Examining long run relationships among Australian beef prices*

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Abstract

The objective of this study is to determine whether long run relationships exist among Australian beef prices at the farm, wholesale and retail levels using cointegration techniques. Monthly data from 1971 to 1994 are used for the analysis. Preliminary results show that while all three prices considered are nonstationary, they are cointegrated. Furthermore, the retail price is weakly exogenous. The latter result is an indication of market inefficiency due in part to price levelling behaviour at the retail level. Implications and areas for further research are also provided.

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Introduction

The price transmission process in the marketing system has received considerable interest from economists because of the implications for market efficiency (Williams and Bewley 1993). Market efficiency implies that in a competitive market with free information flows, arbitrage will ensure that prices in related spatial, temporal or product transformation markets, move in unison. As such, price differentials in related markets are expected to reflect costs of providing marketing services. For example, price differentials in spatially related markets should reflect the cost of transportation while in temporally related markets, the cost of storage (Faminow and Benson 1990). Furthermore, if a market operates efficiently, a price change at one market will be followed by similar price changes in related markets. Therefore, the comovement of related series implied by market efficiency suggests the existence of long run relationships among them. However, market imperfections may lead to delay and distortion in information flows and the breakdown of such price linkages, thereby leading to market inefficiency.

Conventionally, market efficiency issues have been examined using standard econometric methods. However, evolving developments in time series econometrics have cast doubt over the use of standard econometric methods for estimating commodity models because of the nonstationarity often found in time series data (Myers 1994). Moreover, the standard econometric studies have tended to focus on the short run dynamics of price relationships (for example the price levelling work). Possible inconsistencies between short-run and long-run behaviour of prices is also of interest because the nature of the price transmission process has important implications for the distribution of the benefits of R&D or deregulation.

The overall purpose of this paper therefore is to re-examine market efficiency issues within the framework of econometric time series focussing on both the short-run and long-run dynamics prevailing in the Australian domestic beef marketing chain. Beef is the largest component of domestic meat consumption and developments in the beef market are expected to influence prices in related meat markets. The specific objective of this study is to determine whether long run relationships exist among Australian beef prices at the farm, wholesale and retail levels using cointegration techniques. Monthly data from 1971 to 1994 are used for the analysis. Preliminary results show that while all three prices considered are nonstationary, they are cointegrated. Furthermore, the retail price is weakly exogenous. The latter result is an indication of market inefficiency due in part to price levelling behaviour at the retail level.

The paper begins with a brief introduction of the main concepts involved in the econometric time series literature, particularly the relationship between vector autocorrelation, error correction model and cointegration. In the next section, the error correction model is used to determine whether long run relationships exist between beef prices at three different market levels and the estimated results based on the Johansen procedure are reported. Discussion of the results is then provided, followed by areas for further research and concluding remarks.

Cointegration techniques

There are straightforward relationships between vector autoregression (VAR) models, error correction models (ECM) and cointegration (Johansen and Juselius 1990). A standard VAR with lag length p, VAR(p), can be written as:

(1) $x_t = A_0 + A_1 x_{t-1} + ... + A_p x_{t-p} + B D_t + C S_t + e_t, \quad t = 1,...T$

where

p = lag length;

x_t = an (n x 1) vector of endogenous variables;

A's = (n x n) matrices of unknown parameters;

x_{t-j} = an (n x 1) vector of the jth lagged value of x_t;

D_t = a set of centred seasonal dummies;

S_t = a set of dummy variables representing structural changes; and

e_t = an independently and identically distributed (n x 1) vector with zero mean and variance matrix.

An ECM with lag length p, ECM(p), can be derived from the above VAR(p). After term manipulation, it is written as:

(2) $\Delta x_t = \Pi_0 + \Pi_1 \Delta x_{t-1} + ... + \Pi_{p-1} \Delta x_{t-(p-1)} + \Pi x_{t-p} + B D_t + C S_t + v_t$

where

$\Pi_j = -(I - \sum_{i=1}^{j} A_i), j = 1, 2, ..., p - 1;$

$\Pi = -(I - \sum_{i=1}^{p} A_i) = \alpha\beta'$;

Δx_{t-j} = an (n by 1) vector of x_{t-j} in first differences, j = 1, 2, ..., p - 1; and

v_t = white noise but may be contemporaneously correlated.

Other variables are as previously defined. Basically, the ECM(p) is the VAR(p) expressed in first differences (Enders 1995, pp. 389-90).

The Π matrix in equation (2), which is termed the long run impact matrix of the ECM, is of primary importance. First, the rank of Π provides the basis for determining the existence of cointegration or the long run relationship among the variables. According to Johansen (1988), there are three possibilities with regard to the rank of Π :

Case 1. If rank(Π) is zero, then the variables are not cointegrated and the model is equivalent to a VAR in first differences;

Case 2. If $0 < \text{rank}(\Pi) < n$, then the variables are cointegrated; and

Case 3. If rank(Π) = n , then the variables are stationary and the model is equivalent to a VAR in levels.

Secondly, the Π matrix can be decomposed into the product of vectors α and β, ie $\Pi = \alpha\beta'$. While α, the vector of speed of adjustment coefficients, has important implications for the dynamics of the system (Enders 1995), β, the transpose of the cointegrating vector, characterises the long run equilibrium condition of the system (Johansen and Juselius 1990). A large (small) value of α means that the system will respond to a deviation from the long run equilibrium with a rapid (slow) adjustment. On the other hand, if some α are zero, the corresponding variables do not respond to the discrepancy from equilibrium and therefore could be exogenous.

In summary, cointegration of a set of time series implies that a long run stationary relationship exists among the component non-stationary series. That is, these series are linked by common stochastic trends and hence cannot move independently of each other - they are cointegrated. Since the trends of cointegrated variables are linked, the dynamic paths of such variables must bear some relation to the current deviation from the equilibrium relationship.

Data

Monthly beef price data in New South Wales (NSW) during the period January 1971 to September 1994, a total of 285 observations, were used for the analysis in this study. The data set includes prices at three marketing levels: farm, wholesale and retail. The price variables are defined as follows.

FP Monthly auction price (cents/kg) of a composite beef carcase, suitable for the domestic market, adjusted for by-products and shrinkage.

WP Monthly wholesale price (cents/kg) of a composite beef carcase, suitable for the domestic market, adjusted for shrinkage.

RP Monthly retail price (cents/kg) of a composite beef carcase, suitable for the domestic market.

These price series were obtained from the records of the Economic Services Unit of NSW Agriculture. They have been used in various studies of meat price relationships (for example Griffith et al 1991). The procedures for adjusting and weighting these prices can be found in detail in Griffith (1997).

The empirical model and estimated results

In this section, the existence of long run relationships among Australian beef prices is tested based on the Johansen procedure. The Johansen procedure includes the following four steps (Enders 1995, pp. 396-400).

Step 1: Pre-test the order of integration and determine the lag length for the ECM based on a standard VAR.

Step 2: Estimate the ECM and determine the rank of Π.

Step 3: Analyse the cointegrating vector(s) and the speed of adjustment coefficients.

Step 4: Perform causality tests on the ECM to identity the structural model.

The testing procedure for Step 1 involves determining the order of integration of beef prices at each of the farm, wholesale and retail levels. Following the testing procedure suggested in Enders (1995, pp. 257), the augmented Dickey-Fuller (DF) test was used to determine whether the series, both the original and detrended, were difference stationary or trend stationary. Although there was some evidence of seasonality and structural changes in the data, they were not incorporated in the unit root tests because of complications arising from including them as deterministic terms in the DF procedures. Instead, seasonality and structural change were examined within the VAR and ECM framework, as was proposed in Johansen and Juselius (1990).

The unit root test results, presented in Table 1, indicate that both the detrended and the original series of all three beef prices have unit roots and are nonstationary. Further unit root tests on the original series in first differences indicate no unit roots, which confirms that the three price series are indeed difference-stationary. The three price series both in levels and in first differences are shown in Figures 1-3. The unit root tests were performed using SHAZAM (Version 7, 1993).

The finding that the price series under consideration are difference-stationary means that the analysis can now proceed to setting up the ECM and testing for cointegration among the series. The next task is to determine the proper lag length for the ECM model using standard VAR methods.

Following the testing procedures suggested in Enders (1995), pair-wise comparisons between two standard VARs, each with different lag lengths, were done based on likelihood ratio (LR) tests. The variables in the standard VAR (Equation (1)) are now defined more specifically as follows:

$x_t = [FP_t, WP_t, RP_t]'$;

$x_{t-i} = [FP_{t-i}, WP_{t-i}, RP_{t-i}]'$ for i = 1, 2, 3,...,p;

S_t = a dummy variable for structural change; $S_t = 1$ for the period between 1971.1 to 1978.12; and $S_t = 0$, otherwise; and

A's, B and C = parameters to be estimated.

Other variables are as previously defined. S_t is included in the VAR model to reflect a range of changes which occurred during the 1970s. These include the two oil price shocks, changes in Australian beef export demand due to the closure of the North Asian markets in late 1974 and the subsequent emphasis on diversification of export markets, and changes in the production side of the industry in response to the price slump of the mid 1970s and the increasing importance of feedlots.

In this study, three paired comparisons were necessary to determine the lag length, where p varies between 12, 8, 4 and 3. The LR test results, which are presented in Table 2, suggested the lag length be four, ie p = 4. This procedure was done using RATS (Version 4, 1995).

With the lag length of the ECM now determined, the next part of Step 2 is to set up an ECM(4) for these data. Based on the results obtained from Step 1, the ECM for beef prices is specified as:

(3) $$\Delta x_t = \Pi_0 + \Pi_1 \Delta x_{t-1} + \Pi_2 \Delta x_{t-2} + \Pi_3 \Delta x_{t-3} + \Pi x_{t-4} + B D_t + C S_t + v_t$$

where $\Delta x_t = [\Delta FP_t, \Delta WP_t, \Delta RP_t]'$;

$\Delta x_{t-i} = [\Delta FP_{t-i}, \Delta WP_{t-i}, \Delta RP_{t-i}]'$ for i = 1, 2, and 3:

$x_{t-4} = [FP_{t-4}, WP_{t-4}, RP_{t-4}]'$;

Πi's = (3 by 3) matrices of unknown short-run parameters to be estimated;

$\Pi = \alpha \beta'$ are unknown long run parameters to be estimated; and

v_t = white noise but may be contemporaneously correlated.

Other variables are as previously defined. Two versions of the ECM(4), Models A and B, are estimated based on the Johansen procedure using RATS. Model A is the unrestricted model (the trend drift version) where the constant term is incorporated in the equation. Model B is the restricted model where the constant term is incorporated in the cointegrating vectors. The estimated results regarding the rank of Π for both versions are presented in Table 3.

As can be seen in Table 3, the λ_{max} and λ_{trace} test statistics for Model A indicated that the beef prices are cointegrated, but not for Model B. This is because two cointegrating vectors were found in Model A while Model B suggested three cointegrating vectors. To determine whether the ECM should be estimated with a trend drift or a constant term in the cointegrating vector, the LR_λ based on the estimated λ, is computed as suggested in Enders (1995, pp. 393). The LR_λ is defined as

(4) $$LR_\lambda = -T \sum_{i=r+1}^{n} [\ln(1 - \lambda_i^*) - \ln(1 - \lambda_i)],$$

where λ_i^* and λ_i are estimated eigenvalues of the matrix Π for the restricted and unrestricted models, respectively ; r is the number of cointegrating vectors in the unrestricted model; and n is the number of endogenous variables.

Given that n = 3 and r = 2, the computed value for LR_λ is 11.77, which is greater than the critical value of 3.84 with one degree of freedom at the 5 per cent level. Therefore, Model B (the restricted version) was rejected. It was concluded that the ECM should be specified with a trend drift (see bottom of Table 3). Recall that Model A suggests the existence of two cointegrating relations. As such, the estimated results of the ECM reported in Table 4 and further analysis are based on Model A.

As can be seen from Table 4, the majority of estimated individual short run coefficients (coefficients which are associated with lagged first differences) are not statistically significant at the 5 per cent significance level. This may be a result of over-parameterisation where additional terms were included to ensure that the ECM is adequately specified. However, they are statistically significant as a group in the VAR model. There are also significant indications of seasonality and structural change, but the 33 estimated seasonal statistics are not reported for space reasons. The full results are available from the authors.

The estimated long run parameters, which are of main interest, are presented in Table 5. The estimated cointegrating relations or long run equilibrium relationships, normalised by the βs associated with the farm price, can be written as:

(5) $FP_t - 1.12\,WP_t + 0.11\,RP_t = 0$, and

(6) FP_t - [illegible] $WP_t - 0.15\,RP_t = 0$.

That means equations (5) and (6) must hold among the three prices when the market is in equilibrium. When the right hand side is not zero, the market is in disequilibrium. Because equations (5) and (6) do not have *a priori* theoretical underpinning and the main purpose is to test for cointegration, no interpretation is attempted at this stage, nor is any specific hypothesis being tested regarding the signs and size of individual βs.

In any case, since the three series are shown to be cointegrated, the system can be expected to respond to exogenous shocks and return to equilibrium after being perturbed. The speed of adjustment is determined by the magnitude of the adjustment coefficients. From the bottom of Table 5, it can be seen that both α coefficients associated with the retail beef price are statistically insignificant. This result could be an indication that the retail price is weakly exogenous to the system. This possibility is tested based on the Johansen procedure (Step 4). The result, presented in Table 6, suggests that the retail price is indeed weakly exogenous and therefore does not respond to deviations from the long run equilibrium. However, the exclusivity test result presented in Table 6 suggests that the retail prices should not be excluded from the co-integrating relationships. Failing to reject exclusivity implies that the corresponding βs in the last column of Table 5 are not zero.

Discussion of results

The cointegration test suggests that two long run equilibrium relationships exist among Australian beef prices, since the rank(Π) was found to be two, and that the retail price is weakly exogenous.

The finding that the retail beef price does not adjust to deviations from the long run equilibrium, while wholesale and farm prices do adjust, suggests that after a shock, the long run equilibrium in the Australian beef market is restored by adjustment made at the wholesale and the farm levels but not at the retail level. However, the retail price does adjust to short run dynamics in the system. Therefore, the retail price would still have an impact on the beef market despite being found to be weakly exogenous.
The result that the retail price is not responsive to equilibrium errors may be explained by the price levelling behaviour in the Australian meat market which is found in Naughtin and Quilkey (1979) and in Griffith, Green and Duff (1991). Price levelling refers to the practice

of marketers holding their selling prices relatively stable in the face of rising or falling input procurement costs. As a result, the impact of fluctuating input prices on prices charged to consumers is smaller than it would be otherwise (Griffith and Piggott 1994). According to Parish (1967), price levelling destabilises farm level prices while stabilising retail prices. As a result, not only are farm prices more volatile than they otherwise would be, but the changes are not passed on to the higher levels of the market and do not influence consumer purchasing decisions. Therefore, pricing efficiency is lessened.

Similar results were obtained by Larue (1991) and by Larue and Babula (1994). Using Canadian data, they found that the farm output price and the retail food price were weakly exogenous. They explained the findings by demand-pull and cost-push tendencies which dictate the causal relations between input and output prices. Changes in demand structure and increased concentration in the retail market were considered to be possible factors influencing the results. Since the main purpose of the current analysis was to determine whether the long run relationships exist among Australian beef prices, factors which contribute to structural change in the 1970s and to weak exogeneity of the retail price were not fully investigated here. Instead, they are areas for further research.

Conclusion

Long run relationships among Australian beef prices at the farm, wholesale and retail levels are expected to exist because in a competitive market with free information flows, arbitrage will ensure that prices in markets related through derived demand will move in unison. The existence of a long run relationship, in Engle and Granger's use of the term, means that there exists a linear combination of nonstationary variables that are stationary. As such, although individual series may meander, they do not drift far apart from one another. In this study, the long run relationships among Australian beef prices were examined using cointegration techniques.

The results show that while all three prices considered are nonstationary, they are cointegrated. There is also evidence of seasonality, and in addition, structural change in the 1970s. Furthermore, the retail price is weakly exogenous. The latter result may be an indication of market inefficiency due in part to price levelling behaviour at the retail level and structural changes in the Australian beef industry. Consideration of these influences are areas for further research. Also, there is a need to reconsider the common practice of assuming constant marketing margins in equilibrium models of the livestock industries.

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Table 1. Summary of unit root tests[a]

	H_0: presence of unit root H_A: absence of unit root	Test results
Original price series		
farm price	fail to reject H_0	the original series is nonstationary
wholesale price	fail to reject H_0	the original series is nonstationary
retail price	fail to reject H_0	the original series is nonstationary
Detrended price series		
farm price	fail to reject H_0	the detrended series is nonstationary
wholesale price	fail to reject H_0	the detrended series is nonstationary
retail price	fail to reject H_0	the detrended series is nonstationary
Original price series in first differences		
farm price	reject H_0	the original series is difference-stationary
wholesale price	reject H_0	the original series is difference-stationary
retail price	reject H_0	the original series is difference-stationary

[a] Because the testing procedures may involve a number of steps and are cumbersome to report in full, the augmented Dickey-Fuller test statistics are not reported. However, they can be obtained from the authors upon request.

Table 2. Summary of test statistics for determining the lag length in standard VARs

Lag length		Calculated χ^2(df)[a]	Test results
Unrestricted model	Restricted model		
12	8	20.62(36)	fail to reject H_0
8	4	38.72(36)	fail to reject H_0
4	3	17.88(9)	reject H_0

[a] Critical χ^2 values at the 5 per cent significance level are 55.76, 55.76 and 16.92 for 40, 30 and 9 degrees of freedom, respectively.

Table 3. Summary of rank tests on matrix Π

Model A. Incorporating a trend drift in the model, r = 2			
	Estimated λ	λ_{max}	λ_{trace}
λ_1	0.10	28.65 (20.78)[a]	49.91 (29.51)
λ_2	0.07	19.85 (14.04)	21.28 (15.20)
λ_3	0.01	1.43 (3.96)	1.43 (3.96)
Model B. Incorporating a constant in the cointegrating vector, r = 3			
	Estimated λ	λ_{max}	λ_{trace}
λ_1*	0.11	32.89 (21.89)	67.04 (35.07)
λ_2*	0.07	20.90 (15.75)	34.15 (20.17)
λ_3*	0.05	13.25 (9.09)	13.25 (9.09)
LR_λ =11 77 > 3.84(df = 1; α = 5%)			

[a] The figures in parentheses are critical values at the 5 per cent significance level.

Table 4. Estimated ECM for Australian beef market, 1971:1 - 1994:9

	Dependent variables		
Regressor	ΔFPt	ΔWPt	ΔRPt
Constant	9.60[a] (2.98)[b]	16.01 (5.16)	7.08 (2.24)
FPt-1	-0.13 (-2.36)	0.18 (3.31)	0.03 (0.56)
WPt-1	0.01 (0.09)	-0.25 (-4.98)	-0.06 (-1.22)
RPt-1	0.02 (3.21)	0.03 (4.85)	0.01 (1.54)
S_t	-6.63 (-3.32)	-8.08 (-4.21)	-4.28 (-2.19)
ΔFPt-1	0.15 (1.98)	0.26 (3.69)	0.28 (3.82)
ΔWPt-1	-0.04 (-0.64)	-0.08 (-1.21)	0.17 (2.53)
ΔRPt-1	0.13 (2.07)	-0.07 (-1.20)	-0.32 (-5.26)
ΔFPt-2	-0.07 (-0.89)	0.02 (0.32)	0.13 (1.79)
ΔWPt-2	0.05 (0.80)	-0.10 (-1.48)	0.12 (1.89)
ΔRPt-2	-0.01 (-0.18)	0.04 (0.62)	0.01 (0.18)
ΔFPt-3	-0.04 (-0.61)	0.09 (1.37)	0.004 (0.06)
ΔWPt-3	0.15 (2.35)	-0.01 (-0.10)	0.21 (3.40)
ΔRPt-3	-0.01 (-0.08)	0.05 (0.85)	-0.01 (-0.21)

a The numbers in parentheses are t-ratios.

b Estimated coefficients are reported based on two cointegration vectors and normalisation of the farm price.

Table 5. Estimated long run parameters, α's and β's, r = 2

	ÆFPt	ÆWPt	ÆRPt
Estimated β coefficients [a]			
β_1	1	-1.12	0.11
β_2	1	-0.12	-0.15
Estimated α coefficients			
α_1	0.01 (0.24)[b]	0.23 (5.11)	0.06 (1.29)
α_2	-0.14 (-4.51)	-0.05 (-1.58)	-0.03 (-0.87)

[a] T-ratios for β coefficients are not available.

[b] Figures in parentheses are t-ratios.

Table 6. LR test results for stationarity, weak exogeneity and exclusivity, r = 2

	LR test statistics			
	Calculated Chi-squared values			Critical values
	FP	WP	RP	
Stationarity	7.25	9.29	16.00	3.84 (df = 1; α = 5%)
Weak Exogeneity	18.27	25.86	2.27	5.99 (df = 1; α = 5%)
Exclusivity	24.41	25.94	11.11	5.99 (df = 1; α = 5%)

Figure 1. Monthly Australian farm beef prices, in levels and first differences 1971.1 - 1994.12

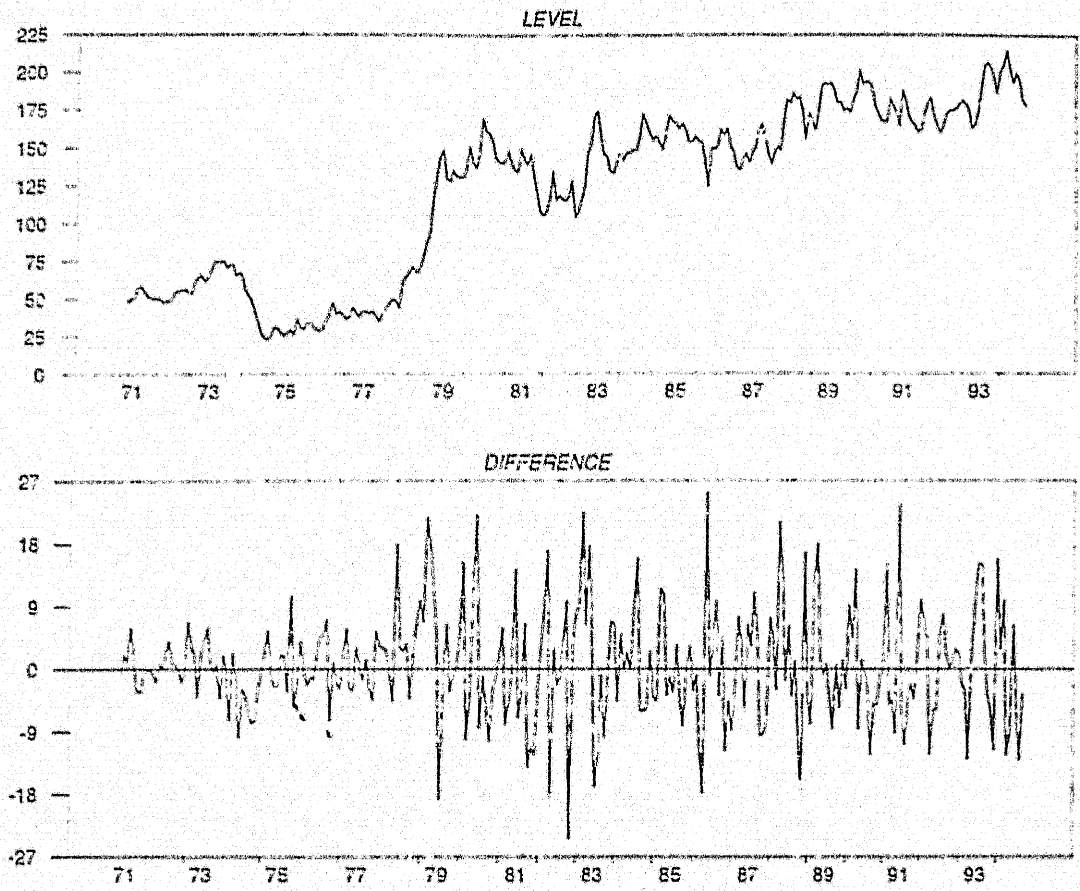

Figure 2. Monthly Australian wholesale beef prices, in levels and first differences 1971.1 - 1994.12

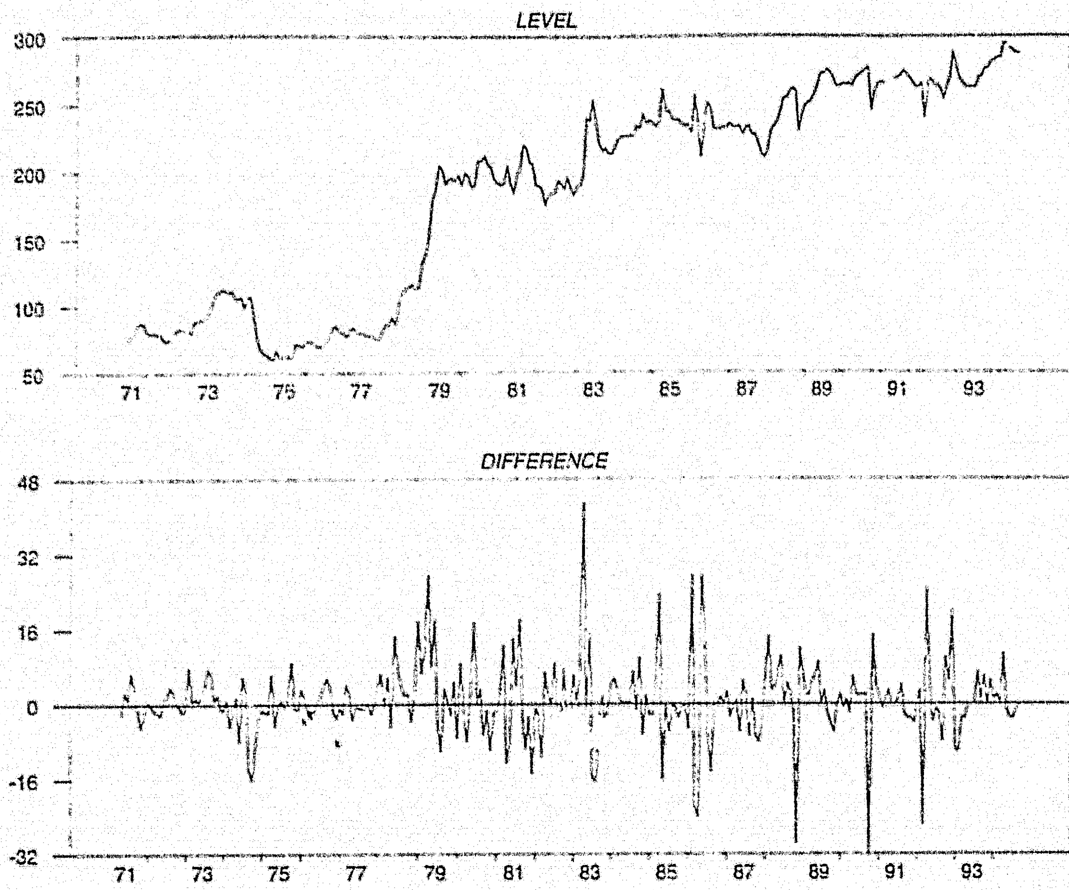

Figure 3. Monthly Australian retail beef prices, in levels and first differences 1971.1 - 1994.12