The Transmission of Price Information at Queensland Cattle Auctions

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Abstract

In the ideal competitive market, perfect or near perfect information flows will guarantee that prices and/or quantities will adjust quickly to any change in demand or supply conditions. There will be no long run opportunities for arbitrage between geographically separate market places with price differentials reflecting only the cost of transfer between the markets. In this paper, the transmission of price information in Queensland cattle auctions is examined and the existence of long run arbitrage opportunities is investigated.

Only one section of the beef cattle market is analyzed, the Jap-Ox market for high quality heavy steers. Price series for four saleyards, covering the period March 1986 to August 1989 are examined for evidence of price differentials inconsistent with the free flow of price information between the saleyards.

Contributed Paper, 34th Annual Conference, Australian Agricultural Economics Society to be held at the University of Queensland, February 12-15, 1990.

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Introduction

In the ideal competitive market, perfect or near perfect information flows will guarantee that prices and/or quantities will adjust quickly to any change in demand or supply conditions. There will be limited opportunity for arbitrage between geographically separate market places with price differentials reflecting only the costs of transfer between the markets. Average prices at different centers will move together.

The auction system has often been identified as coming close to the competitive ideal, with many agents operating, freedom of entry and good information flows. However, there are many market characteristics in Queensland cattle auctions which suggest that they may be significant departures from the competitive ideal:

- there may be many sellers at auctions but, particularly at the smaller or more remote saleyards, the number of buyers can be as low as three;

- information may not be freely or symmetrically available to all participants, with buyers transacting in the market statewide and year round while sellers may sell fewer than five times a year and in a limited geographical area[1];

- there are barriers to trade within Queensland, in the forms of tick zones, which may act as an impediment to inter-regional trade.

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[1] The existence of livestock market reports for cattle sold at the main saleyards in Queensland may lessen the impact of the asymmetry of information.

In this paper, the transmission of price information in Queensland cattle auctions is modeled to determine how quickly price changes in one geographical sector of the market are diffused to other areas.

Since not all categories of cattle are offered for sale at each market place on any one day, the analysis of price transmission must be conducted by constructing a suitable index or by focusing on one category that is frequently transacted. The former solution requires an hedonic price model to be specified that relates various weights, fat scores, ages, and sex to a common pricing base. However, the lack of variability of information on any one day renders it difficult to build independent models for each market place and day. It is, therefore, a natural first step to take the latter approach and investigate temporal effects for a single type of beast, in this case the Jap-Ox.[2]

The Jap-Ox Market

One very specific type of cattle has been chosen for this analysis - the so-called Jap-Ox. These cattle are used almost exclusively for one end-market, that of Japan. With other types of cattle, there is the possibility of different areas supplying some type of cattle for the export market while other areas may use the same type of cattle for the domestic market. Thus the

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[2] For price studies that consider the transmission of price through cattle types, see Ehrich (1969), Franzman and Walker (1972), Barksdale, Hilliard and Ahlund (1975), Buccola and Jesse (1979), Buccola (1980), Spreen and Shonkwiler (1981), Bessler and Brandt (1982), Marsh (1985), Schultz and Marsh (1985), and VanTassell and Bessler (1988).

price of cattle may be affected by changes in both domestic and export market conditions. This complication can be minimized by analyzing a sector of the market which is heavily dominated by one market - the export market of Japan. The conclusions drawn from this paper are thus restricted to this small but important section of the Queensland beef cattle industry. However the methodology can be modified to analyze more heterogeneous segments of the beef cattle market.

The classification Jap-Ox is very precise and is thus appropriate for this exercise, abstracting from problems of heterogeneity and the associated averaging problems associated with most types of cattle. The cattle considered as Jap-Ox have an estimated minimum liveweight of 550kg and a minimum fat score of 4 (indicating a fat cover of at least 13mm as measured at the rump). For this analysis, only grass-fed animals were included in the data set, having a much larger and wider representation throughout the State.

While there is some room for quality variation even within this narrow classification, it has been minimized by the choice of this cattle type. Any remaining quality variation is explained by breed differences and 'finish' differences. Consistent differences in breed type between areas would not be expected to cause anything other than a constant differential between prices in the two areas. Seasonal differences in the 'finish' of the cattle may, however, cause seasonal shifts.

The data used in this analysis are average price series derived from livestock market reports collected by the Livestock Market Reporting Service (LMRS) of the Livestock and Meat Authority of Queensland. The LMRS collect data on every lot of cattle sold at 16 major saleyards in Queensland. The average price series are derived by dividing the total value of Jap-Ox sold by the number of Jap-Ox sold. The series used here are for four of the major saleyards in Queensland for the Jap-Ox market:

Rockhampton - Monday sale
Toowoomba - Tuesday sale
Toowoomba - Wednesday sale
Townsville - Wednesday sale

The time series techniques used in this analysis require data points to be equally spaced in time with no missing observations. While the former is readily satisfied with the weekly auction, the latter is not so easily managed. Christmas, Easter and other public holidays, breakdown of electronic data collection devices and adverse weather all can cause the cancellation of an auction or the omission of the record of an auction which did take place. In each case, missing observations were replaced by the average of the adjacent prices.

The Unrestricted Model

The four price series are presented in Figure 1. All three saleyards are located in the main cattle producing areas of Queensland with Townsville at the North and Toowoomba at the South; Rockhampton is located approximately halfway between the other two saleyards and is dominant in terms of saleyard volumes. Prices relative to those of Rockhampton are presented in Figure 2 through 4 and the growth rates of Rockhampton prices are given in Figure 5.

Figure 1 : Weekly Average Price
1986 - 1989

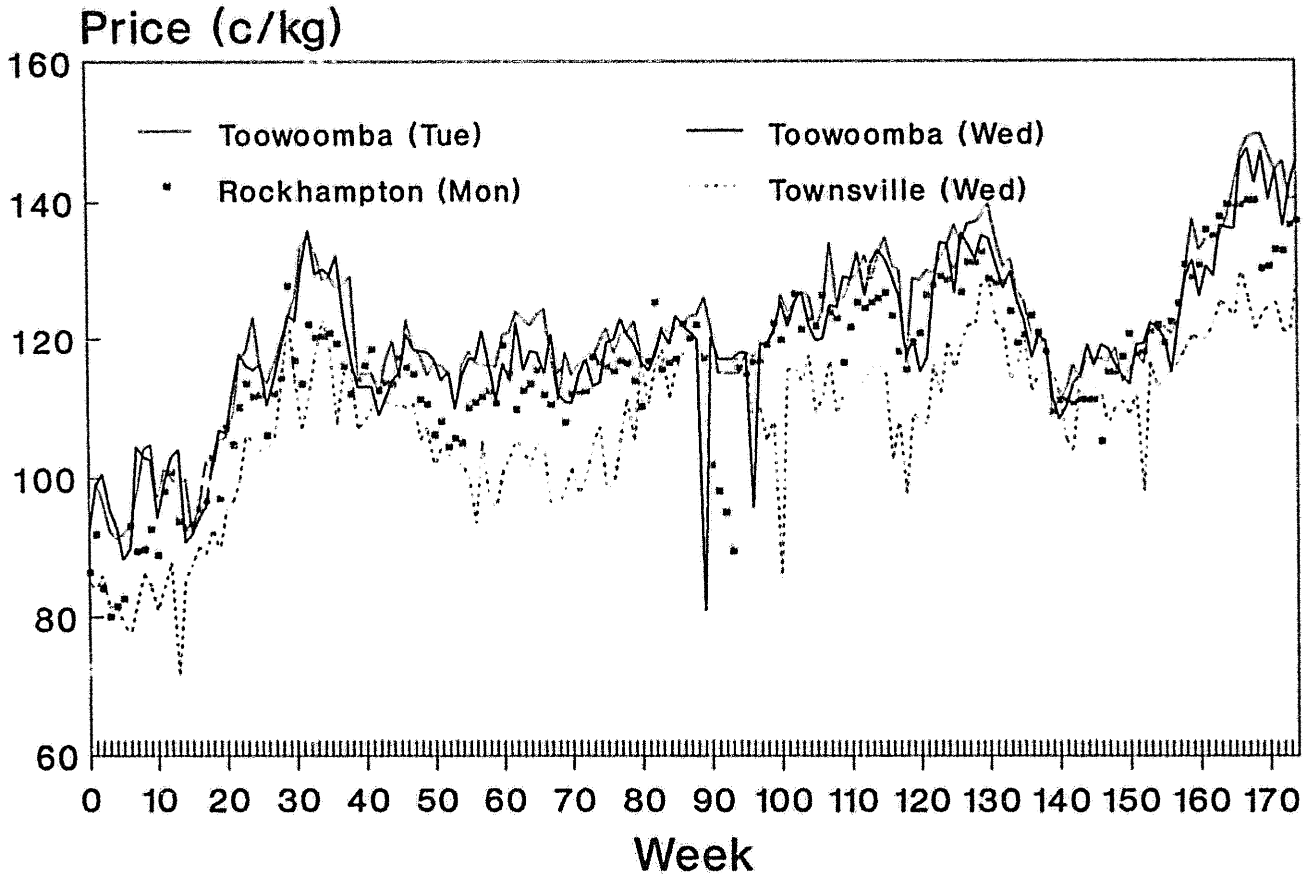


Figure 2 : Log Relative Price
Toowoomba (Tue) to Rockhampton (Mon)

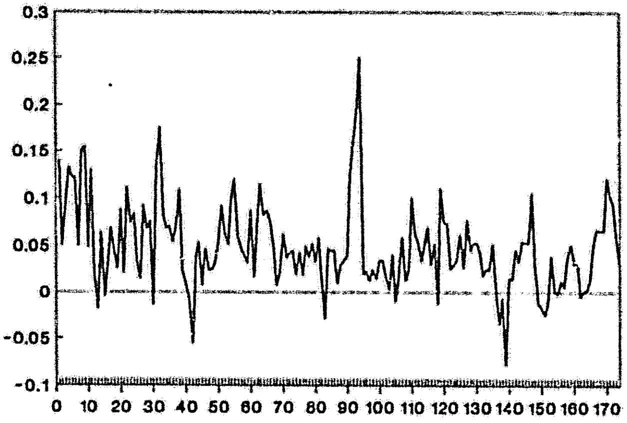


Figure 3 : Log Relative Price
Toowoomba (Wed) to Rockhampton (Mon)

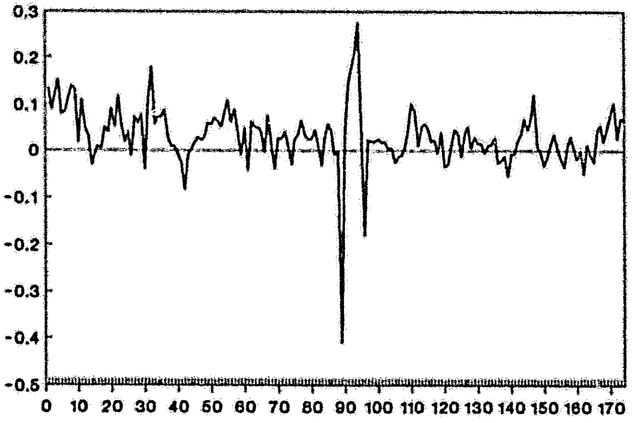


Figure 4 : Log Relative Price
Townsville (Wed) to Rockhampton (Mon)

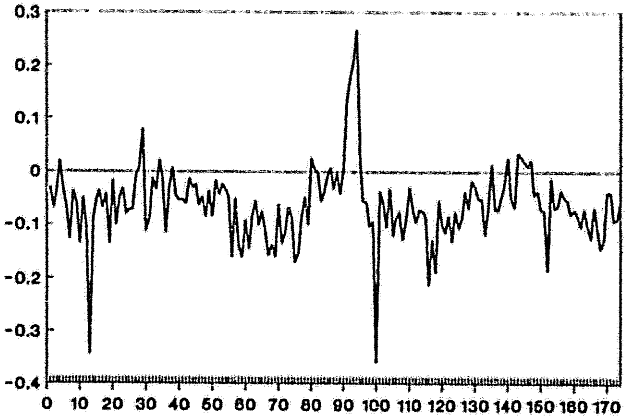
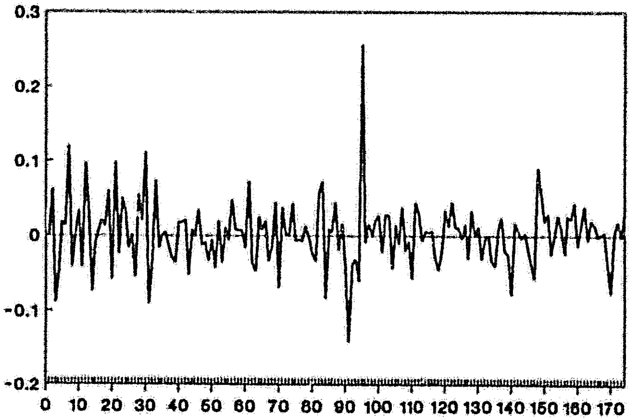


Figure 5 : Log-Change Price
Rockhampton (Mon)



Clearly, the individual prices are nonstationary.[3] The fact that the price ratios are less trending suggests that there might be a common time trend to all prices. These assertions can be tested with ADF [Augmented Dickey-Fuller (1979)] tests. The following notation is used throughout this study:

y_1 = log of average price at Monday meeting of Rockhampton saleyard
y_2 = log of average price at Tuesday meeting of Toowoomba saleyard
y_3 = log of average price at Wednesday meeting of Toowoomba saleyard
y_4 = log of average price at Wednesday meeting of Townsville saleyard

An ADF test for levels versus differences, involves the regression

$$\Delta y_{it} = \alpha + \beta\, y_{i,t-1} + \sum_{j=1}^{p-1} \phi_j\, \Delta y_{i,t-j} + u_{it} \tag{1}$$

for an appropriate value of p, where u_{it} are white noise disturbances. If $\beta = 0$, equation (1) collapses to a regression only in first differences of y_{it} while if $\beta \neq 0$, equation (1) is equivalent to a simple autoregressive model in the levels of y_{it}. If u_{it} has constant variance, a levels model implies y_{it} is stationary, that is time-invariant mean and variance, and referred to as I(0) following Granger (1981). Repeated application of the test to the differenced data helps to determine whether or not the differences are stationary. If they are, the series are said to be I(1). In general, if a time series has to be differenced d times before it is stationary, the series is said to be I(d).

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[3] Stationarity implies constant mean and variance over time. In the current study, the constancy of variance is achieved through a logarithmic transformation of the data. Trends in mean are usually accounted for by differencing the data, including deterministic time trends, or both.

Owing to the bias in the t-ratio under the null of $\beta = 0$, the appropriate one-sided 5% critical value is 2.88 (Fuller 1976, p.373) rather than 1.64 under asymptotic normality. A sequence of regressions starting from p = 8 to p=1 for equation (1) were estimated and the trailing coefficient tested for significance from zero as $\phi_{p-1} = 0$. The sequence was truncated at p = 3 since the associated test for $\Phi_3 = 0$ was rejected for one of the series. The ADF test statistics are presented in Table 1.

Table 1 : Augmented Dickey-Fuller Tests for Nonstationarity

	Null Hypothesis		
Variable	d = 1	d = 2	Conclusion
y_1	2.96	10.37	I(0)
y_2	2.03	10.33	I(1)
y_3	2.53	12.31	I(1)
y_4	2.68	13.50	I(1)
y_2-y_1	5.75	12.88	I(0)
y_3-y_1	7.16	12.84	I(0)
y_4-y_1	4.46	13.54	I(0)

It follows from Table 1 that, with the exception of y_1, the price levels are nonstationary. However, y_1 is only just significantly different from I(1) and tests discussed in the next section suggest that it is preferable to consider y_1 to be I(1). All three log price ratios are stationary. Using the same critical value, there is no evidence of second differencing being required. Thus, all of the series are stationary except for y_{2t}, y_{3t} and y_{4t}, which need to be differenced before they have constant mean.

Following Sims (1980), an *atheoretical* approach has been adopted to modeling the price transmission mechanism[4]. Sims argues that possible misspecification bias from inappropriate economic theories can be replaced by the inefficiency of an over-parameterized dynamic reduced form system known as a VAR (Vector Autoregressive) model. Providing that a reasonable sample size is available, the relatively small loss of efficiency is more than outweighed by the lack of specification bias.

In its simplest form, a VAR model for the current price transmission mechanism simply expresses a four-equation model, one for each price, in terms of the the four prices in the previous week and a constant. There are, therefore, four 5-variable regressions with identical right hand sides and so OLS is identical to maximum likelihood. More complex VAR models contain higher order lags, Bayesian priors on the regression coefficients, and mechanisms for handling trends in price data[5].

Because a VAR is an unrestricted reduced form system, there is an infinite number of possible structural forms associated with it. Sims argues that a structure can be imposed through what is known as an innovation analysis but it should be noted that this method is dependent on the order of the equations.[6]

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[4] Sims methodology was also adopted by VanTassell and Bessler (1988).

[5] For a discussion of Bayesian priors in an agricultural context see Bessler and Kling (1986) or a discussion of handling trending (nonstationary) data, see Johansen (1988) and Bewley, Fisher and Parry (1988).

[6] Specifically, the disturbance covariance matrix is triangularized with a Choleski decomposition and the reduced form system premultiplied by the triangular matrix. Thus, a recursive system is defined with the first variable being exogenous, the second being dependent on the first, *etc.*

Since the four auctions occur on three separate days, the problem of ordering the equations is substantially reduced. The only duplication of market days occurs on Wednesdays with sales at Toowoomba and Townsville. Since there is a Tuesday sale at Toowoomba, it is reasonable to assume that price information would be transmitted to the Wednesday Toowoomba sale not later than the Townsville sale. Thus, the ordering problem is a minor issue in the present study. A far more important consideration is how to allow for the nonstationarity in the data.

VanTassell and Bessler (1988), in the 'Minnesota' tradition established by Sims (1980), augment the VAR regressions with a simple linear time trend.[7] While this might alleviate the nonstationarity problem, it is unreasonable to assume that over a long period, behavior can be described by deterministic time trends. Importantly, this long-run solution to the problem would imply that prices would continue to diverge in a linear fashion unless the coefficients on time were forced to be the same in each equation.

Using a sequence of adjusted likelihood ratio (LR) tests (Sims, 1980), the appropriate lag length in this study was found to be two.[8] The trend augmented model is

$$Y_t = a + b.t + A_1 Y_{t-1} + A_2 Y_{t-2} + v_t \tag{2}$$

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[7] If some allowance is not made for nonstationarity, hypothesis tests are severely biased and the dominance of the 'own-price' effect might make it difficult to identify cross-price effects.

[8] The third lag required in the single equation analysis of Table 1 was not significant when the interaction effects were accounted for. Indeed, for reasons stated in the next section, the second lag was not found to be necessary when testing $A_2 = 0$ but has been retained for uniformity and exposition.

where Y_t is the 4-element vector of prices, A_1 and A_2 are 4×4 matrices of parameters, a and b are 4-element vectors of parameters and v_t is the 4-element disturbance vector with covariance matrix Ω.

By backward substitution, equation (2) can be solved as an infinite moving average process:

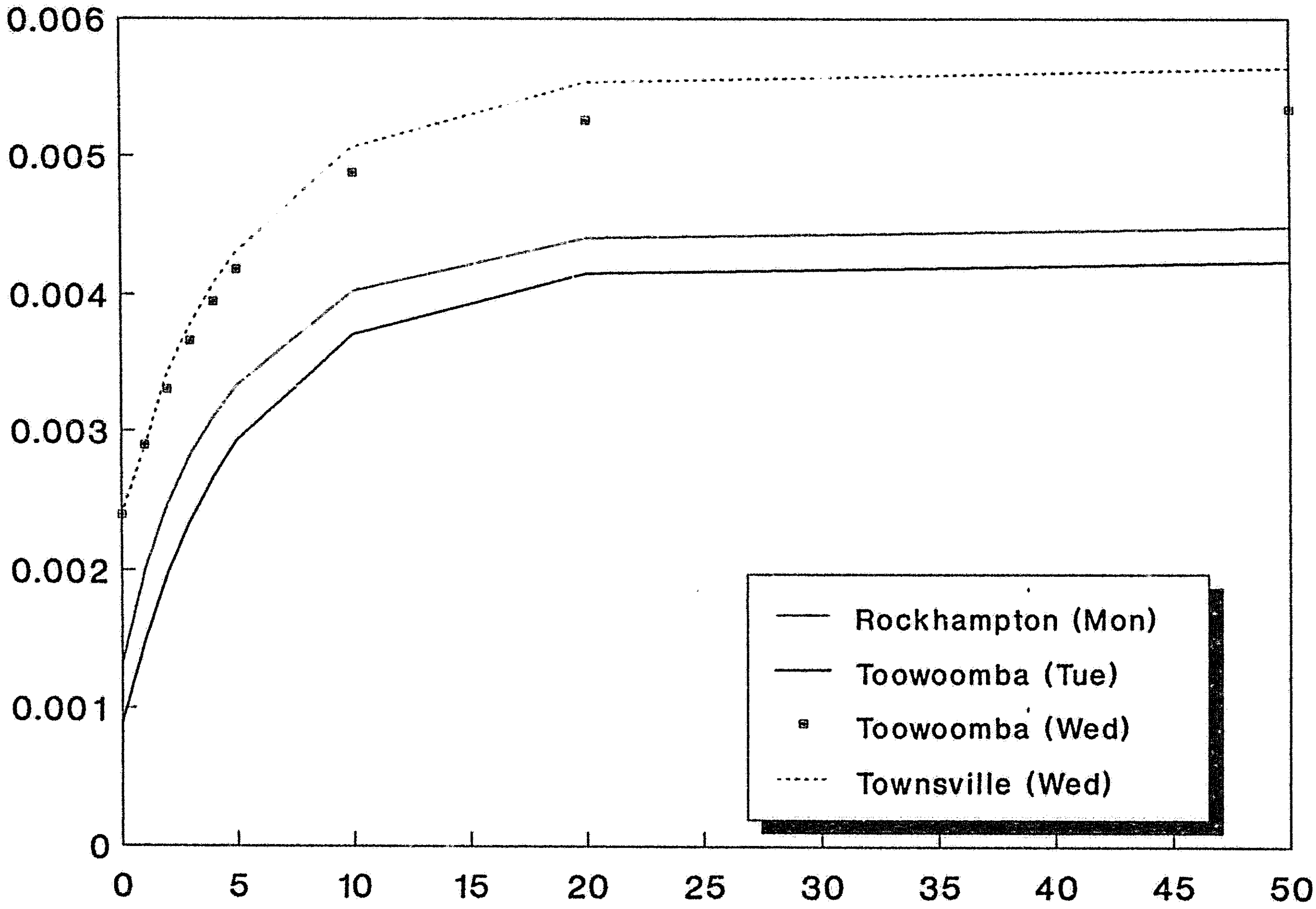
$$Y_t = c + d.t + v_t + B_1 v_{t-1} + B_2 v_{t-2} + B_3 v_{t-3} + \ldots \tag{3}$$

where the parameters are functions of those in equation (2). From equation (3) the forecast variance can be deduced at various lead times. Typically, deterministic components are omitted in this analysis; that is forecast variances about a time trend are considered. These are displayed in Figure 6.

Not surprisingly, Townsville, which is geographically isolated and subject to tick-zone problems, produced the greatest forecast variance. Because the time trend has disguised the nonstationarity problem, the variances asymptote to a constant as lead times increase. It would appear that the Wednesday meeting at Toowoomba has a greater unanticipated variation than the Tuesday meeting, possibly because it contains information from the previous main Rockhampton meeting <u>and</u> the Tuesday meeting at Toowoomba plus any 'news' that might occur between the meetings.

The innovation analysis uses the order stated above which is supported by the forecast variance analysis. The innovation diagrams are given in Figures 7 through 10. These paths have been found by premultiplying equation (3) by a lower triangular matrix, H, where $\Omega = HH'$ [see Sims, 1980].

Figure 6 : Forecast Variances



Partly because of the ordering of the variables and partly due to the strength of the relationships, it can be seen from Figure 7 that a shock of one standard error in the price at Rockhampton immediately flows through to the other three markets with the greatest effect in the Tuesday Toowoomba meeting followed by the Wednesday meeting at Toowoomba and finally Townsville. Of course the timing within a given week implies that, in this context, contemporaneous shocks relate to a chronological flow-through effect. After a one to two period effect, all responses decline rapidly to zero in some exponential fashion.

It is important to note that the triangular nature of H implies that price shocks on Tuesday at Toowoomba cannot affect the corresponding price on Monday at Rockhampton. In this case the assumption is in accord with due economic process but, in other cases, the strict recursive structure should be treated with caution. A shock on the Tuesday auction at Toowoomba (see Figure 8) has its largest effect on the next day's sales at that place but with a strong effect at the Townsville meeting. Because of the structure, there is no immediate effect on Rockhampton but there is a well defined flow through to following meetings at Rockhampton.

Again in accord with expectations from the chronological ordering, a shock to the Toowoomba Wednesday price (see Figure 9) has a swift impact on the next sales at Rockhampton and Toowoomba (Tuesday) with a more diffuse impact on the Townsville meeting that same day. The implication of this weaker effect, given that it is the only price that can admit an immediate impact from the structure of the H matrix, is that the isolated location of Townsville has produced very little of an instantaneous effect from Toowoomba and, indeed, is generally less affected than the other saleyards.

Figure 7 : Innovation Analysis
Effects of Shocks on Rockhampton (Mon)

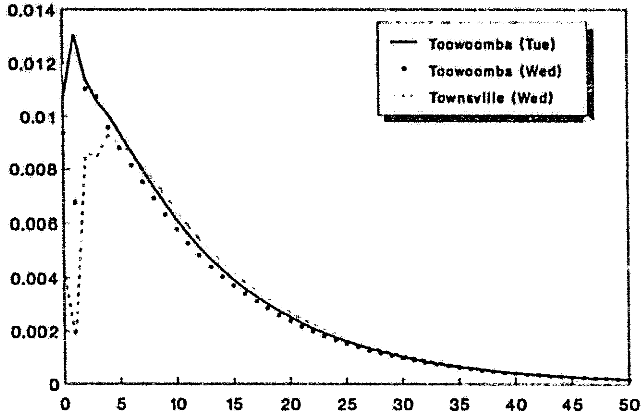


Figure 8 : Innovation Analysis
Effects of Shocks on Toowoomba (Tue)

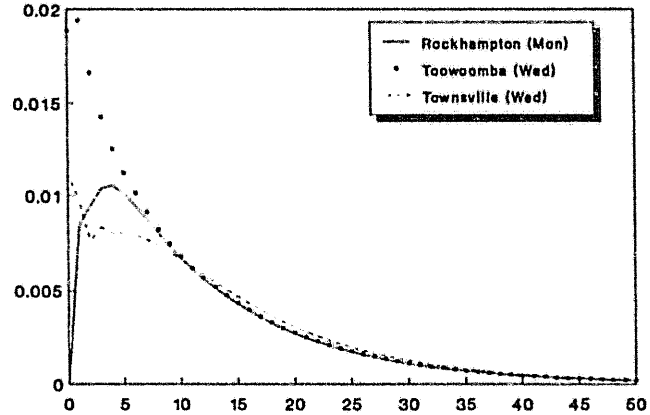


Figure 9 : Innovation Analysis
Effects of Shocks on Toowoomba (Wed)

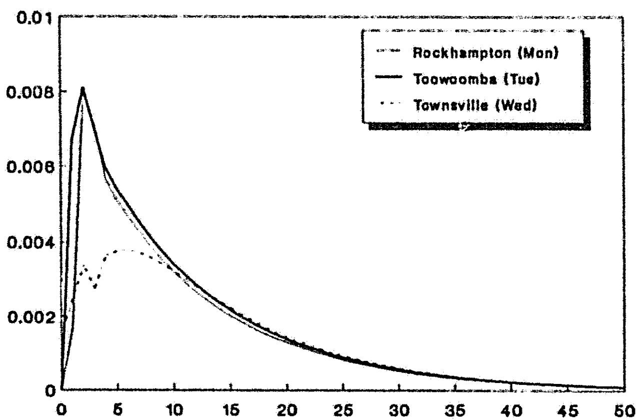
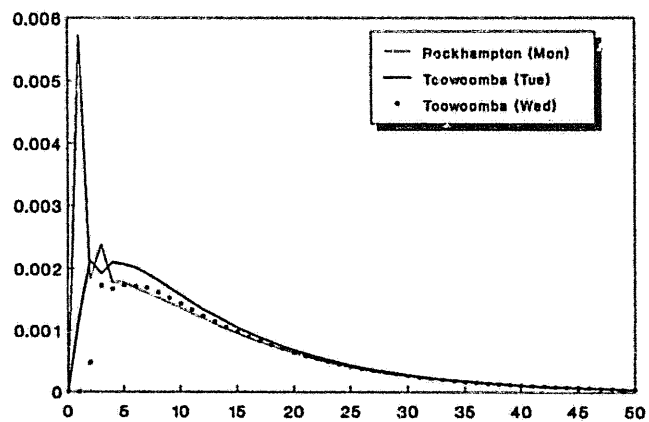


Figure 10 : Innovation Analysis
Effects of Shocks on Townsville (Wed)



Finally, a shock to Townsville (see Figure 10) has a short, sharp impact on the following Rockhampton meeting which is then rapidly absorbed by the other saleyards.

Although the preceding analysis imparts useful information about how a shock to a price affects other saleyards, it suffers from two problems. First, it does not exploit any information that might exist in the long-run between saleyard price formation. Secondly, it is difficult to derive the impact on price differentials. Both problems follow from the nonstationarity nature of the price data and can be readily resolved within a cointegration framework.

In the following section, two recent approaches to estimating multi-cointegrating VAR systems are used on the data set to highlight features that are obscured by the dominant time trends in certain of the price series.

Modeling Price Differentials

The basic problem with modeling nonstationary time series is that the levels model do not account for the trends in the data while first-differencing all of the series removes too much information and biases the coefficient estimates. This polarity is highlighted by considering an error correction framework.

Equation (2) can always be written as

$$\Delta Y_t = a + b\ t + \psi\ \Delta Y_{t-1} + \Theta Y_{t-1} + v_t \tag{4}$$

where $\Theta = I - A_1 - A_2$ and $\psi = -A_2$. Clearly, if Θ is unrestricted (*i.e.* rank(Θ) = 4 in the current context), equations (2) and (4) are observationally equivalent. On the other hand, if $\Theta = 0$ (*i.e.* rank(Θ) = 0) a first-difference model is appropriate. If 0 < rank(Θ) < 4, there are restrictions being placed on A_1 and A_2 such that some differencing is required but not necessarily of observed data. Bewley, Fisher and Parry (1988) show that the Box and Tiao (1977) solution to the nonstationarity problem is formally equivalent to this error correction model.

In the Box and Tiao procedure, some linear combinations, found from canonical analysis, should be differenced while others should not. Typically the trend term in equation (4) is unnecessary because of the differencing. Even when the trend is absent, unconstrained estimation of the constant vector, a, implies drift in the model.[9] When there is no drift, but Θ is not of full rank, ΔY_t = 0 in equilibrium and equilibrium *relationships* of the form $\Theta Y = -a$ exist. These linear combinations of Y_{t-1} can be thought of as long-run regression equations.

The basic problem in estimating equation (4) is in determining the restrictions on Θ, and, hence, which linear combinations of Y implicitly need differencing. Following Box and Tiao (1977) and Bewley and Elliott (1988), one useful solution in the current context is to test the differentials for stationarity. As noted above, all three log price ratios are stationary and since all nonstationary behavior cannot be removed by linear transformation,

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[9] A random walk with drift model $\Delta y = a + \upsilon$ model has a deterministic time trend in the forecasts. The vector error correction system requires $a \neq 0$ to accommodate nonzero means in stationary combinations of Y but unrestricted estimation admits drift in the nonstationary components (see Bewley, Fisher and Parry).

one (arbitrary) log price series must be differenced. Interestingly, one price series was on the boundary of being stationary but such results are mutually inconsistent. Thus, the Rockhampton price is also assumed to be nonstationary for the current purposes.

The transformed model can be written as a simple two-lag, four-variable VAR model without time trend. The first variable in the sequence is the change in the log of the Rockhampton price, ignoring its apparent I(0) classification, and the three price differentials in the order previously given. The forecast variances for this model are presented in Figure 11 and the innovation responses in Figures 12 to 15.

It can be noted from a comparison of Figures 6 and 11 that, with the exception of Townsville, forecast variances have been substantially reduced and, in all cases, asymptotic behavior is more rapidly reached.[10]

The shock on the change in price at Rockhampton is shown in Figure 12 to have a negative impact on all price differentials. That is, the other prices absorb some of the impact.

Figure 13 has a particularly interesting interpretation. Given that Rockhampton, which provides the base price in the differentials, is chronologically prior to the other sales, impact changes in the differentials cannot be due to changes in the base. It is, therefore, of some importance that the impact changes in Figure 13 are broadly similar to those of Figure 8. The main difference lies in the approach to zero which is hastened in the

[10] Note that the time axis has been expanded to highlight the earlier responses, given the more rapid approach to equilibrium.

Figure 11 : Forecast Variances

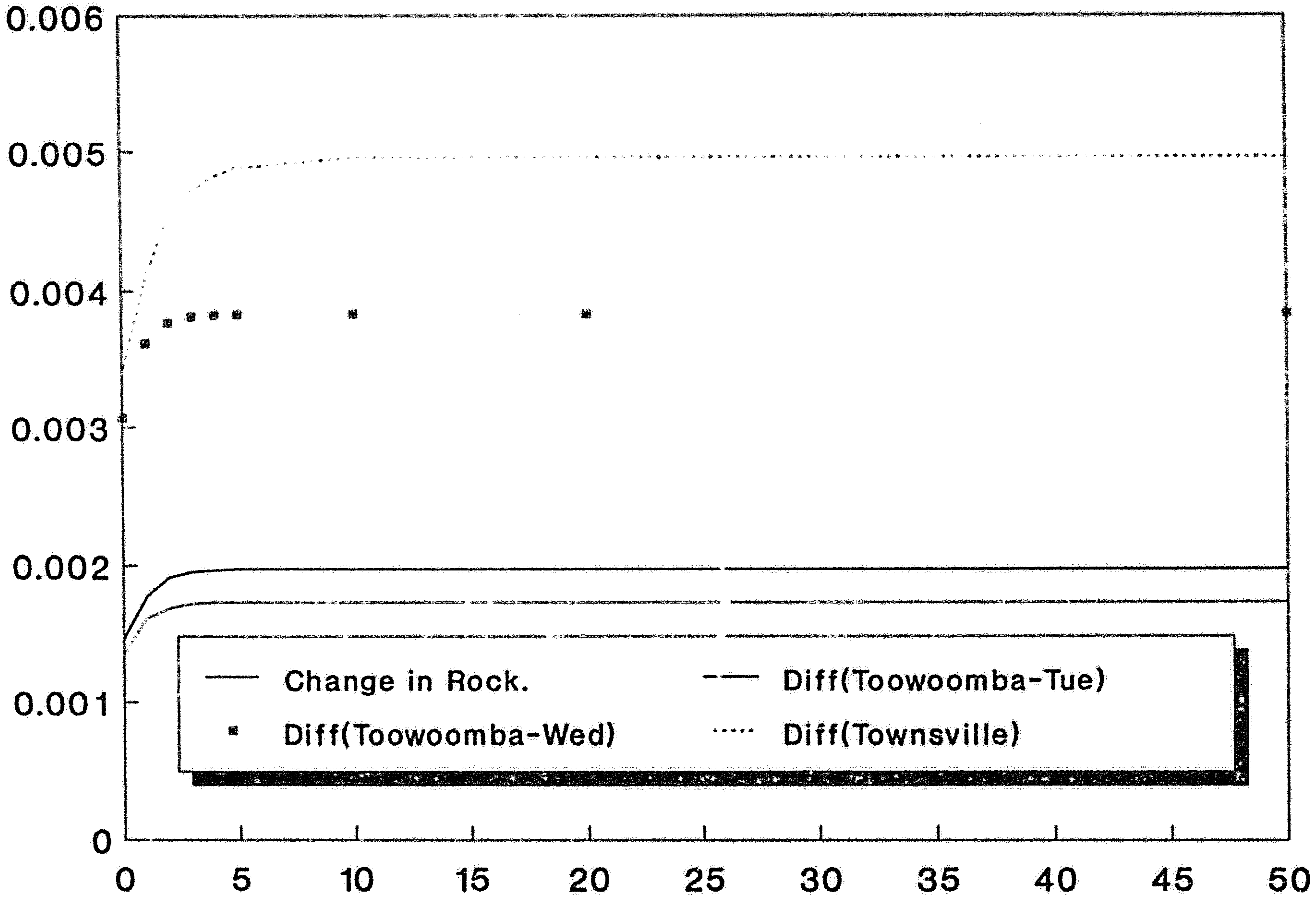


Figure 12 : Innovation Analysis
Effects of Shocks on Change in
Rockhampton Price

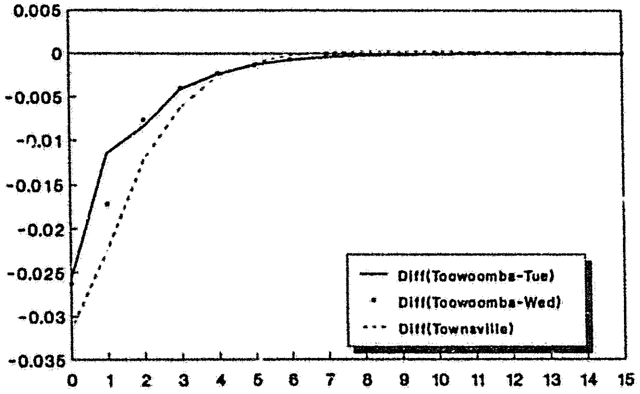


Figure 13 : Innovation Analysis
Effects of Shocks on Change in
Toowoomba (Tue) Price Differential

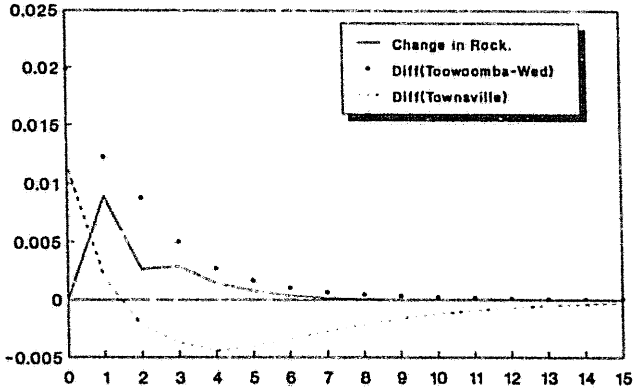


Figure 14 : Innovation Analysis
Effects of Shocks on Change in
Toowoomba (Wed) Price Differential

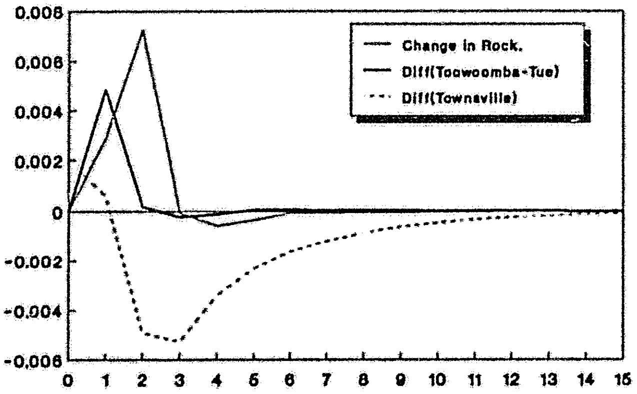
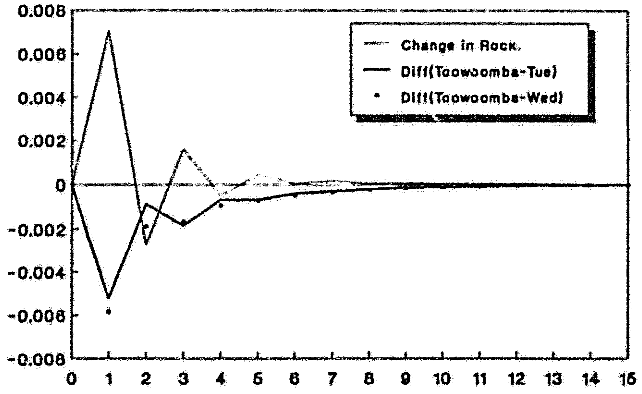


Figure 15 : Innovation Analysis
Effects of Shocks on Change in
Toowoomba (Wed) Price Differential



differentials model. Thus, there is a residual nonstationary component in the levels plus time trend model that is contaminating its higher-order response. Following these conclusions, it is interesting to note the speed with which disequilibria in differentials, and new price information via a change in Rockhampton prices are transmitted throughout the system. By far the greater proportion of a response occurs within 1-2 weeks with the exception of Townsville which takes an extra week, possibly due to the time taken to get Jap-Ox to the saleyards after a price signal is recognized.

While the differentials model imparts alternative and better information than the over-parameterized levels model, certain conclusions are still obscured. In particular, it is not entirely convincing to difference the Rockhampton price nor is it a trivial matter to investigate the difference between the long-run and short-run responses. It was entirely fortuitous that three stationary transformed variables, the differentials, were identified. The following, more general approach formalizes the whole modeling strategy.

The Error Correction Model

In the Box and Tiao (1977) framework, as developed in Bewley, Fisher and Parry (1988), a levels model is estimated and canonical components are defined. That is, four linear transformations or weighted prices are derived from the four original series with the property that the first index is the most predictable; the second is the second most predictable while being uncorrelated to the first, *etc.* The four components determined, z_i, for this study are

$$z_1 = -0.1388\ y_1 + 0.7424\ y_2 - 0.6548\ y_3 + 0.0288\ y_4$$
$$z_2 = -0.8260\ y_1 + 0.4856\ y_2 + 0.1962\ y_3 + 0.2081\ y_4$$
$$z_3 = -0.1377\ y_1 + 0.7371\ y_2 + 0.0929\ y_3 - 0.6551\ y_4$$
$$z_4 = 0.5667\ y_1 + 0.7648\ y_2 + 0.0997\ y_3 + 0.2899\ y_4$$

with canonical correlations of 0.02, 0.25, 0.38, and 0.93, respectively. Given that correlations near unity are associated with those components that require differencing, only canona 4 requires differencing and this is supported by ADF tests of the four canona.

The implicit restrictions on equation (4), ignoring the time trend for reasons discussed above, can be expressed as

$$\Delta Y_t = a + \psi\ \Delta Y_{t-1} + \Xi Z_{t-1} + v_t \qquad (5)$$

where Z_t is the 3×1 vector of stationary canona and Ξ is a 4×3 matrix of parameters. Z and Y are connected by $Z_t = MY_t$, where M is the 3×4 matrix of weights listed above on the stationary canona. Thus $\Theta = \Xi M$.

It is important to note that the sum of the weights in the first three canona are approximately zero (-0.0224, 0.0639, 0.0372, respectively). This indicates that an approximate homogeneity of degree zero in prices exists in these canona while the fourth, nonstationary canona has only positive weights in the style of a Divisia index. The dominance of the Rockhampton and Toowoomba (Tue) prices in the overall price index follows from their relative smoothness, or predictability.

Table 2 : Error Correction Model

Regressors	Dependent Variable			
	Δy_{1t}	Δy_{2t}	Δy_{3t}	Δy_{4t}
$\Delta y_{1,t-1}$	-0.054 (0.67)	0.030 (0.45)	-0.088 (0.81)	-0.208 (1.92)
$\Delta y_{2,t-1}$	0.115 (1.02)	-0.007 (0.08)	-0.099 (0.67)	0.112 (0.75)
$\Delta y_{3,t-1}$	-0.124 (1.85)	-0.063 (1.15)	0.036 (0.41)	-0.022 (0.25)
$\Delta y_{4,t-1}$	0.066 (1.14)	-0.008 (0.17)	-0.013 (0.17)	-0.278 (3.59)
Constant	0.003 (1.07)	0.003 (1.10)	0.003 (0.78)	0.004 (0.94)
$\tilde{z}_{1,t-1}$	-0.132 (0.99)	-0.377 (3.47)	1.156 (6.56)	-0.137 (0.78)
$\tilde{z}_{2,t-1}$	0.432 (4.77)	-0.080 (1.08)	-0.281 (2.35)	-0.254 (2.11)
$\tilde{z}_{3,t-1}$	0.013 (0.17)	-0.110 (1.80)	-0.083 (0.84)	0.379 (3.82)

NB The tilde on the canona indicate that they are in deviations from the mean form. t-ratios are given in parentheses.

Estimates of the error correction model are given in Table 2. It can be noted from Table 2 that each stationary canona is significant at the 5% level in at least one equation and each equation has at least one significant stationary canona. Joint tests of significances suggest that the deletion of any one of these canona from the system as a whole would be rejected at even the 0.1% level of significance. It can also be noted that the fourth canona, which has implicitly been differenced, is clearly nonstationary with an ADF test statistic of 2.22 which is in contrast to the arbitrary differencing of the Rockhampton price in the previous model.

It is also clear from Table 2 that $\Delta y_{4,t-1}$ is highly significant in the Δy_{4t} equation but all other lagged changes are insignificant at the 5% level. A simple LR test as recommended by Sims would only just suggest a rejection of the joint significance of this Ψ matrix with a test statistic of 28.31, compared to a 5% critical value of X^2 with 16 degrees of freedom equal to 26.3. However, in the levels model with trend, the same LR test fails to reject that $A_2 = 0$ with a test statistic of 25.64.

The importance of detecting the lagged effect in the Townsville equation is that this geographically isolated saleyard is the only one of the four that reacts directly to its own past changes. The other three prices are more sensitive to the differentials in the market place; that is the degree to which markets are out of line. Thus the Townsville saleyard has a significant self-determining influence.

Since the constant term is insignificantly different from zero in each equation, both individually and jointly, there is no drift in the model.[11] Accordingly, the model was reestimated without a constant and all lagged changes excluded, except for $\Delta y_{4,t-1}$ in the Δy_{4t} equation.

The equilibrium solution to this final model can be solved by setting $\tilde{Z} = M\tilde{Y} = 0$, where $\tilde{Y}$ is Y also expressed in deviations from mean form. This stable long- run solution is:

[11] Since the canona have been expressed in deviations from the mean, any significant constants would reflect drift.

$$y_2 = 0.9307\ y_1 + 0.3769$$

$$y_3 = 0.9626\ y_1 + 0.1155$$

$$y_4 = 0.8856\ y_1 + 0.5740$$

but, as the differentials are also found to be stationary, it can be concluded that these unrestricted estimates are not significantly different from a model with unit coefficients on y_1.

In the short-run, deviations from the equilibrium price differentials can be expected to close so that there may be opportunities to exploit disequilibria in the system. From the innovation diagrams in Figures 12 - 14, it can be noted that these opportunities are short-lived and the transactions costs associated with attempting to profit from forecasting prices might outweigh the potential gains.

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