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Table and Manufacturing Quality Beef Cattle Price Relationships in Australia

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A derived reduced form simultaneous equation model is specified to explore the hypothesis of joint determination of prices for table quality and manufacturing quality beef cattle in Australia. Quarterly data for the period 1966 (1) to 1979 (4) are used. Estimated coefficients for the two types of cattle suggest significant price transmission effects between the two markets. This study may be viewed as an attempt to explicitly recognize the heterogeneous nature of beef cattle in the context of a formal econometric model.

Introduction

Fluctuations in beef prices increasingly have been recognized as a problem in recent years. The relative price stability of the 1960s has been replaced by instability in the 1970s. Concern about the effects on consumers is evidenced in the Parliament of the Commonwealth of Australia (1973) and about effects on beef producers in Industries Assistance Commission (1975). A variety of policy recommendations have subsequently been considered, including price stabilization and production controls implemented through various forms of taxes and subsidies (*e.g.* B.A.E. 1979).

Effective policies in relation to the beef industry and particularly to beef prices, must be based on a clear understanding of factors determining saleyard prices for beef. Econometric studies of the Australian beef industry have already appeared widely in the literature. A selection of more recent contributions include the work of Freebairn (1973), Freebairn and Gruen (1977), Longmire and Main (1978), Marceau (1967), Papadopoulos (1973), Reeves, Longmire and Reynolds (1980) and Throsby (1974). With the exception of the works of Papadopoulos, Longmire and Main and Reeves *et al.*, the above studies focus attention on the structure of supply and/or demand for beef.

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The distinguishing feature of the present paper is an explicit treatment of beef cattle as a heterogeneous commodity and the recognition of the joint determination of prices for different types of beef cattle. Most previous studies have employed some *average* saleyard price for all types of beef cattle in either Australia or an individual State. An exception is a study by Hinchy (1978) which examined movements in the prices of different "classes" of cattle using spectral analysis. Hinchy provided a description of the coherence among the different price series. Evidence was found of close correlations between the prices of older, more export-intensive, types of beef cattle and young, less export-intensive, types of beef cattle in the short term (3 months). However, spectral analysis does not provide empirical information on the economic relationships underlying the variations in prices.

The type of model proposed in this paper may shed new light on the interrelationships between prices for various beef cattle types. In particular, the model may serve partially to explain the effects of changes in prices for cattle for the export market on prices paid for cattle for domestic consumption.

Modelling, Estimation and Data

This section includes an explanation of the structure of the model, assumptions used in its construction, and an overview of the equation system, data and estimation technique used in the analysis.

Beef Cattle as a Heterogeneous Commodity

Beef cattle are produced under a range of pastoral and climatic conditions in Australia, and various market outlets have different quality requirements. Factors determining prices may therefore vary between types of cattle, although they are likely to be close substitutes in the saleyard where prices are jointly determined.

The domestic market and the Japanese market are the major outlets for table quality beef cattle and the U.S. is the major outlet for manufacturing quality beef cattle.

The climatic and pastoral differences between regions in Australia and the physical characteristics of animal carcasses are such that *beef cattle* is not a homogeneous commodity. In the more climatically favoured areas, cattle are primarily produced for table beef markets and are slaughtered between the ages of 6 and 24 months. This type of production occurs in Victoria, New South Wales and Southern Queensland. Older and generally leaner cattle, more suited to the manufacturing trade, are produced in regions with pastures which are both poor in quality and markedly seasonal in growth. This latter production is mainly in the northern regions of Australia. Thus, for example, the B.A.E. (1976) found that the quantity of total beef production exported from Victoria ranged from 37 to 58 per cent over the period 1968 to 1974, while for New South Wales the range was from 22 to 51 per cent, and for Queensland the range was from 66 to 84 per cent. The same B.A.E. study shows that Victoria and New South Wales produced respectively 30 per cent and 37 per cent of Australia's "breed vealers" in 1971, which were used solely for the domestic (table) market, while Queensland produced only 9 per cent.

The northern and southern regions of Australia may be characterized, in part, as producers of different types of beef cattle. Manufacturing type cattle from northern Australia are only likely to enter the domestic or chilled export beef markets indirectly through first being sold in store condition and fattened in southern producing areas[1]. Southern produced cattle, on the other hand, may directly enter the manufacturing beef market in a number of situations. When supplies of table quality cattle rise, due for example to good seasonal conditions, some of these may be diverted to manufacturing beef markets. It may occur during the summer months when northern Australia experiences its wet season and is unable to supply the market. The tendency for cattle to be leaner during the winter months in southern Australia may also render them suitable for manufacturing purposes.

There is also variation within an individual beef carcass. Inferior quality parts of carcasses from southern Australia may be sold for manufacturing purposes while the more valuable cuts go to the domestic or chilled export beef markets. Ideally, this study should be undertaken on the basis of the quantities and prices of beef of various qualities produced in Australia. Unfortunately, disaggregated data on actual quantities produced and the associated prices received and market outlets for the various quantities of beef are not available. Analysis must therefore be constrained to a study of different qualities of beef cattle based on the assumption that the markets for these cattle adequately represent the markets for beef meat of various qualities. Thus the beef cattle market is assumed to consist of two interdependent sub-markets: the market for *table quality* beef cattle; and the market for *manufacturing quality* beef cattle.

A Model of Beef Price Formation

In order to construct a model of beef cattle price formation, a number of simplifying assumptions are made. It is necessary to assume that the cattle market can be adequately represented by a competitive model of price formation. This is widely argued to be acceptable in analysing the market for agricultural products and permits the derivation of theoretical relationships between prices and quantities (*e.g.*, Ritson 1977, Ch. 3).

In general, there is some production possibility curve in the Australian beef industry. Given the broad regional differences which lead to the production of the two types of beef cattle assumed earlier and the likelihood of increasing opportunity costs of production of both cattle types, the production possibility curve is likely to be concave to the origin as depicted in Figure 1. In any one quarter, it is assumed that the quantity of beef slaughtered is predetermined and represented by the production possibility curve. The shape and location of the production possibility is assumed to be largely determined by decisions made by Australian beef producers and seasonal conditions prior to the current quarter[2]. The rate at which one animal can be converted from one sub-market to the other is represented by the slope of the production possibility curve.

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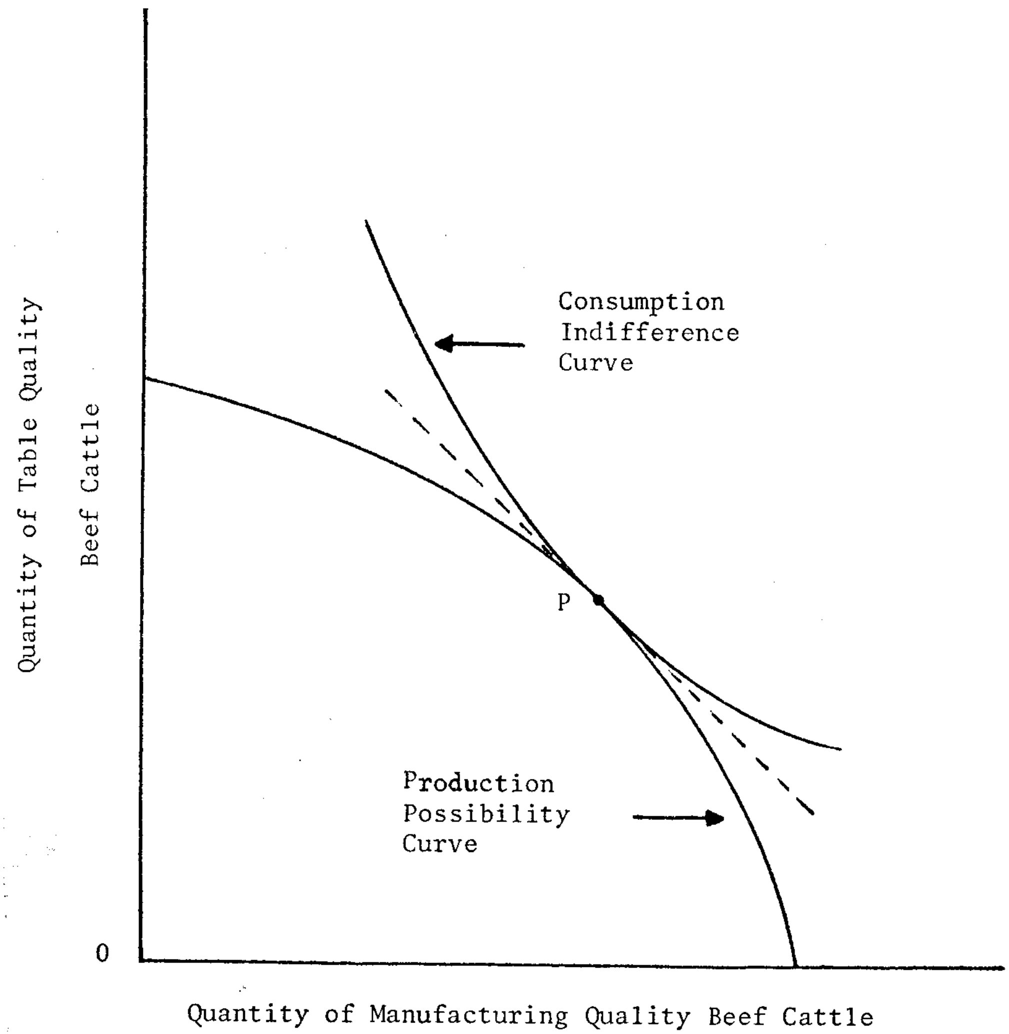
[1] This may include movements of store stock to Victoria, South Australia, New South Wales and some parts of Queensland.

[2] It is assumed that the biological nature of beef cattle production restricts adjustment in the number of animals supplied for slaughter in response to price changes within one quarter (*e.g.*, Longmire and Main 1977; Papadopoulos 1973; Throsby 1974); whilst the effects of changes in seasonal conditions on beef carcass weight is likely to be only regionalized and counteracted by other regions in determining aggregate quarterly beef production in Australia.

Figure 1: Hypothetical Quarterly Production Possibility and Consumption Indifference Curves in the Australian Beef Cattle Market



The combinations of table and manufacturing type beef cattle that are consumed at the saleyard level within a quarter and which yield some amount of utility to buyers in aggregate, may be represented by some indifference curve as illustrated in Figure 1. The slope of the indifference curve represents the substitutability between table and manufacturing qualities in consumption. The assumption of substitutability is reasonable given the apparent existence of *market clearing* prices in Australian saleyards and variations in the shares of beef to either the table or manufacturing sub-markets.

The equilibrium quantities and prices within a quarter in the table and manufacturing sub-markets, and consequently the Australian beef market, are given by the point, say *P* in Figure 1, where the slope of the production possibility curve equals the slope of the indifference curve. The value of these slopes is also equal to the ratio of the price of table quality cattle to the price of manufacturing quality cattle.

For a given beef cattle type, a variety of factors may be hypothesised to affect the quarterly price function. The price of the other beef cattle type is presumed to be an endogenous factor. The hypothesised joint determination of beef cattle prices forms the basis for the specification of a set of simultaneous equations.

The Estimated Model

The above discussion can be summarized as a structural model for the two beef cattle types. From the structural model a restricted reduced form simultaneous equation model for the prices of the two beef cattle types can be derived. The objective is to test the hypothesis that the available data are consistent with a model of simultaneous price determination and to estimate price determining factors.

The structural model may be written as follows:

(1) $ST_t = f(PT_t, QTM_t, D_1, D_2, D_3, Z)$

(2) $SM_t = QTM_t - ST_t$

(3) $DT_t = f(PT_t, PM_t, PL_t, Y_t, Z)$

(4) $DM_t = f(PT_t, PM_t, QUS_t, Z)$

(5) $ST_t = DT_t$

(6) $SM_t = DM_t$

where

ST_t = quantity of table quality beef cattle supplied in quarter t ('000 tonnes),

SM_t = quantity of manufacturing quality beef cattle supplied in quarter t ('000 tonnes),

DT_t = quantity of table quality beef cattle demanded in quarter t ('000 tonnes),

DM_t = quantity of manufacturing quality beef cattle demanded in quarter t ('000 tonnes),

PT_t = table quality beef cattle saleyard price in quarter t (cents/kg),

PM_t = manufacturing quality beef cattle saleyard price in quarter t (cents/kg),

QTM_t = total quantity of table quality and manufacturing quality beef cattle produced, *i.e.* total beef production, in quarter t ('000 tonnes),

PL_t = table quality lamb saleyard price in quarter t (cents/kg),

Y_t = per capita disposable income in Australia in quarter t (dollars),

QUS_t = quantity of Australian exports of manufacturing quality beef to the U.S. in quarter t ('000 tonnes),

D_1, D_2, D_3 are the seasonal dummy variables, and Z is the constant term.

The quantity of table quality cattle supplied is expected to be related to its own-price, the price of manufacturing quality cattle, and total beef production. As there is a seasonality component in the supply of table quality cattle, quarterly dummy variables are included. The supply of manufacturing quality cattle is specified as the difference between total quantity of beef supplied and the quantity of table beef cattle supplied[3].

[3] This essentially makes the manufacturing quality beef market the *residual* market. Alternatively, the table quality beef market could have been regarded as such. The specification of a residual market is deemed necessary since total quantity (QTM) is predetermined within each quarter.

Own-price, the prices of the substitutes (manufacturing quality cattle and table quality lamb), and income are hypothesised to be the major factors affecting table quality cattle demand[4]. Japan's quota allocation for imports of Australian chilled beef is not included as an explanatory variable as the quantity is small in relation to the major outlet for table quality cattle, namely the domestic market.

The U.S. is the largest market for the manufacturing-type cattle produced in Australia. Exports of chilled beef to the U.S. have been prohibited since 1963 and all beef imported is of manufacturing quality. Changes in the level of Australian exports to the U.S. is included as an explanatory variable in the manufacturing quality cattle function, along with own-price and the price of table quality cattle. Changes in quotas on imports, imposed by both the U.S. and Japan, may affect prices for beef of the types being studied. It is difficult to determine whether quotas affect prices or vice versa[5].

Equations (5) and (6) in the structural model are *market clearing* identities, thus prices within quarters are equilibrium or *market clearing* prices. Rewriting the structural model in additive form and using the market clearing identities as shown in the Appendix yields the following:

$$(7)\ PT_t = f(PM_t,\ QTM_t,\ PL_t,\ Y_t,\ D_1,\ D_2,\ D_3,\ Z)$$

$$(8)\ PM_t = f(PT_t,\ QTM_t,\ QUS_t,\ D_1,\ D_2,\ D_3,\ Z)$$

Equations (7) and (8) are restricted reduced form simultaneous price equations with endogenous variables PT_t and PM_t and exogenous variables QTM_t, PL_t, Y_t, QUS_t, D_1, D_2, and D_3. The model is over-identified and its parameters can be statistically estimated.

Estimation and Data

A number of econometric methods have been developed to estimate the parameters of simultaneous equation models. Comprehensive accounts of the methods are provided by, for example, Dhrymes (1970), Johnston (1972) and Koutsoyiannis (1973). Two Stage Least Squares (2.S.L.S.) is used to estimate the parameters of equations (7) and (8) because price determination for various beef types is hypothesised to be simultaneous.

The data series used in the analysis are available from the authors. In several cases where raw data were not readily available, aggregation or disaggregation of existing series were performed. Quarterly data were collected for the period from the first quarter of 1966 to the last quarter of 1979, inclusive. This data period includes observations from the period (1973 to 1975) when large price changes occurred. All prices and incomes were deflated by the Consumer Price Index so they are in real rather than nominal terms[6].

[4] Lamb prices are assumed to be exogenous in beef price determination because lamb constitutes a relatively small share of the meat market and has generally proven to be non-significant in studies of the demand for beef (*e.g.*, Longmire and Main 1977; Reeves, Longmire and Reynolds 1980; Richardson 1976).

[5] There is some evidence that prices and quotas are jointly determined. Japanese quotas are based on past prices (*e.g.*, Longworth 1976) and in the U.S. case quotas were adjusted on the basis of domestic prices in 1973 (*e.g.*, Houck 1974). Freebairn (1972) developed a model in which consideration is given to this problem in the light of U.S. beef policy.

[6] In order to study the structural aspects of the beef industry, it was considered that market participants base their decisions on relative prices and income and not on absolute values, over time.

It is assumed that the quarterly average auction price for yearling cattle at Newmarket saleyards in Victoria adequately represents table quality cattle price (PT)[7]. Manufacturing quality cattle price (PM) is represented by the price paid for manufacturing type cows at Cannon Hill saleyards in Queensland[8]. The lamb price (PL) is the quarterly average auction price for lambs at Newmarket saleyards in Victoria. Australian income (Y) is the quarterly disposable income per capita in Australia.

The quantity variable used in the analysis is quarterly production of beef in Australia (QTM) expressed in thousands of tonnes carcass weight and is hypothesised to represent supplies of table and manufacturing types of cattle.

Other variables are quarterly exports of Australian beef to the U.S. in thousands of tonnes carcass weight (QUS) and quarterly dummy variables ($D_1 = 1$ in the first quarter of each calendar year and zero elsewhere, $D_2 = 1$ in the second quarter and zero elsewhere, $D_3 = 1$ in the third quarter and zero elsewhere). QUS can be regarded as a proxy for Australia's entitlement of U.S. beef imports arranged under a system of voluntary restraint (*e.g.*, Australian Meat Board 1977, p. 37).

The Estimated Model

Evaluation of Estimated Equations

The 2.S.L.S. estimates of the parameters of the model, corrected for first-order autocorrelation, are reported in Table 1. The estimated equations were corrected using the Cochrane-Orcutt iterative technique (*e.g.*, Fair 1970) following preliminary estimation which indicated that positive autocorrelation was likely to be present. Australian income (Y) was omitted as an explanatory variable in the model reported; the coefficient estimate was found to be non-significant and its omission did not significantly alter the magnitude of the other coefficient estimates in equation (7).

In Table 1, the estimated coefficients are reported with their asymptotic standard errors, coefficients of multiple determination (R^2)[9], the Durbin-Watson d statistic (d_1)[10], and a statistic for testing for fourth-order autocorrelation (d_4)[11].

In the estimated model, all the coefficient estimates are of expected sign. The relationships between table cattle prices (PT_t) and manufacturing cattle prices (PM_t) are positive. The negative coefficient on QTM_t in equation (7) suggests that an increase in the quantity of beef produced in Australia is

[7] Victoria is the State most oriented towards the production of younger cattle suitable for the table beef market (*e.g.*, BAE 1976).

[8] Hinchy (1978) found that beef cattle prices in Brisbane were closely related to U.S. prices and led other Australian beef price series. Brisbane cow prices are used in this study because it is less likely that cow beef cuts enter the table beef market (Australian Meat and Livestock Corporation, personal communication). Although Hinchy found that heavy ox prices led cow prices in Brisbane, the time lag (about 2 weeks) between the two series is unlikely to significantly influence the quarterly estimates.

[9] R^2 has been calculated at the second O.L.S. stage. It is recognized that in a simultaneous-equations system, R^2 is not a rigorous test of the "goodness of fit" of the estimated equations (*e.g.*, Tomek 1973).

[10] Durbin (1957).

[11] Wallis (1972).

Table 1: 2.S.L.S. Parameter Estimates of Quarterly Beef Cattle Price Formation: 1966 *to* 1979[a]

Equation No.	Dependent Variable	Explanatory Variables									R^2	d_1	d_4
		Constant	PT_t	PM_t	QTM_t	PL_t	QUS_t	D_1	D_2	D_3			
(7) ..	PT_t	24.03	..	0.76	−0.05	0.34	..	−3.45	2.32	5.14	0.97	1.96	1.28
	..	..	..	(0.10)	(0.01)	(0.08)	..	(1.15)	(1.48)	(1.28)	..	..	..
(8) ..	PM_t	27.11	0.27	..	−0.03	..	0.08	0.62	−1.50	−2.87	0.95	1.56	1.95
	..	..	(0.15)	..	(0.02)	..	(0.03)	(0.97)	(1.61)	(1.65)	..	..	..

[a] Figures in parentheses are asymptotic standard errors.

associated with a significant reduction in table cattle prices. The results indicate that the quantity of beef produced (QTM_t) and manufacturing cattle prices are also negatively related. Changes in lamb prices (PL_t) have a positive effect on table cattle prices. Australian beef exports to the U.S. (QUS_t) has a significant positive effect on manufacturing cattle prices.

Price Flexibilities

Price flexibilities[12] estimated at the sample means of the variables are reported in Table 2. The price flexibilities for table and manufacturing cattle with respect to the quantity of beef produced in Australia are −0.34 and −0.25 respectively. These results indicate that *ceteris paribus* a 10 per cent rise in QTM_t is associated with a 3.4 per cent fall in table cattle price and a 2.5 per cent fall in manufacturing cattle price. The magnitudes of these results compare favourably with price flexibility estimates reported in other studies. Papadopoulos (1973) estimated direct price flexibilities of −0.44 (Vic.), −0.41 (N.S.W.), −0.26 (S.A.) and −0.05 (Qld.); Longmire and Main (1978) calculated a price flexibility of beef supply in Australia of −0.26; while Freebairn (1973) and Marceau (1967) reported flexibilities for N.S.W. of −0.27 and −0.34 respectively. Although Papadopoulos found a relatively high price flexibility in export-oriented Queensland compared to other states, the smaller range in our results appears to be due to the form of the estimated model. The quantity variable (QTM_t) is an aggregation of table and manufacturing qualities, and it may be difficult to estimate the true *direct* price flexibilities[13] in a stochastic linear model, as it may be necessary to account for the simultaneous determination of market shares of each beef type.

Table 2: Estimated Price Flexibilities for Table and Manufacturing Qualities of Beef Cattle: 1966 to 1979[a]

Farm price	Price Flexibility				
	PT_t	PM_t	QTM_t	PL_t	QUS_t
PT_t	..	0.58	−0.34	0.26	..
PM_t	0.35	..	−0.25	..	0.20

[a] Flexibilities calculated at the sample means of the relevant variables.

The percentage change in the price of one beef type in response to a one per cent change in the price of the other, shall be referred to as the *flexibility of price transmission*. Estimates of the flexibility of price transmission are of particular interest because they reflect the interdependence between prices in the two sub-markets studied. These results appear in the first two columns of Table 2.

[12] The price flexibility measures the percentage change in price associated with a one per cent change in an explanatory variable.

[13] The direct price flexibility measures the relationship between price and own quantity.

The flexibility of price transmission of table cattle price with respect to manufacturing cattle price is 0.58. This result suggests that changes in table quality cattle prices are inflexible to changes in manufacturing quality beef cattle prices. The opposite transmission flexibility, that of manufacturing price with respect to table price, is 0.35, suggesting that changes in manufacturing cattle prices are inflexible to changes in table cattle prices at auction. The results indicate that the effect of manufacturing cattle prices on table cattle prices is greater than the effect of table cattle prices on manufacturing cattle prices.

Other *flexibilities* reported in Table 2 relate to lamb prices and Australian exports of beef to the U.S. The flexibility of price transmission of table cattle with respect to lamb price is 0.26 and compares with 0.10 and 0.08 reported by Freebairn (1973) and Marceau (1967) respectively for lamb and sheepmeat prices. The relationship between manufacturing price and beef exports to the U.S. is positive, as expected, and inflexible.

Flexibilities of price transmission calculated at the annual means of table and manufacturing prices are reported in Table 3. The estimates suggest that the effect of manufacturing cattle prices on table cattle prices is greater in a price increasing phase than in a price declining phase. This situation is depicted in Figure 2. At manufacturing cattle price *OA* in Figure 2, buyers are prepared to pay a higher price *OC* in the price increasing phase than price *OB* in the price declining phase.

Table 3: Estimated Flexibilities of Price Transmission for Table and Manufacturing Qualities of Beef Cattle: 1966 *to* 1979[a]

Year	Flexibility of Price Transmission	
	PT_t w.r.t. PM_t[b]	PM_t w.r.t. PT_t
1966	0.58	0.35
1967	0.54	0.37
1968	0.55	0.37
1969	0.58	0.35
1970	0.62	0.33
1971	0.64	0.32
1972	0.68	0.30
1973	0.70	0.29
1974	0.47	0.43
1975	0.37	0.55
1976	0.48	0.42
1977	0.55	0.37
1978	0.55	0.37
1979	0.60	0.34

[a] Flexibilities of price transmission calculated at the annual means of the relevant prices.
[b] w.r.t.—with respect to.

The flexibilities of price transmission of manufacturing cattle with respect to table cattle prices suggest more flexibility in a price declining phase than in a price increasing phase. As represented in Figure 3, the table cattle price *OD* is associated with manufacturing prices *OE* and *OF* in the declining price phase and increasing price phase, respectively.

Figure 2: Table Quality Beef Cattle Price as a Function of Manufacturing Quality Beef Cattle Price

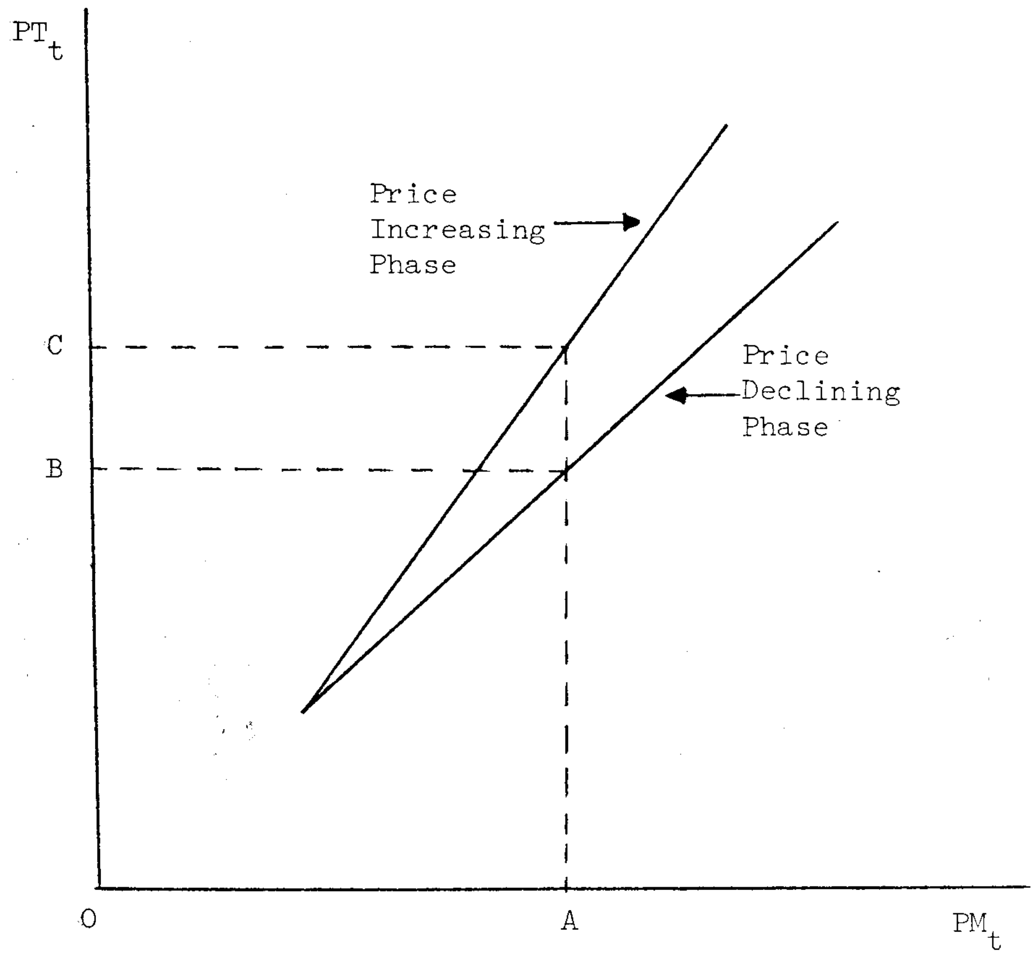
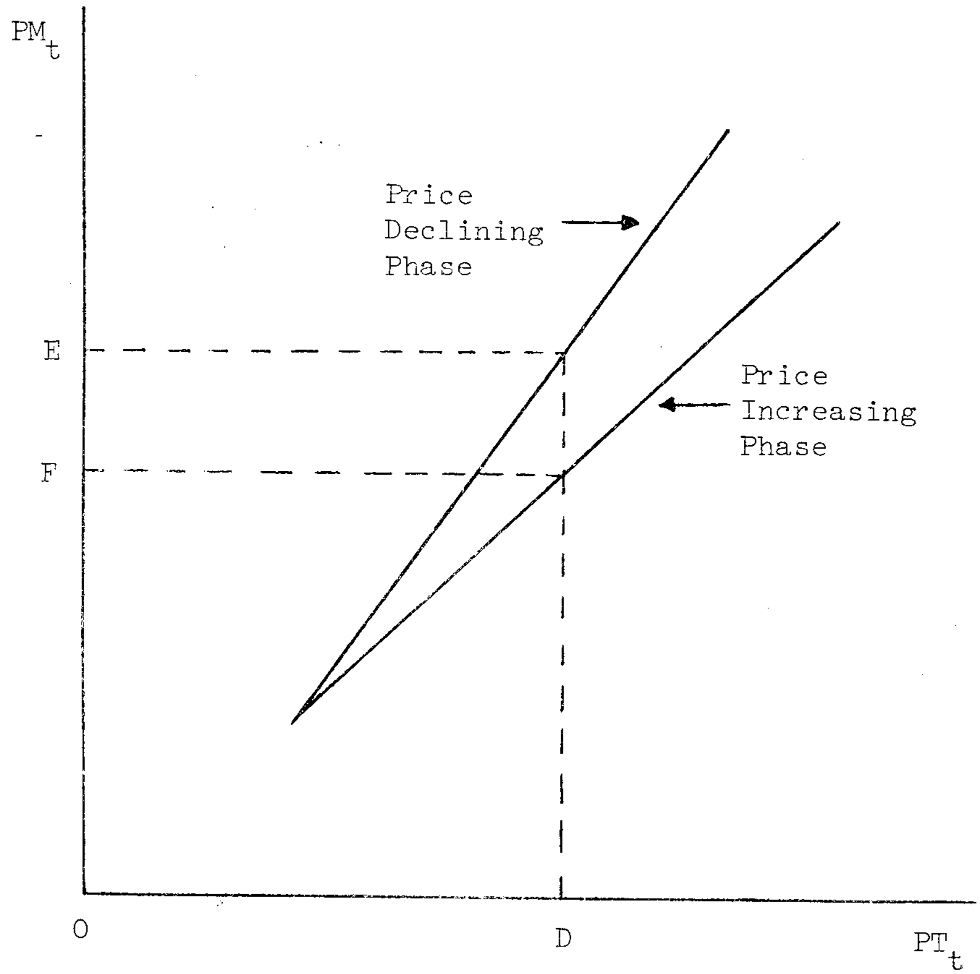


Figure 3: Manufacturing Quality Beef Cattle Price as a Function of Table Quality Beef Cattle Price



Conclusions

The purpose of this study has been to empirically estimate relationships between the two major quality-types of beef cattle in Australia. The two equations model is unlikely to provide estimated coefficients whose magnitudes are directly interpretable for policy purposes. Instead, the results have more fundamental implications as discussed in the next section.

This analysis provides insights into factors determining beef prices which are not derivable from previous literature. Disaggregation of beef cattle types identifies different factors determining prices for each beef cattle type. Based on the data used in this study, the joint dependence of prices for these cattle types has been identified using a simultaneous equation model. Estimates of the magnitude of coefficients relating prices in the two sub-markets studied, have been reported in the form of flexibilities.

On the basis of this and other Australian studies, export beef demand and the supply of beef cattle in Australia are significant factors in the determination of beef cattle prices at auction. Estimated coefficients for the table and manufacturing price equations suggest significant price transmission effects between the two sub-markets at the saleyard level. The table beef cattle market which commands the largest share of total output of Australian beef has a significant positive impact in the manufacturing beef cattle sub-market. Similarly, because of the larger proportion of Australian beef cattle exports in the form of manufacturing quality beef, the price of manufacturing type cattle has a significant positive effect on the prices of table quality beef cattle. However, the price transmission from the manufacturing to the table beef cattle sub-market is greater than that from the table to the manufacturing sub-market.

Implications

Implications that can be drawn from the results relate to the market share of each type of beef cattle. The larger proportion of the total output of Australian beef is shared between the export manufacturing beef sub-market and the domestic table beef sub-market. There are significant but unequal price transmission effects between the table and manufacturing beef cattle sub-markets. This suggests that the value of the information in, for example, aggregative econometric models may be improved through the specification of a system of price determination relationships rather than some *average* aggregate price relationship for beef at the saleyard level in Australia (*e.g.*, Richardson 1976).

Mention is made in the paper of the degree of substitutability of the different beef types. It is likely that this will have an effect on relative market shares of each beef type and consequently the corresponding prices. At the same time, the prices of each beef type are likely to affect market shares. Further analysis would be required to identify and quantify these effects.

The positive price transmission effects between the two sub-markets have potentially important policy implications. Intervention policies designed to stabilize or raise prices to Australian beef producers would, for example, depend for their success on the isolation of such prices from influences from the export market, and in particular the U.S. market. For example, if Australia introduced a price stabilization scheme for beef, reduced imports of Australian beef by the U.S. would make the scheme expensive in terms of government support. While a two-price scheme may avoid such costs, it may result in increased supplies in the long run, unless export producers received returns which reflected the prices in the export market.

There are a number of areas in which the model could be refined in an attempt to provide more information. The quality of the data available for this study was not ideal. There is a need for analysis of more disaggregated data on the quantities of beef of various qualities produced in Australia. Although there is regional variation in quality, there is also variation within an individual carcass. Therefore, more disaggregated data on actual quantities produced, as well as the prices received and the market outlets for the various qualities, would greatly assist in further analysis.

Little has been said in this paper on the effects of restrictions in international market access through quotas. Some argue that changes in such quotas are largely a reflection of changes in domestic prices in the importing countries. While the possibility of joint or recursive determination of U.S. and Japanese quotas with their respective domestic prices has not been directly studied here, such a relationship would appear to have important implications for table and manufacturing prices in Australia.

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APPENDIX

Simultaneous Price Equations

Expressing the structural model in additive form:

(1) $ST_t = Z_1 + a_1PT_t + a_2PM_t + a_3QTM_t + a_4D_1 + a_5D_2 + a_6D_3 + u_{1t}$

(2) $SM_t = QTM_t - ST_t$

(3) $DT_t = Z_3 + c_1PT_t + c_2PM_t + c_3PL_t + c_4Y_t + u_{3t}$

(4) $DM_t = Z_4 + d_1PT_t + d_2PM_t + d_3QUS_t + u_{4t}$

(5) $ST_t = DT_t$

(6) $SM_t = DM_t$

Equating equations (1) and (3):

(7) $PT_t = Z_7 + \alpha_1PM_t + \alpha_2QTM_t + \alpha_3PL_t + \alpha_4Y_t + \alpha_5D_1 + \alpha_6D_2 + \alpha_7D_3 + \mu_{7t}$

where

$Z_7 = (Z_1 - Z_3) / (c_1 - a_1)$
$\alpha_1 = (a_2 - c_2) / (c_1 - a_1)$
$\alpha_2 = a_3 / (c_1 - a_1)$
$\alpha_3 = -c_3 / (c_1 - a_1)$
$\alpha_4 = -c_4 / (c_1 - a_1)$
$\alpha_5 = a_4 / (c_1 - a_1)$
$\alpha_6 = a_5 / (c_1 - a_1)$
$\alpha_7 = a_6 / (c_1 - a_1)$
$\mu_{7t} = (u_{1t} - u_{3t}) / (c_1 - a_1)$

Rewriting equation (2):

$SM_t = -[Z_1 + a_1 PT_t + a_2 PM_t + (a_3 - 1) QTM_t + a_4D_1 + a_5D_2 + a_6D_3 + u_{1t}]$

and equating with equation (4):

(8) $PM_t = Z_8 + \beta_1 PT_t + \beta_2 QTM_t + \beta_3 QUS_t + \beta_4 D_1 + \beta_5D_2 + \beta_6D_3 + \nu_{8t}$

where

$Z_8 = -(Z_1 + Z_4) / (a_2 + d_2)$
$\beta_1 = -(a_1 + d_1) / (a_2 + d_2)$
$\beta_2 = (1 - a_3) / (a_2 + d_2)$
$\beta_3 = -d_3 / (a_2 + d_2)$
$\beta_4 = -a_4 / (a_2 + d_2)$
$\beta_5 = -a_5 / (a_2 + d_2)$
$\beta_6 = -a_6 / (a_2 + d_2)$
$\nu_{8t} = -(u_{1t} + u_{4t}) / (a_2 + d_2)$