable is that it better allows consideration of the export destinations of Australian wheat exports, and has the potential to add, when combined with more detailed information on export quantities in the longer term, to our understanding of factors driving the wheat export price in Australia.

The co-integration and error-correction approaches taken in this paper overcome a number of potential empirical problems. In particular, the need to determine arbitrary lag structures for variables in their levels forms.

The use of co-integration techniques in this study has imposed an accepted structure to the modelling process. Thus it has considered the order of integration of the measures of the underlying variables—the Australian wheat export price, alternative measures of the exchange rate, and the global USD wheat contract price—used. The order of integration of these variables determines the nature of the "true" relationship between the Australian wheat export price, exchange rates, and the global USD wheat price. However, while the co-integrating regression helps us refine the relation between the variables it does not add the granularity that a more detailed dynamic model would.

The results of the modelling and analysis in this paper suggest that a number of acceptable representations of the aggregate data generation process are to be able to be produced, each one using an alternative measure of the exchange rate. However, these models cannot be considered as providing any final answers on the issue of the determinants of the Australian wheat export price. Most importantly, the results of this study suggest a need for further analysis of the factors that may (or should) impact Australian wheat export pricing decisions and hedge strategies. In particular, to further refine the model and hedging strategies based upon its results it will be necessary to dynamically adjust the GETWI and determine if this adds explanatory power to the model.

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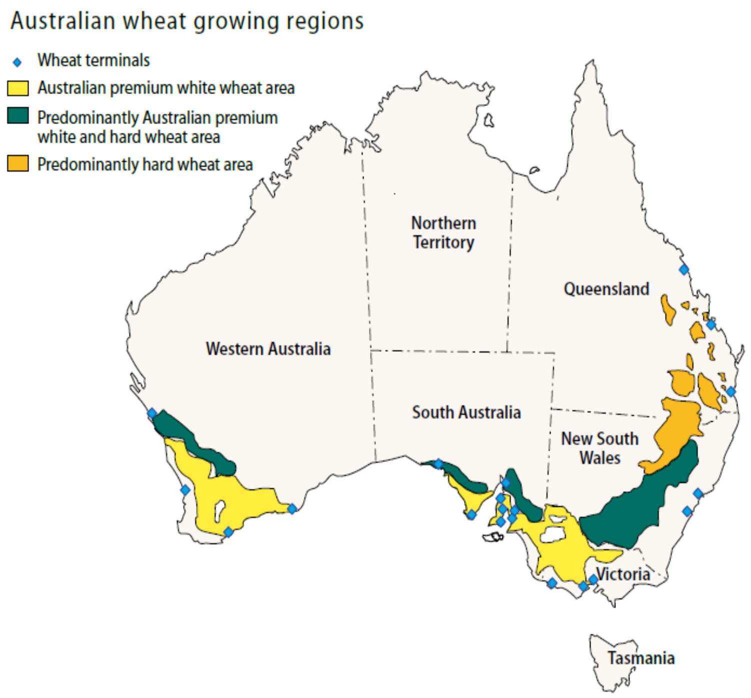
Thompson Reuters (2012) Data derived from: FTSE100 daily index time-series data 2007-2011.

Appendix

The majority of Australian domestic demand for wheat is based on the eastern seaboard and is generally not sourced from the South or west Australian markets. These origins export the bulk of the production**.**



Source: Australian Crop report 15 February 2011