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A CROSS-SPECTRAL APPROACH TO MEASURING PRICING EFFICIENCY IN THE NEW SOUTH WALES PIGMEAT MARKET*

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This paper is concerned with determining the nature of and the relationships between movements in a number of New South Wales pig and pork price series. Spectral and cross-spectral methods are applied to some ten series differentiated by type of pig and market level. Results indicate that over the long term there are in general strong correlations between the various price pairings examined, but that in the shorter-run, price changes are not well reflected throughout the pig market. The role of imperfect information is noted as a major contributor to this observed short-run price independence.

1 INTRODUCTION

1.1 BACKGROUND

At the present time there are a number of reforms being considered which relate to the marketing of pigs and pigmeats in Australia.[1] These reforms are based on the contention that this market is inefficient in forming and transmitting prices, and in allocating products amongst consumers. If adopted they would incur substantial set-up costs and may alter the present system of pigmeat marketing quite significantly. Before embarking on these reformations it would seem advisable to determine whether they are soundly based in the sense that they would overcome or alleviate the perceived deficiencies in the present system. A thorough knowledge of the workings of the marketing system currently in use is therefore required.

Over the last decade there have been a number of studies examining various aspects of pigmeat marketing in Australia [9, 10, 19, 20, 22, 23, 24, 28, 42], so information has accumulated in a haphazard fashion about this market. Little attention has been focused though on the area of

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[1] The most relevant of these reforms in the present context is the proposed National Pig Carcase Measurement and Information Service [54].

pricing efficiency,[2] which Rogers [44, p. 6] refers to as ". . . the central and major problem of agricultural marketing". In the longrun, prices help optimize resource allocation and consumer satisfaction, while in the shorter-term they facilitate trading and the orderly and timely movement of goods from producers to consumers. The neglect of pricing in studies of agricultural markets leads to inaccurate and misleading results and recommendations, so to gain a thorough knowledge of the current system of pigmeat marketing in Australia we at least require a comprehensive study of its pricing efficiency.

Pricing efficiency is a well-defined concept: for example it is ". . . the establishment of market prices representative of general supply and demand conditions within the overall market which are responsive to changes in those conditions" [37, p. 15]. The difficulty, though, is ". . . in finding or developing either objective or subjective measures of pricing efficiency" [53, p. 75], and in most cases the only operational method of evaluating it is to compare actual pricing practices to some suitable benchmark.

Most texts on agricultural prices [7, 45, 49, 52] adopt the benchmark of perfect competition, which has in general four major aspects: (1) that spatial price relationships are determined by transfer costs between regions, (2) that grade price relationships are determined by substitution costs between grades, (3) that temporal price relationships are determined by storage costs between time periods, and (4) that relationships between different forms of the product are based on processing costs between forms.

As Trierweiler and Hassler [50] point out though, a rigorous analysis would involve a micro-economic appraisal of least-cost equilibrium transfers from each level of the system to the next. But even if this were done, the basic assumption of perfect, costless information about the past, present and future in general still does not hold. This has led Rogers [44, p. 6], for example, to suggest that under conditions which are imperfect, efficiency may be acceptable if the pricing system provides values within some reasonable range. A less rigorous form of analysis may therefore also be acceptable.

1.2 Aims of the Study

In general terms, the aim of this paper is to provide some information on the pricing aspects of pig marketing in New South Wales which, when used in combination with other studies of pig marketing, will be useful in determining the overall performance achieved by the system currently in use in this country.[3]

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[2] Some exploratory work has been done by the Bureau of Agricultural Economics on spatial price differences using correlation analysis, but this was based on only the three years ended 1969–70 [10, p. 12].

[3] This paper is derived from a more comprehensive Australia-wide study [21], which examined hypotheses concerned with price relationships between different locations and different methods of sale as well as those reported here.

Based on the principles outlined above and previous work done in this field, the specific objectives of this paper are to test the following two hypotheses:

(1) The prices of various types of pigs or pigmeats in one location are not related to the prices of other types of pigs or pigmeats in the same location; and

(2) The prices of various forms of the product in one location are not related to the prices of other forms of the product in the same location.

An additional objective related to hypothesis (2) is to test for the existence and duration of price levelling in wholesale and retail prices, and to compare these results with those obtained from an econometric model [20, pp. 229–231].[4] Woodward [55, p. 168] has suggested ". . . that spectral techniques are appropriate for testing price levelling, as they yield useful information on the periods over which prices are levelled and on the levelling process itself". He has compared results relating to price levelling for beef, lamb and mutton from spectral and regression analyses.

The paper is partitioned as follows: Section 2 describes the data used, outlines the choice of a technique and notes some of the methodological considerations in applying spectral analysis. Results are reported in section 3 and section 4 summarizes the results in terms of the hypotheses set up above and concludes the paper with some implications for marketing policy decisions.

2 METHODOLOGY

2.1 Data Availability

The price data available to the Australian meat and livestock industries have often been described as seriously deficient [2, 12, 40]. In this study these deficiencies are not so important, as we are interested not in the actual price levels but in the relationships between the prices of different types of pigmeat.

Reliable information on the weekly prices of various types of porkers and baconers sold at auction, and of wholesale pork and bacon and retail pork prices is available for New South Wales from the Division of Marketing and Economics of the New South Wales Department of Agriculture.[5]

This study therefore uses some ten pig and pigmeat price series. They are defined as follows:

PAPH (L, H) = average weekly Homebush auction prices in c/kg for good to prime quality light (23–27 kg) and heavy

[4] Price levelling refers to the practice of wholesalers (retailers) holding their selling price stable in the face of rising or falling auction (wholesale) prices.

[5] The emphasis on the auction-wholesale-retail channel of distribution ignores that considerable proportion of pigs sold in Australia by consignment or other non-auction means. The lack of data on prices paid for pigs sold by non-auction methods is then a limitation of the study.

(36–41 kg) porkers: 676 observations from 1962 (1)–1974 (52).

BAPH (L, H) = average weekly Homebush auction prices in c/kg for good to prime quality light (50–55 kg) and heavy (59–73 kg) baconers: 676 observations from 1962 (1)–1974 (52).

PWPH (L, H) = average weekly wholesale prices in c/kg of good to prime quality light (23–27 kg) and heavy (36–45 kg) pork carcases delivered to Sydney meat retailers from the Metropolitan Meat Industry Board Meathall at Homebush: 676 observations from 1962 (1)–1974 (52).

BWPH = average weekly Homebush wholesale prices in c/kg of a side of bacon: 676 observations from 1962 (1)–1974 (52).

PRPS (L, C, H) = average weekly retail prices in c/kg of pork legs, chops and hands respectively as sold to consumers from a sample of Sydney retail outlets: 416 observations from 1967 (1)–1974 (52).

As seen in this data listing, some of the series which are to be compared are incompatible in terms of the number of observations. During the analysis, longer series have been shortened to attain compatibility in the number of observations.

2.2 Choice of Technique

There have been quite a number of studies concerned with measuring various aspects of pricing efficiency in agricultural markets. Some have emphasized spatial prices [8, 31, 46, 47], others grade relationships [14, 36, 48], form differences [20, 25, 55] or merchandizing methods [11]. Those which have attempted to examine the problem comprehensively [4, 5, 6, 16, 38, 50] have mostly used regression analysis and therefore have neglected the temporal aspect, or if not, have treated it superficially by, for example, comparing results from an annual model with results from a monthly model [38]. Papers which have concentrated on temporal relationships have employed more sophisticated time series methods [1, 30, 34, 39], but generally have ignored the other dimensions of pricing efficiency, such as spatial or form relationships.

Spectral and cross-spectral analysis are techniques capable of combining all aspects of pricing efficiency into the same analysis. Spectral analysis decomposes a stationary time series into a set of frequency bands and measures the relative contribution of each of these frequency bands to the overall variance or power of the series. By examining the estimated spectrum we can precisely determine the periodicity and dominance of fluctuations at different frequencies, i.e., if the spectra has a clear peak at a particular frequency the suggestion is that this frequency (or the frequencies in this neighbourhood) is of particular importance in explaining the variance of the series. This implies a cycle occurs at that frequency [33, p. 20].

Confidence bands can be estimated to see if an apparent peak in the spectrum could have arisen due to mere random fluctuation in the estimated spectrum [18, p. 63; 29, p. 234].[6]

Cross-spectral analysis in addition to identifying periodicities can measure the association between pairs of time series in terms of linear, timing and amplitude relationships. It does this by calculating three statistics: *coherence*, which indicates the proportion of the variance of the output series at a given frequency explained by the variance of the same frequency component of the input series;[7] *gain*, which indicates the scalar by which the amplitude of the input series must be multiplied to produce values in the output series at given frequencies;[8] and *phase*, which measures the time difference between the output series and the input series in terms of radians.[9] Pairs of series can therefore be analysed in the time dimension and any other dimension simultaneously. Significance tests are also available for the cross-spectral statistics, but they require the same stringent stationarity assumptions.

The relationship between cross-spectral analysis and pricing efficiency is now clear. If the coherence between two price series is high, this implies that information about the factors that cause variation in one of the prices is accurately transmitted to the other price formation sphere. If the gain coefficient is high, the response of the two prices to the factors causing variation is similar, indicating the commodities are closely related in either a competitive, complementary or supplementary way. If the phase angle is not close to zero or 2π the two series are out of phase and the information about factors causing variation is not being quickly transferred from one market to the other.

Spectral and cross-spectral methods are used as the technique of analysis in this paper. The theory has been well documented in the literature [15, 17, 18, 26, 27, 29, 32, 41] as have a number of applications to agricultural markets [1, 3, 30, 34, 35, 39, 43, 48, 51, 55]. It will not be discussed further here, except to mention in the next section those considerations which determine the use of the technique in particular situations.

2.3 Methodological Considerations

There are a number of methodological questions in the application of spectral and cross-spectral analysis which have to be resolved in each particular case. Spectral texts cover these points in detail, so they are presented below without elaboration.

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[6] Confidence limits for estimated spectra depend heavily on the assumption of stationarity of the mean and variance of the series, so care must be taken in their use. See for example [26, p. 432].

[7] Coherence is similar in concept and interpretation to R^2 in regression analysis, and therefore lies between 0 and 1.

[8] The regression coefficient of $Y = a + b\,X$ can be interpreted as an average gain coefficient over all frequencies.

[9] Phase angle can be converted into a time "lag" by the formula

$$\text{Time lag} = \frac{\text{phase angle}}{2\pi} \, . \, C \quad \text{where } C = \text{cycle length.}$$

(1) For all series the number of observations (n) exceeds 200, so Granger and Hatanaka's [18, p. 61] desirable minimum n is reached.

(2) The theory of spectral analysis is based on stationarity in the series, i.e., the mean and variance are constant over time. If the series is non-stationary, for example containing a trend, it must be removed. Following an examination of the autocorrelation functions of these pig price series, a quasi-first difference filter $F(Y_t) = Y_t - 0{\cdot}99 Y_{t-1}$ was used to achieve approximate stationarity. It is considered to work satisfactorily in the present situation.[10]

(3) The choice of the number of lags (m) to use depends on a considertion of the general rule that $m < \frac{n}{3}$ [26, p. 432; 34, p. 13], and of the fact that m should be chosen to provide integer estimates of the relevant frequencies in which we are interested.[11] For these weekly models a maximum lag of 52 was selected so that the annual component and its harmonics would be estimated.

(4) The programmes used to estimate the spectra and cross-spectra are contained in the Australian National University Econometric Package. They use the Parzen lag window.

3. RESULTS

This section reports the results of the spectral and cross-spectral estimations. Comparison of the results with the hypotheses proposed in section 1.2 is left to the summary in section 4.

3.1 Auction, Wholesale and Retail Prices Separately

This first set of results examines separately the four weekly auction prices (PAPHL, PAPHH, BAPHL, BAPHH), three weekly wholesale prices (PWPHL, PWPHH, BWPH) and three weekly retail prices (PRPSL, PRPSC, PRPSH).

(a) *Spectral Estimates*

Figures 1, 2 and 3 report the estimated recoloured power spectrum in terms of logarithms of the three sets of prices. For auction and wholesale prices $n = 676$, $m = 52$ and $n/m = 13$. For retail prices, $n = 416$, $m = 52$ and $n/m = 8$.

The first noticeable aspect of the auction price spectra is the difference in shape of PAPHL, i.e., the light porker price series. It is much flatter than the other series, having lower power in the low frequency bands and higher power in the higher frequency bands. The other three series all have very similar shapes.

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[10] The first-difference filter has been used in other studies with acceptable results [3, 34]. Even if it is imperfect, most cross-spectral statistics have been shown to be remarkably robust to mild violation of the stationarity assumption [18, p. 168].

[11] The more lags used (the less the frequency band width) the easier it is to localize the period of the cycle and the more likely is the estimated spectrum to contain a peak when the true one does. However the sampling variance rises as bandwidth decreases, so there is a trade-off between clarity and statistical stability.

FIGURE 1: SPECTRA OF HOMEBUSH WEEKLY AUCTION PRICES

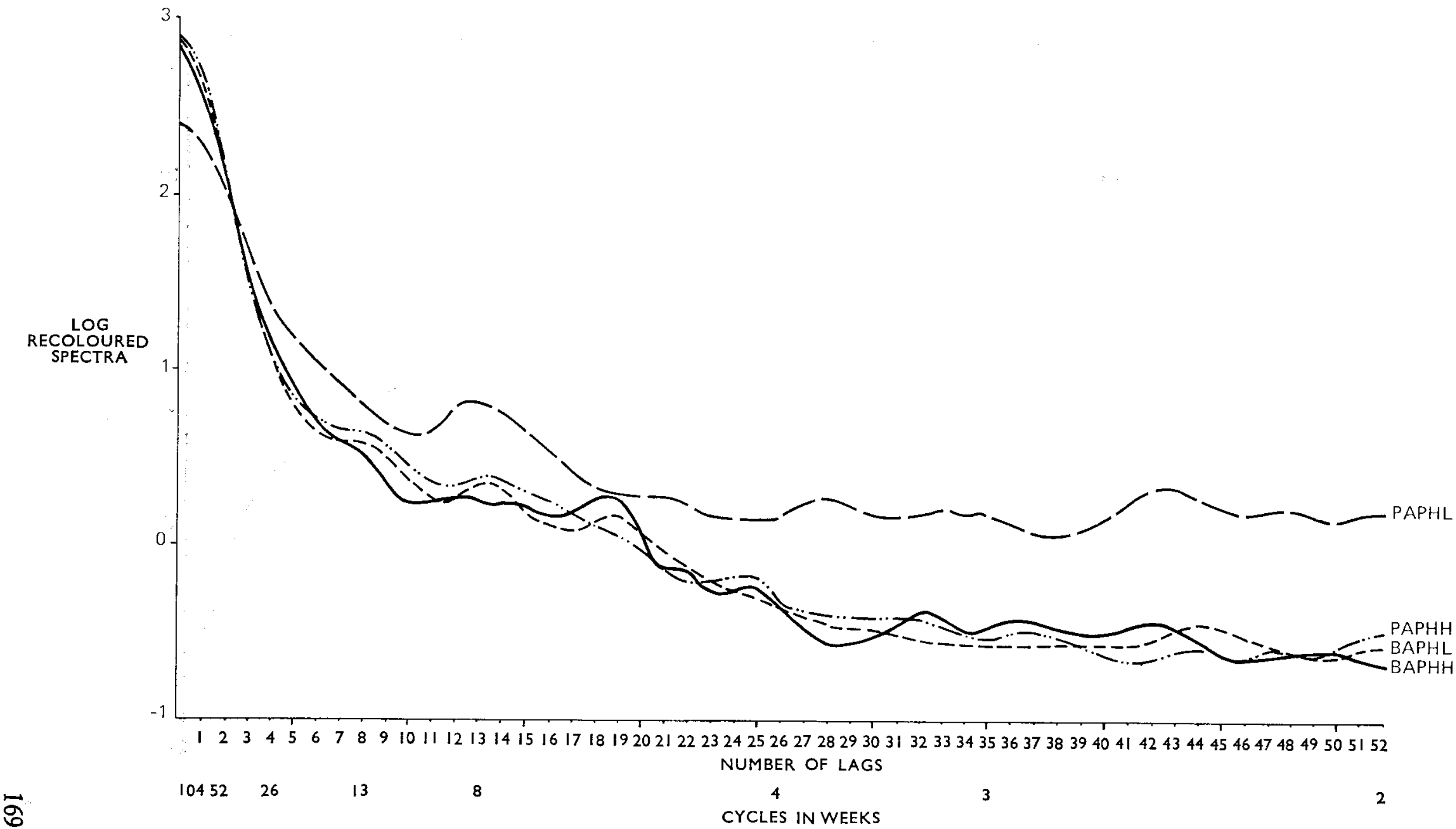


FIGURE 2: SPECTRA OF HOMEBUSH WEEKLY WHOLESALE PRICES

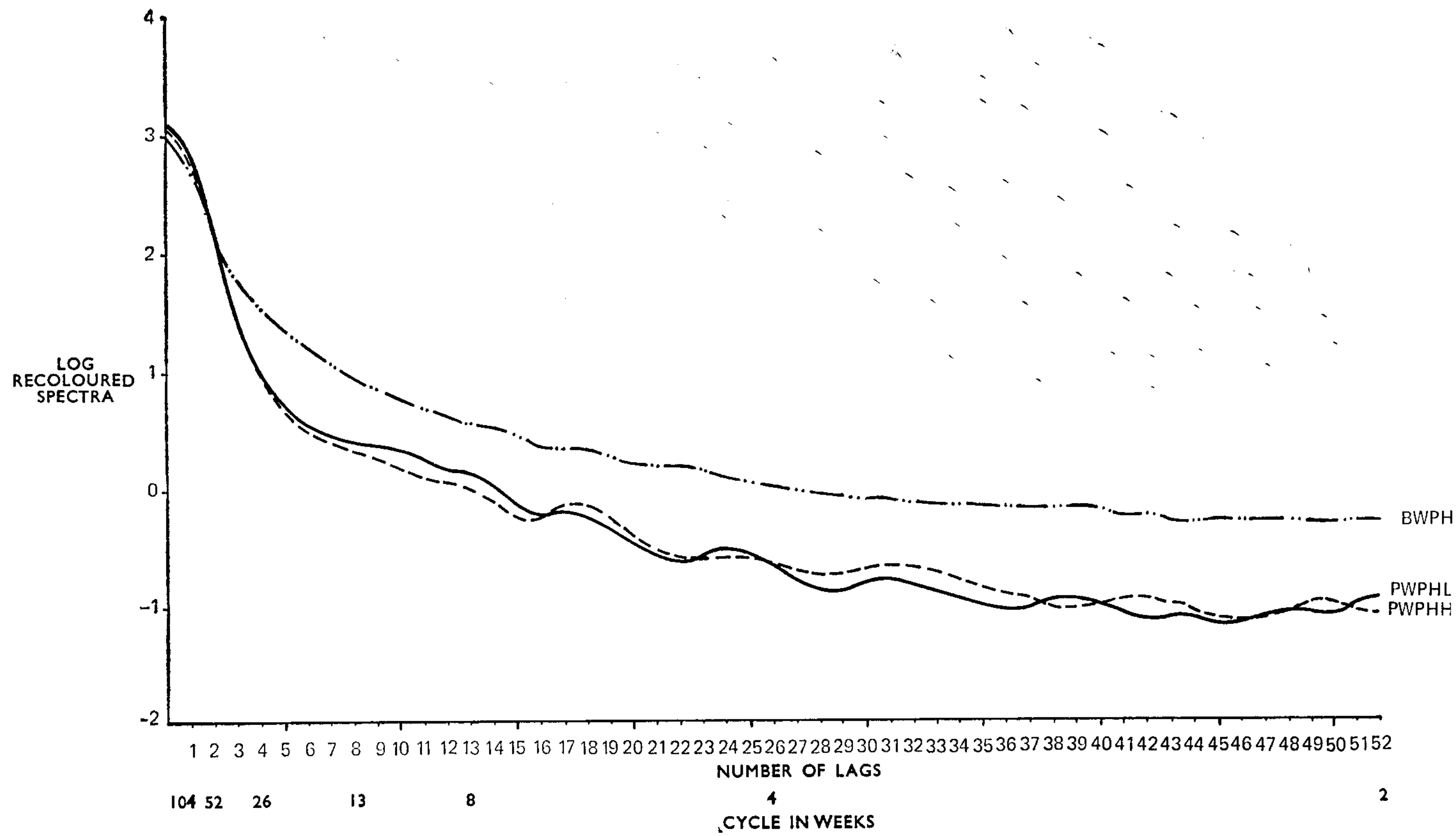
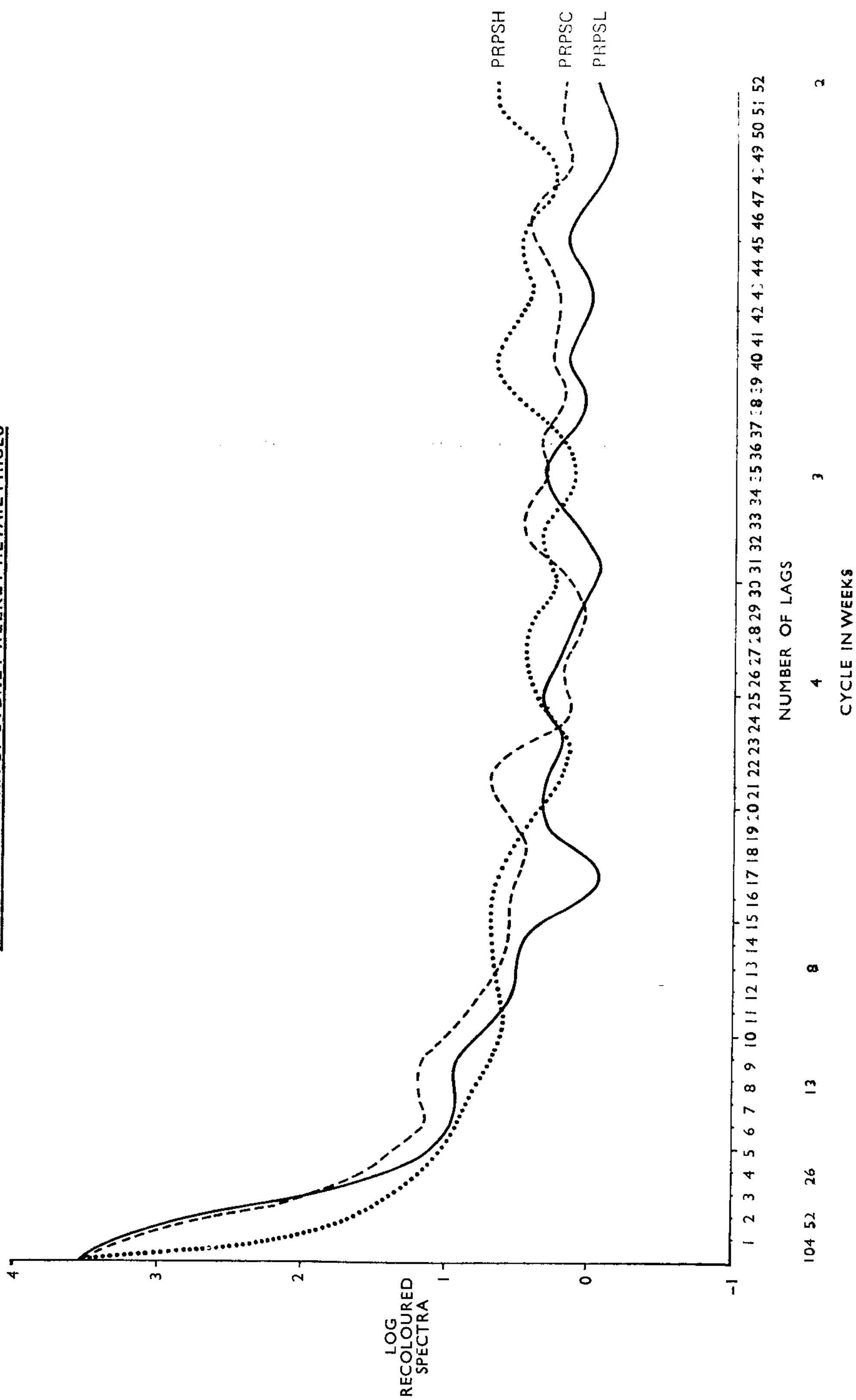


FIGURE 3: SPECTRA OF SYDNEY WEEKLY RETAIL PRICES



The peak at cycle length 8 weeks appears to be significant in the PAPHL series, but that is the only distortion to the smooth spectral shapes.[12]

In figure 2 we again find a dichotomy—this time between BWPH and the two PWPH series. The BWPH series is an almost perfect example of Granger's [17, p. 155] "typical spectral shape". The two PWPH series are almost as smooth but have less power than BWPH at all frequencies except the very low.

The retail spectra estimated in figure 3 are fairly similar in shape and show more variation than either the auction or wholesale results. PRPSC has a peak at around the 5 week cycle length and may also have a 13 week cycle, and PRPSH shows high power around cycles of 2 and 2½ weeks, but apart from these isolated cases the spectra are reasonably smooth.

(b) *Cross-Spectral Estimates*

(i) *Coherence*

Tables 1 and 2 summarize the coherence values at selected frequencies for auction, and wholesale and retail prices respectively.

We also reject the use of significance tests for the cross-spectral statistics on the basis of probable violation of the stationarity assumption. For coherence statistics, the general rule applied is that coherence exceeding 0·5 is regarded as "moderate" and exceeding 0·75 is regarded as "high". Some authors, for example Parikh [39, p. 22], have regarded coherence as significant if it exceeds 0·3, but given the close relationship to R^2 in regression analysis, this seems much too low.

In general the values in these tables reflect the patterns in the spectrum diagrams noted above. Table 1 shows that PAPHL is poorly correlated with the other auction prices, having only moderate coherence at the cycle of 8 weeks and at the cycle length of 26 weeks in the first two pairings only. On the other hand, the other three auction price pairings show moderate to high coherence over most frequencies, with the correlation between adjacent weight ranges being the highest.

TABLE 1

Coherence Values for Weekly Auction Prices at Homebush

Lag	Cycle Length	PAPHL: PAPHH	PAPHL: BAPHL	PAPHL: BAPHH	PAPHH: BAPHL	PAPHH: BAPHH	BAPHL: BAPHH
1	104	·464	·421	·385	·979	·955	·989
2	52	·400	·329	·285	·945	·874	·968
4	26	·523	·502	·357	·789	·610	·887
8	13	·139	·134	·169	·750	·579	·787
13	8	·596	·651	·565	·770	·611	·720
26	4	·004	·098	·254	·306	·114	·426
52	2	·029	·102	·035	·452	·078	·283

[12] In this study we have not used statistical tests of significance for the estimated spectrum because of the probable violation of the stationarity assumption and the extreme sensitivity of confidence bands to this assumption. We use instead the less sophisticated but still useful method of testing the reality of a peak by looking for its harmonics [18, p. 63].

TABLE 2

Coherence Values for Weekly Wholesale and Retail Prices at Homebush and Sydney, Separately

Lag	Cycle Length	PWPHL: PWPHH	PWPHL: BWPH	PWPHH: BWPH	PRPSL: PRPSC	PRPSL: PRPSH	PRPSC: PRPSH
1	104	·990	·616	·622	·917	·077	·125
2	52	·978	·517	·504	·853	·100	·095
4	26	·836	·203	·201	·550	·090	·057
8	13	·868	·097	·102	·550	·005	·045
13	8	·748	·003	·010	·284	·030	·006
26	4	·707	·038	·012	·248	·145	·050
52	2	·158	·002	·025	·003	·138	·048

Wholesale prices of porker carcases are highly correlated over all frequencies but the two highest, however, porker carcases and bacon sides have only moderate coherence values at very low frequencies. A similar situation is apparent in the relationships between retail pork prices—the two fresh pork prices are highly correlated over the two low frequency bands, but coherence values between fresh and corned pork at all frequencies are very small.

(ii) *Gain*

Gain (and phase) statistics provide very little information on the nature of the relationships between two series if coherence is low at the specified frequency [33, p. 25; 39, p. 21]. Accordingly the gain (and phase) statistics are only discussed in following sections for frequencies with high or moderate coherence.

The patterns in the gain coefficients of Table 3 are very similar to those observed for the coherence values: price pairings that had low coherences also had low gain coefficients, while pairings with consistently high coherence values had gain coefficients in the range 0·8–1·0, indicating that price changes in these pairings were reasonably efficiently transferred from one auction price to another, one wholesale price to another, and one retail price to another. Except for those between the two retail prices, the gain coefficients tended to decline as frequency increased but not to a great degree.

TABLE 3

Gain Coefficients for Weekly Auction, Wholesale and Retail Prices, Separately

Lag	Cycle length	PAPHL: PAPHH	PAPHL: BAPHL	PAPHL: BAPHH	PAPHH: BAPHL	PAPHH: BAPHH	BAPHL: BAPHH	PWPHL: PWPHH	PWPHL: BWPH	PWPHH: BWPH	PRPSL: PRPSC
1	104	..	..	..	·948	·913	·968	·925	·691	·747	1·009
2	52	..	..	..	·941	·909	·989	·944	·710	·735	·979
4	26	·515	·496	..	·872	·827	1·016	·897	..	..	·910
8	13	..	..	..	·814	·643	·798	·828	..	..	1·005
13	8	·467	·467	·404	·820	·678	·788	·720	..	..	..
26	4	..	..	..	..	..	..	·850	..	..	..
52	2	..	..	..	..	..	..	..	..	..	..

(iii) *Phase*

Table 4 presents the phase angle statistics which are relevant in this section. Applying the formula in footnote 9 enables us to calculate the extent to which any two cycles are out of phase, but we cannot distinguish whether these phase relationships are leads or lags except by using *a priori* information.

TABLE 4

Phase Angle Statistics for Weekly Auction, Wholesale and Retail Prices, Separately

Lag	Cycle length	PAPHL: PAPHH	PAPHL: BAPHL	PAPHL: BAPHH	PAPHH: BAPHL	PAPHH: BAPHH	BAPHL: BAPHH	PWPHL: PWPHH	PWPHL: BWPH	PWPHH: BWPH	PRPSL: PRPSC
1	104	..	..	..	6·270	6·243	6·259	·013	·289	·275	6·214
2	52	..	..	..	6·254	6·190	6·229	·030	·560	·568	6·166
4	26	5·964	6·210	..	·176	·117	6·267	·119	..	..	6·017
8	13	..	..	..	·180	·239	·105	·102	..	..	5·932
13	8	·126	·064	·059	6·228	6·192	6·237	6·254	..	..	..
26	4	..	..	..	..	..	..	·020	..	..	..
52	2	..	..	..	..	..	..	..	..	..	..

At the auction level only the pairing PAPHL: PAPHH shows evidence of being out of phase, and that is only by 2 weeks at the biannual cycle. Amongst the wholesale prices, the heavy and light pork prices are in phase over all frequencies shown, but the pork and bacon price pairings both consistently show a phase shift of some four to five weeks over the long run. The structure of the industry would infer that wholesale pork prices lead wholesale bacon prices by this amount. Finally, the retail prices are out of phase at the annual cycle by just over one week, but this can probably be regarded as insignificant for all practical purposes.

3.2 Auction, Wholesale and Retail Prices Jointly

This second set of results examines the joint price relationships at the auction, wholesale and retail levels.

(a) *Spectral Estimates*

Figures 1, 2 and 3 report the relevant spectra.

(b) *Cross-Spectral Estimates*

Where auction and wholesale prices are compared, $n = 676$, $m = 52$ and $n/m = 13$. Where retail prices are compared to auction or wholesale prices, $n = 416$, $m = 52$ and $n/m = 8$.

(i) *Coherence*

Table 5 outlines the coherence values for selected combinations of auction and wholesale prices, wholesale and retail prices, and auction and retail prices.

Except for the pairing PAPHH:PWPHH which had high coherence values at the cycles of 104 weeks and 52 weeks, the correlation between auction and wholesale prices was poor. At high frequencies there was virtually no relationship between changes in auction prices and changes in wholesale prices, while at lower frequencies the coherence values were only moderate.

TABLE 5

Coherence Values for Weekly Auction, Wholesale and Retail Prices, Jointly

Lag	Cycle length	PAPHL: PWPHL	PAPHH: PWPHH	BAPHL: BWPH	BAPHH: BWPH	PWPHL: PRPSL	PWPHL: PRPSC	PWPHH: PRPSL	PWPHH: PRPSC	PAPHL: PRPSL	PAPHL: PRPSC	PAPHH: PRPSL	PAPHH: PRPSC
1	104	·369	·934	·548	·502	·877	·901	·875	·897	·151	·177	·760	·794
2	52	·255	·888	·452	·368	·791	·790	·792	·786	·059	·058	·648	·663
4	26	·343	·451	·313	·174	·191	·174	·254	·182	·094	·110	·027	·132
8	13	·041	·501	·034	·007	·366	·297	·423	·281	·012	·063	·369	·223
13	8	·182	·323	·066	·030	·206	·111	·193	·063	·075	·000	·075	·061
26	4	·043	·108	·093	·032	·031	·110	·049	·121	·135	·028	·077	·087
52	2	·000	·000	·007	·004	·020	·001	·117	·026	·231	·001	·003	·275

The relationships between wholesale and retail prices were an improvement in terms of the size of the coherence values at low frequencies, but this tapered off extremely quickly so that there were not even moderate coherences at the biannual cycle or shorter.

In the auction/retail cross-spectra, high or moderate coherences were only recorded for the two heavy porker and fresh pork combinations where coherence values reached about 0·7 at the two lowest frequencies. The ignorance of PAPHL movements in retail pricing backs up the poor correlation between PAPHL and wholesale prices.

(ii) *Gain*

Gain coefficients for frequencies having high or moderate coherence are listed in the following table.

TABLE 6

Gain Coefficients for Weekly Auction, Wholesale and Retail Prices, Jointly

Lag	Cycle length	PAPHH: PWFHH	BAPHL: BWPH	BAPHH: BWPH	PWPHL: PRPSL	PWPHL: PRPSC	PWPHH: PRPSL	PWPHH: PRPSC	PWPHH: PRPSL	PAPHH: PRPSC
1	104	1·142	·865	·849	1·371	1·449	1·514	1·560	1·555	1·254
2	52	1·088	..	..	1·316	1·370	1·436	1·490	1·386	4·721
8	13	·486	..	..	..	..	..	..	..	..

These coefficients show that in general, auction price changes are associated with about equal changes in wholesale prices at low frequencies, and that this relationship seems larger for porker-type pigs than for baconer-type pigs.

At all frequencies, having high coherence, retail prices show between 120–160 per cent increase on movements in wholesale prices. A similar type of response is evident in the relationships between auction prices and retail prices.

(iii) *Phase*

Table 7 presents the phase angle statistics for the relevant frequencies. There are only two instances of out-of-phase relationships of about 5 to 6 weeks in the 2-year cycle of the auction and wholesale baconer pairings. Again we would infer that auction prices lead wholesale prices.

TABLE 7

Phase Angle Statistics for Weekly Auction, Wholesale and Retail Prices, Jointly

Lag	Cycle length	PAPHH: PWPHH	BAPHL: BWPH	BAPHH: BWPH	PWPHL: PRPSL	PWPHL: PRPSC	PWPHH: PRPSL	PWPHH: PRPSC	PAPHH: PRPSL	PAPHH: PRPSC
1	104	·015	·309	·345	·020	·010	·004	6·278	·000	6·272
2	52	·042	·620	·707	·049	·020	·013	6·267	·024	6·282
8	13	·677	..	..	..	..	..	..	..	..

4 CONCLUSIONS

This section briefly summarizes the results of the previous section, compares them with the hypotheses postulated in 1.2, and indicates the implications these results have for marketing policy decisions.

4.1 Results in Relation to the Hypotheses

Hypothesis (1): the prices of various types of pigs or pigmeats in one location are not related to the prices of other types of pigs or pigmeats in the same location.

The results from section 3.1 can be used to test this hypothesis.

In this analysis there are a mixture of results. Between heavy porker and both baconer auction prices, both porker wholesale prices and both fresh pork retail prices, coherence values are high in the medium to long term, gain coefficients are high and there is little evidence of out-of-phase relationships. For these series over the shorter-run though, and for pairings involving light porker auction prices, bacon wholesale price and corned pork retail price, coherence is very poor and in some cases negligible, gain coefficients are considerably lower and there are more instances of significant timing relationships. Hypothesis (1) can therefore not be rejected.

Hypothesis (2): the prices of various forms of the product in one location are not related to the prices of other forms of the product in the same location.

Section 3.2 is used to test this hypothesis, and once again the results show that the hypothesis cannot be rejected. Coherence values for auction and wholesale prices are in general only moderate at low frequencies and close to zero at higher frequencies. The exception is the pairing between heavy porker auction and wholesale prices, which shows high or moderate coherence down to an 8 week cycle length. Coherences are higher in the long term for wholesale-retail price pairings but these correlations quickly taper off. The only high coherences between auction and retail prices were recorded for the two heavy porker, fresh pork combinations but again these correlations tailed off rapidly.

At low frequencies auction price changes are associated with an almost similar change in wholesale prices, but this relationship lessens as frequency increases. There is between 120–160 per cent increase in retail prices over both auction and wholesale price changes. There are only two major instances of out-of-phase relationships and that is of about 6 weeks in the 2 year cycle of the auction and wholesale baconer pairings.

To test the price levelling at high frequencies aspect of these results we use the following three criteria developed by Woodward [55, pp. 144–145]:

(i) retail price series will have lower power in the spectrum than wholesale or auction prices;

(ii) there will be low coherence between retail, wholesale and auction prices; and

(iii) the gain in retail prices over wholesale and auction prices will be less than unity.

An examination of figures 1, 2 and 3, and tables 5 and 6 reveal that on point (i) the opposite is more likely to be the case, on point (ii) the criteria is certainly correct, and on point (iii) gain coefficients are not presented for high frequencies because coherence values are very low. Since the gain coefficient test is probably the best as it summarizes both the spectral and coherence functions, Table 8 reports the gain coefficients for high frequencies between auction, wholesale and retail prices. As mentioned previously though, gain coefficients provide little information on the nature of the relationship between two series if coherence is low, so extreme care should be taken in interpreting these coefficients. They should be used only to provide an indication of the relationship and not as concrete evidence.

For the high frequency bands considered (cycle lengths of 8 weeks and shorter), the gain coefficients are in general substantially less than unity and in some cases negative. These results indicate that a considerable degree of short-run price levelling exists in the market for pigs and pigmeat in Sydney, substantiating the results obtained from an econometric model of meat margin behaviour [20]. The existence of several cases of gain coefficients exceeding unity also validates the conclusions of the econometric model that some compensatory price increases were necessary for retail and wholesale prices to accurately reflect auction price changes in the longer-term.

The different relationship of both light and heavy wholesale pork prices with retail prices of pork leg and pork chops indicates some price averaging may be occurring within retail pork cuts. This result ties in with the low coherence values at high frequencies shown in table 2 for the PRPSL: PRPSC price pairing.

On the basis of these limited results, we cannot reject the hypothesis of the presence of price levelling between auction and wholesale porker prices and between wholesale and retail pork prices.

4.2 Some Implications for Policy Decisions

The point has been emphasized in this study, that we are measuring pricing efficiency not by comparing price differentials and transport, storage or processing costs, but by examining the relationships between certain pig price series. In general the results have shown that over the long term, there is a strong correlation between the various price pairings examined. We found that in the shorter-run however, prices were not well related throughout the market and in some cases there was no correlation whatsoever. There may be some justification then for the view that the pig market in New South Wales is not performing efficiently as a mechanism of trade and a guide to production.

TABLE 8

High Frequency Gain Coefficients for Weekly Auction, Wholesale and Retail Prices, Jointly

Lag	Cycle length	PAPHL: PWPHL	PAPHH: PWPHH	BAPHL: BWPH	BAPHH: BWPH	PWPHL: PRPSL	PWPHL: PRPSC	PWPHH: PRPSL	PWPHH: PRPSC	PAPHL: PRPSL	PAPHL: PRPSC	PAPHH: PRPSL	PAPHH: PRPSC
13	8	·195	·348	·244	·243	·749	·278	·752	·489	·186	− ·023	·288	·297
17	6	·221	·160	·447	·233	·475	·127	·378	·391	·086	− ·280	·097	·119
26	4	·083	·233	·480	·272	·616	·224	·736	1·051	·516	·131	·576	·554
35	3	·073	·016	·142	·164	2·532	·294	2·247	1·230	·522	− ·403	·644	1·032
42	2·5	·020	·121	·412	·419	1·292	− ·173	·763	·829	·187	− ·265	·366	·204
52	2	·004	·000	·115	·096	·423	·048	1·394	·860	·495	·148	·074	1·004

Tomek and Robinson [49, pp. 132–150] argue that this short-run price independence may be due to a number of factors, including different short-run demand and supply schedules for each type or grade of pig; a monopolistic market structure; technical, legal or institutional barriers to trade; imperfect information, and the high costs of obtaining better information; irrational consumer or producer preferences; or simply inaccurate data. A further factor would be that in the short-run it may be physically impossible to make the appropriate supply adjustment.

All of these factors will often be relevant and in different circumstances one or more will dominate. For example, markets widely separated geographically will most likely be subject to different short-run supply and demand forces, so uncorrelated prices from these markets would not necessarily imply inefficiency.

In the present case the markets are not geographically separate and the product is perishable, so the short-run demand and supply schedules should be quite closely related. Further, this overall market has been shown to have a structure that is acceptably competitive with few barriers to trade [23]. Of the remaining factors, imperfect information would seem to be the most significant in explaining this observed short-run price independence. This has also been noted by Manning [37, p. 24] who concluded his study of the Alberta pig industry ". . . the major determinant of market disorganization appears to be the lack of adequate market information".

There are two broad aspects to this question of market information in the pig market. The first relates to the accurate determination of the value of the pig or pigmeat for sale, which will depend both on the overall price level that equates demand and supply, and on the specific value placed on a carcase of certain characteristics. Any marketing reforms that assemble large numbers of buyers and sellers and/or provide objective means of carcase description are therefore to be recommended.

The second aspect is more an operational problem and relates to the methods of collecting, collating and distributing market information in the most accurate and expedient way. Any market innovation which attempts to do this is similarly to be recommended.[13]

Advances made along these lines would not only allow all market participants to make better marketing decisions and to speed up the rate of supply adjustment, but would also provide a more accurate data base on which to conduct future research into the industry.

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[13] These recommendations are subject to the qualification, of course, that the costs of researching, implementing and maintaining such reforms are less than anticipated benefits.

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