Are Australian wholesale vegetable markets LOOPy?

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Are Australian wholesale vegetable markets LOOPy?[*]

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Literature regarding the pricing efficiency of Australian wholesale vegetable markets is very limited. The objective of this paper is to test whether or not vegetable products traded in these markets are priced efficiently and satisfy the law of one price (LOOP). To that end, the price relationships between Adelaide and Melbourne markets are tested, using the Johansen cointegration approach, Granger causality and impulse response functions. The empirical findings do not appear to satisfy the LOOP. Policy implications of the analysis are explored.

Key words: law of one price, Australian wholesale vegetable markets, pricing efficiency.

1. Introduction

Australian wholesale vegetable markets have recently attracted much attention of government bodies and growers. In 2008, after a prolonged period of high food prices the Australian Competition and Consumer Commission (ACCC) released a report analysing the competitiveness of the Australian food supply chain. Due to a lack of empirical data available, the ACCC drew the largely analytically-based conclusion that "the wholesale market(s) appears to operate efficiently. Prices in the wholesale market appear to be set by supply and demand" (2008, p. 273). In this report, however, growers have also expressed concerns regarding the transparency of negotiations between wholesalers and retailers. This information asymmetry leads to reduced pricing efficiency and an inefficient allocation of resources, which may be caused by a lack of market information provided to market agents.

Wholesale vegetable markets play an important role in the Australian vegetable supply chain. These markets are centralised and located between the farm production and the food retail stages of the food supply chain. Centralised markets are designed to reduce search costs between growers and retailers by bringing them together in one physical location (Kohls and Uhl 1998, p.36). The markets are where most of the food retail sector sources their produce (excluding major supermarket chains) (ACCC 2008). Also, the wholesale price is used as a reference price for alternative methods of procuring produce such as direct supply relationships, which are used by Australian major supermarket chains, between growers and retailers (Spencer 2004). Therefore, the market performance of Australian wholesale vegetable markets is important to the entire vegetable supply chain.

Market performance is broadly judged by two types of efficiency: operating and pricing. Operating efficiency relates to the optimising of the output to input ratio (Kohls and Uhl 1998, p.36). In turn, the operating efficiency of these markets is strongly influenced by its pricing

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efficiency. Pricing efficiency is defined as the ability for prices to reflect all relevant information accurately, quickly and effectively (Williams and Stout 1964). Therefore, efficient pricing means that prices reflect a more competitive equilibrium, leading to more informed decision making in the wholesale markets and throughout the supply chain.

Pricing efficiency is often measured using the law of one price (LOOP) (Sexton *et al.* 1991; Kohls and Uhl 1998, p. 157). Under competitive conditions, if the wholesale market agents are informed and rational, then arbitrage activity should occur between spatial locations, until prices reach equilibrium, net of transfer costs, unless these costs are excessive. In addition, efficient arbitrage implies that markets are highly competitive and that agents can gain no greater than market returns (Lohano and Mari 2006).

The primary objective of this paper is to assess if the LOOP is satisfied in the Australian wholesale vegetable markets for the purpose of measuring pricing efficiency. This will be investigated by empirically testing the price relationship of a selection of the most produced and consumed vegetables in Australia. To this end, weekly average prices for Adelaide and Melbourne's wholesale markets are used, and policy implications explored.

2. Background

Six billion dollars of sales and 25 million transactions per annum are estimated to occur in Australian wholesale vegetable markets (Brisbane Produce Markets Limited 2007). The Melbourne and Adelaide central markets generate 1.6 billion and 600 million dollars of sales of produce annually (Central Market Association of Australia 2007). Also, 53 per cent of growers sold a third of the total volume of vegetables at their local wholesale central market (Ashton 2007, p.7). This figure is likely to be even higher, considering a further 19 per cent is sold interstate, a large proportion of which is expected to be traded at other central wholesale markets. The pricing efficiency of such large scale markets has a significant impact on the real incomes of growers, retailers and ultimately consumers of fresh vegetables. For markets to be price efficient, the LOOP must be satisfied. The LOOP requires markets to be competitive, and the ability for arbitrage to be executed between these central markets. An important requirement in any competitive market is for a high level of market information to be available to growers, wholesalers and retailers to permit informed decision making. The ability to conduct arbitrage activities relies on the condition that transfer costs are less than the price differential between locations. Transfer costs primarily consist of freight costs, although loading, unloading fees and arbitrage information costs are also included. If transfer costs are excessive, a market boundary will emerge and the LOOP relationship will not hold.

Market information is comprised of any information about demand, supply, prices and inventory, in addition to government policies and other background factors affecting the market that the agent bases his/her actions (Weissel and Whittingham 1978, p.9). Market information generated in central markets is generally higher than in other market systems due to the concentration of buyers and sellers in the one physical location and the nature of the open cry system used (Kohls and Uhl 1998, p.159). A high level of market information being available to all agents has positive repercussions for pricing efficiency of the markets and the LOOP. Increased market information leads to improved decision making which results in price signals better reflecting the

competitive market equilibrium. Hence, if there is a high level of market information, agents are informed about conditions in other central markets and, therefore, arbitrage activities may occur. The end result is the LOOP being satisfied.

There has been a significant fall in the level of market information in central wholesale markets, since the removal of statutory vegetable marketing authorities in Australia. These authorities that were largely government sponsored included marketing boards, state and federal departments and industry organisations which provided an array of market information, including market assessments, prices, quantities and forecasts until the 1970s. Reliable volume and trade statistics for vegetables were largely available, as wholesale vegetables went through these statutory marketing boards and committees (Weissel and Whittingham, 1978, p.10). Currently, the only statutory marketing authority remaining is the Western Australian Potato Marketing Board. The Australian Bureau of Statistics (ABS) and the Australian Bureau of Agricultural and Resource Economics (ABARE) collect various industry statistics along with several industry groups such as Horticulture Australia Limited (HAL), although they are very limited in scope and often incompatible (Industry Commission 1993, p.44). Due to the bulky nature of produce, volume and trade data collection is a costly exercise which industry groups are not willing to fund, as marketing and research and development projects are seen as being more beneficial.
Price information for fresh vegetables is available daily for all markets on a user pays basis from private consultants or from selected markets such as Adelaide and Melbourne. Price information is also reported on radio and through market reports. Within the market, price information is disseminated through the central market's traditional open cry system. Wholesale price information faces several challenges. One is that prices can change rapidly intraday, where the average prices collected may not reflect this range. Also average price data and ranges do not reflect the variations in product quality which may be an important violation of the homogeneity assumption of competitive markets (Industry Commission 1993, p.44; Spencer 2004, p.60). Moreover, collection methods are often based on the wholesalers submitting their price and volume data. This has led to allegations of data manipulation by wholesalers that have an incentive to understate prices in order to artificially lower the farm gate prices (Spencer 2004, p.60). On the other hand, price monitoring by retailers may counteract the incentive to data manipulation. In summary, price information suffers several limitations that reduce its credibility, especially the difficulty in accounting for quality; nonetheless it is generally available and appears sufficient.

When assessing market information, it is also important to consider the effects of arbitrage. Across distance, arbitrage is conducted by purchasing produce in a surplus market and transferring it to the deficit/shortage market for the price differential additional revenue. This activity should occur until the transfer costs are equal to the price differential and an equilibrium is established between the two central markets. Arbitrage assumes that agents are risk adverse and profit maximisers. In the absence of explicit transfer cost and trade flow information, the empirical method used to test the LOOP requires that transfer cost data be stationary during the sample period.

The Adelaide and Melbourne central markets are relatively close in terms of distance, at 730km (Google Australia 2008). Therefore, if transfer costs are linearly related to distance, then these two markets are more likely to trade between each other rather than other markets. Figure 1

suggests a relatively significant level of non-bulk trade which includes vegetables, occurring between Adelaide and Melbourne. Another indicator of tradeflow is that in 2005-06, 19% of total vegetable volume was sold interstate (Ashton 2007, p. 22). A large portion of this volume is sold in other wholesale markets. However, the likelihood of a market boundary should be different for various products, as it depends on the value per unit. For instance, potatoes are a low value per unit product compared to mushrooms, making transfer costs a relatively more significant cost component.

Transfer costs are generally known to be difficult to estimate, as they are highly variable between individuals and produce, and have been decreasing over time between markets. Figure 2 estimates the road and rail non-bulk interstate transportation costs in real terms between 1964 and 2001. The general price of road and rail freight has been declining since 1972. Since the introduction of articulated trucks in the 1970s, interstate non-bulk, including vegetables, road freight costs have halved in real terms (Productivity Commission 2006, p.32). The decrease in freight costs appears to be due to productivity improvements such as, information communication technology and more efficient trucks with greater capacity (Productivity Commission 2006, p.32). Figure 2 shows that the price of road transport has not changed considerably between 1988-89 and 2000-01. It has been characterised by low variance and a constant trend. When using time series analysis, it is important that transfer costs be stationary for the analysis to be accurate. Otherwise, we may incorrectly fail to reject that the LOOP holds. For transfer costs to be considered stationary, the mean, variance and covariance must be stationary over time. We assume, therefore, that transfer costs are stationary over the sample period of this study. For the purpose of the analysis, we extend these characteristics to suggest that over the 2006-2008 sample period transfer costs will be stationary. The short two-year sample period used in the study implies that this should be a reasonable assumption.
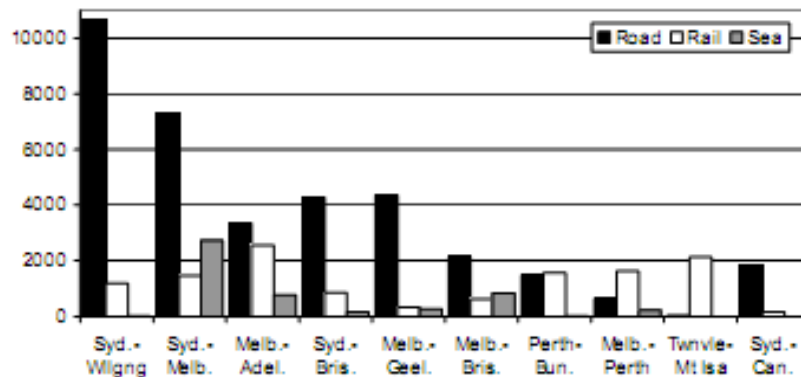

Figure 1 Top 10 Auslink corridors by tonnage, 1999 (in '000 tonnes)
Source: Bureau of Infastructure (2002) and Productivity Commission (2006, p.23)
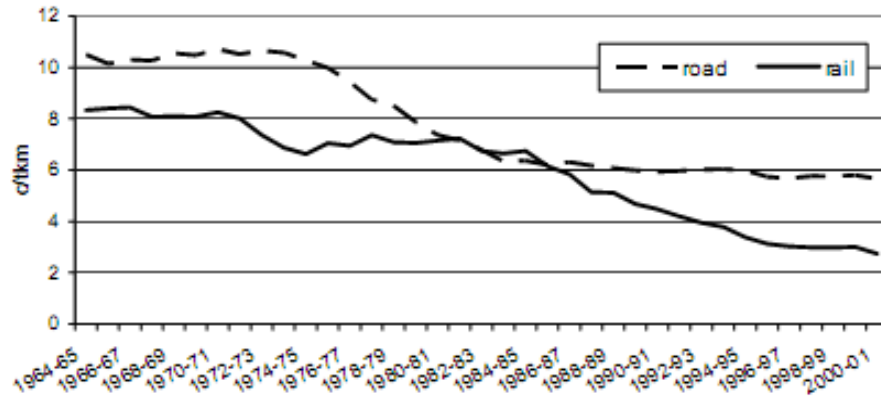
Figure 2 Road and rail interstate non-bulk freight rates in 2006 dollars
Source: Bureau of Infrastructure (2002) and Productivity Commission (2006, p.32)

Finally, information within these central markets is higher than alternative market systems, although this does not assist in generating information regarding other central markets. There is a distinct lack of volume information in these markets which is necessary in determining the supply conditions. However, price information is generally available to agents, although its key limitation is that it does not accurately account for changes in product quality. Arbitrage between Melbourne and Adelaide is highly likely to occur, as various trade statistics presented for goods with similar characteristics are shown to be high. In addition, the distance between locations is relatively short. As the presence of a market boundary is unlikely, the paucity of market information, particularly volume statistics, is a significant impediment to the LOOP being satisfied.

3. Previous studies

The literature treats pricing efficiency as tantamount to the LOOP. There is a lack of studies examining pricing efficiency in Australian wholesale vegetable markets, although there are general studies that show pricing efficiency has been positively affected by changes in the level of market information. The empirical approaches to measuring pricing efficiency have become more sophisticated over time, and culminated in two key models being employed in previous studies: switching regime and cointegration.

Barrett and Li (2002) and McNew and Fackler (1996) consider pricing efficiency as a price-based view of the competitive market equilibrium, where arbitrage forces lead to prices in the two central markets equalising, net of transfer costs. This definition of pricing efficiency is synonymous to the LOOP (Barrett 2001). The difference between these two terms is the context in which they are used. Pricing efficiency is the outcome and the LOOP is the condition that must hold.

Published research on Australian wholesale vegetable markets is scanty, especially with regard to pricing efficiency. The last known empirical study looking at pricing efficiency in Australian wholesale vegetable markets was an occasional paper by Weissel and Whittingham (1978). They

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used price information from 1969 to 1976, and focused on the larger central markets located in eastern states. Using cross spectral analysis, they concluded that prices were generally efficient. They also concluded that there was a limited opportunity for arbitrage of about eight weeks (Weissel and Whittingham 1978, p. 23). Australian wholesale vegetable markets have since been privatised, and market information services regarding volumes have been reduced. Other studies analysing these markets, although not dealing with pricing efficiency directly, have been based on analytics and anecdotal evidence from market agents, including the Industry Commission (1993), Spencer (2004) and the ACCC (2008). The consensus in these studies is that prices appear to be determined largely by supply and demand conditions, although they also suggest that market information is problematic.

Sporadically, there have been international studies undertaken on the effects of market information on price efficiency. Buccola (1985) found that central markets were more price efficient than other market systems as a result of lower search costs between suppliers and demanders in discovering the general market conditions. There have also been studies looking into the relationship between market information and pricing efficiency. Anderson *et al.* (1998) using simulation demonstrated that decreasing price and quantity information leads to higher price variance and lower pricing efficiency. Bastian *et al.* (2001) go a step further, and use simulation to show that mandatory price reporting reduces price levels and variance, while price efficiency improves. Market information, therefore, should have a positive effect on price efficiency based on a *priori* expectation.

Empirical testing of pricing efficiency using the LOOP has undergone much development since the initial use of correlation and static regression by Richardson (1978); Protopapadakis and Stoll (1983). Currently, there are two main approaches used by researchers testing the LOOP: switching regime models and cointegration. A switching regime model was applied by Spiller and Huang (1986), employing three different trading regimes, the probabilities of each regime occurring are estimated. Sexton *et al.* (1991) also used a similar approach to test for the LOOP in a unidirectional trade situation by defining the regimes as different arbitrage possibilities rather than the trade possibilities used by Spiller and Huang (1986). A significant advantage is the incorporation of the variation in transaction costs over time (Baulch 1997). Models that fail to account for this transaction cost variation, such as cointegration, may tend to over-reject the LOOP (for example, Barrett and Li 2002; Goodwin and Grennes 1998). Although the switching regime model addresses problems of other models, it faces limitations of its own. The interpretations of results from switching regime models are sensitive to the underlying distributional assumptions, particularly where economic theory makes no recommendation about a distribution (Barrett and Li 2002; Fackler *et al.* 2001; McNew and Fackler 1997). Also spatial regime models assume that the tendency of locations to adhere to the LOOP is constant with respect to time, which may be implausible, when policies that are employed over time may increase the pricing efficiency of markets up to the LOOP such as investment in transportation and communication infrastructure. By relaxing the assumption that prices adjust instantaneously, cointegration can be used to test the LOOP as a spatial equilibrium. Generally speaking, therefore, cointegration is a test using time series data for establishing whether or not a long-run equilibrium relationship exists between variables. Ardeni (1989) demonstrates that cointegration is a better price-based method than earlier approaches such as correlation and static regression, as it does not suffer from spurious problems. Since most economic time series are non-stationary,

cointegration appears to be a relevant method, as linear regression is not valid because normal inference theory is not applicable to non-stationary data (Engle and Granger 1987; Gujarati 1988; Vinuya 2007). Although cointegration does have problems, it is still useful. If the transfer costs are non-stationary and there is no evidence of trade between two markets, cointegration is not informative (McNew and Fackler 1997; Barrett and Li 2002). Ultimately the problem is not with cointegration, but with the level of data available. The use of only price-based data means that the reliability of empirical results is reduced. Finally, for more informative results, actual trade flow and transfer cost information should be incorporated (Barrett 1996; McNew and Fackler 1997).

4. Analytical framework

When markets are efficiently priced, agents must be informed about prices in other spatial locations. Assuming agents are rational and no trade restrictions, arbitrage activity occurs up to the point where the difference in price is equal to transfer costs. An equilibrium price will emerge between the two locations. This captures the core of the LOOP. The LOOP is discussed particularly with respect to a more relaxed variant named the weak LOOP, which is an equilibrium condition, more applicable to these markets. The equilibrium property is important in terms of the applicability of cointegration as the empirical method used in this paper.

Mathematically, Equations (1) and (2) show the strong and weak LOOP conditions, respectively. $P_{1,t}$ and $P_{2,t}$ are the prices in locations 1 and 2. In addition, $T_{1-2,t}$ represents all the costs associated with the movement of the goods from one location to the other. Transfer costs include the costs of transportation, information, storage and handling costs (Rapsomanikis *et al.* 2006; Tomek and Robinson 1990). If Equation (1) is satisfied the strong LOOP holds. Arbitrage forces should not allow the price difference to exceed the transfer cost.

$$P_{1,t} - P_{2,t} = T_{1-2,t} \qquad (1)$$
$$P_{1,t} - P_{2,t} \leq T_{1-2,t} \qquad (2)$$

Equation (2) is referred to as the weak LOOP, because it relaxes the equality sign in Equation (1) by allowing prices to move by no more than transfer costs. This is also known as the spatial arbitrage condition as suggested by Fackler *et al.* 2001. They propose that the weak LOOP is an equilibrium condition. The reasoning is that in Equation (1) the observed price differential may be less than the transfer costs with no force to raise it back to the equality, which is known as the transfer band. On the other hand, in Equation (2) the transfer band is acknowledged and accepted, in the long run. However, spatial arbitrage opportunities will lead to the price differential between the two markets approaching transfer costs.

The fact that the weak loop condition is an equilibrium condition suggests that cointegration is a suitable empirical approach to testing. Cointegration is useful because it signifies the existence of a long-run equilibrium relationship between time-series variables. If two non-stationary price series are cointegrated, they move together linearly in the long run, while in the short run they may drift apart. This characteristic is entirely applicable to the markets, as in the short run

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delivery lags and grower-wholesaler relationships prevent the instantaneous adjustment of prices required in Equation (1). In the long run, this should not be an issue as spatial arbitrage will ensure that price divergence is not permanent.

The weak LOOP is an equilibrium condition which is more suitable to the nature of Australian wholesale vegetable markets. Transportation lags and the stickiness of grower-wholesaler relationships imply that the LOOP is more applicable as a long-run equilibrium concept. The weak LOOP and the timely nature of any long-run equilibrium relationship suggest that cointegration is a relatively strong empirical counterpart. Therefore, the weak LOOP will be used to test the price efficiency between Adelaide and Melbourne central markets.

5. Data and empirical procedures

Wholesale price information for three common vegetables that are sold in Adelaide and Melbourne will be used to test if the LOOP holds. The price data are generally characterised by low levels of variance which can be explained by changes in supply conditions. In order to test the LOOP, the Johansen cointegration test is used as well as Granger causality and impulse response functions.

The products considered need to be homogeneous in the Adelaide and Melbourne markets so that retailers do not have different willingnesses to pay. This has been achieved by controlling product size, state of origin and specific vegetable crop variety. Product quality, however, could potentially be a significant factor that has not been accounted for. The vegetable products of various package sizes used are carrots, potatoes, and tomatoes. These vegetables are high selling in the markets. Specifically, they include large Western Australian carrots (per carton), washed white cocktail South Australian potatoes (per 15kg carton) and cherry red Queensland tomatoes (per 250gram punnet). Weekly time series is used which varies in sample period depending on the vegetable product. The longest sample is potatoes from June 2006 to June 2008 and the shortest is tomatoes between 2006 and December 2007. The number of observations for each vegetable is shown in Table 1. Although the sample sizes are sufficiently large, cointegration is a long-run concept and may be limited due to the relatively short time span. The data are sourced from their respective official market reporting services and collected voluntarily from wholesalers. The Adelaide and Melbourne wholesale price data were collected by the Adelaide Produce Markets limited and the Victorian Chamber of Fresh Produce Wholesalers Incorporated, respectively.

The price series is characterised by low levels of variation, as shown in Table 1 and Figures 3, 4 and 5. This can be explained by the differing perishability and supply conditions for these staple vegetables. While demand is relatively constant all year for these vegetables, the price of tomatoes is the most varied, as they are far more perishable and more sensitive to supply factors such as weather conditions in comparison to those for carrots and potatoes. Furthermore, a statistical explanation could suggest that average price data collected do not accurately reflect the variations in product quality (Industry Commission 1993 and Spencer 2004). Although the variation is lower than expected, there are some periods of constant prices. However, it is believed the two price series vary sufficiently for testing cointegration.

Table 1 Descriptive statistics of wholesale price information used.

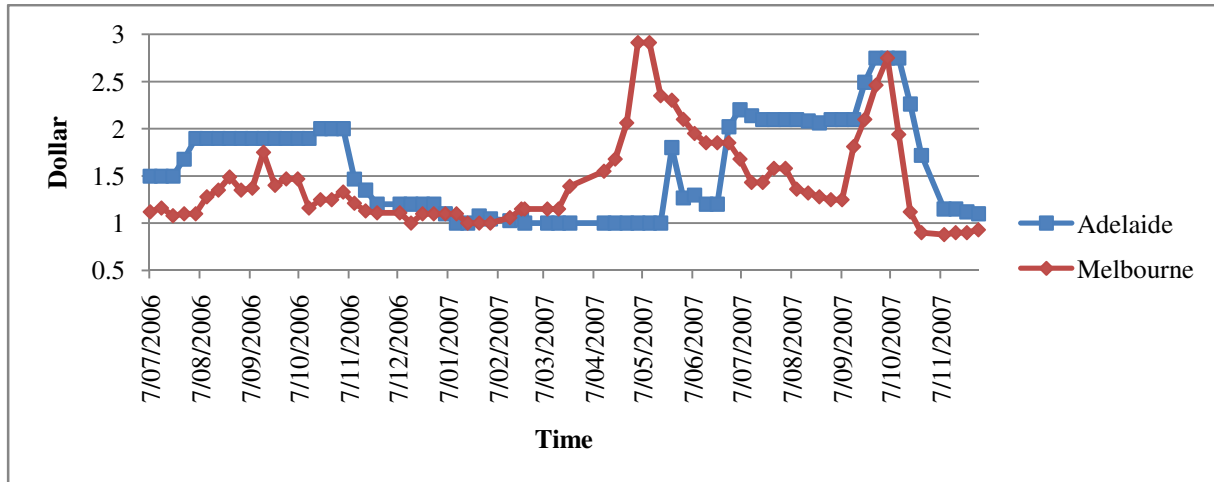| Product	Central market	Observations	Mean price	Standard deviation	Correlation
Large WA carrots	ADL	74	$17.47	$2.19	N/A
	MEL	74	$17.23	$3.94	0.79
Washed white cocktail	ADL	97	$24.12	$4.00	N/A
SA potatoes	MEL	97	$23.14	$4.58	0.78
Cherry red QLD	ADL	69	$1.60	$0.51	N/A
tomatoes	MEL	69	$1.44	$0.48	0.24

Figure 3 Cherry red Queensland tomatoes wholesale prices (per 250 grams)
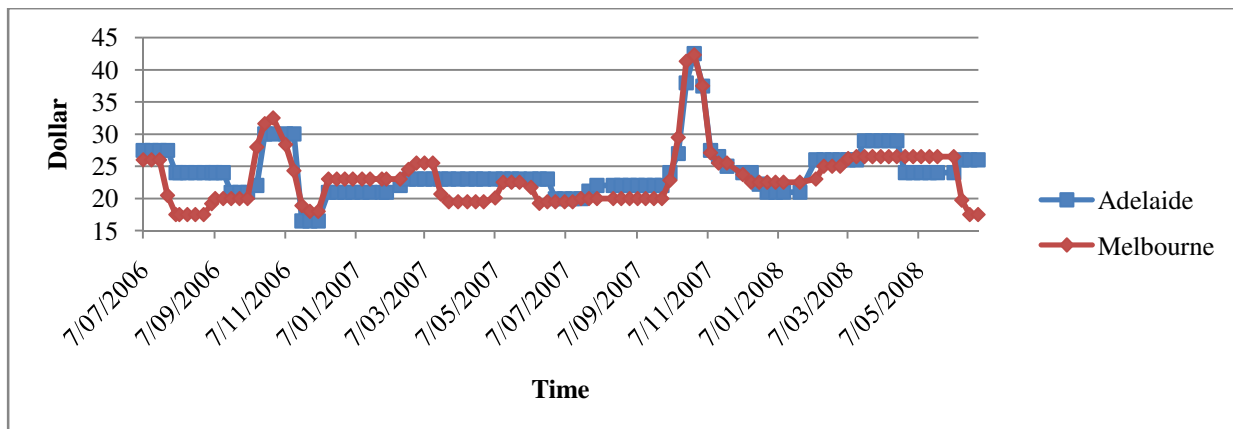

Figure 4 Washed white cocktail South Australian potatoes wholesale prices (per 15kg carton)
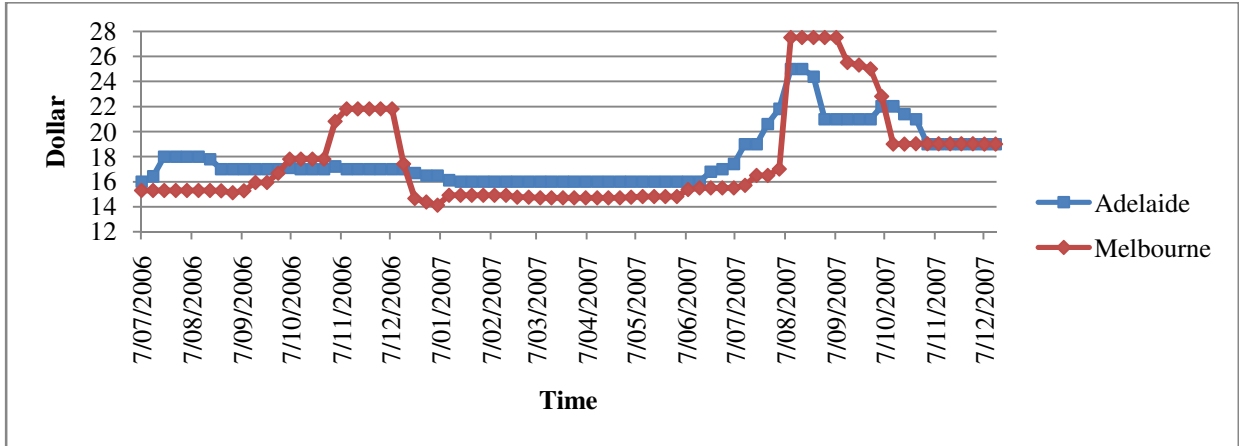
Figure 5 Large Western Australia carrots wholesale prices (per carton)

The empirical procedures are adopted from Rapsomanikis *et.al* (2006) who use the Johansen cointegration as a test for the LOOP. First, the wholesale prices are tested for the order of their stationarity, using the Augmented Dickey Fuller (ADF) and Phillips Perron (PP) tests. If the null hypothesis that a unit root exists is rejected by the ADF and PP tests of order *d,* we conclude that it is integrated of order I(*d*). In the event that price series for the same product in different markets are both integrated of the same order, which is commonly I(1), we test further for cointegration, using Engle Granger (Engle and Granger 1987) and the Johansen tests (Johansen 1988; Johansen 1991) . However, if both price series are integrated of different orders, we reject the notion that they are cointegrated, and suggest that these markets do not satisfy the LOOP. Granger causality and impulse response functions are also performed to assess the direction and size of influence, if any, between Adelaide and Melbourne markets.

If both price series are integrated of the same order, i.e. I(1), the Engle Granger and Johansen cointegration procedures are used to assess if prices are cointegrated. To be cointegrated the Engle Granger procedure requires that the ordinary least squares residual series of the two price series be I(0). This is done by testing for unit roots with the ADF and PP tests. The Engle Granger procedure does not have the capacity for hypothesis testing necessary for the LOOP. However, the Johansen test allows a hypothesis test for the LOOP. The Johansen procedure is also used to complement the Engle Granger procedure.

Both a trace test and a maximum eigenvalue test are used to identify the rank of the cointegration vector. In short, if the null hypothesis of no cointegration is rejected, using the trace and maximum eigenvalue tests, we conclude in favour of a cointegrated relationship between the two price series. The LOOP requires the cointegrating vector β to be equal to 1 and for the estimated residual to be distributed $0, \sigma^2$ (Ahmadi-Esfahani 2006; Palaskas and Harriss-White 1993).

The Johansen approach can be summarised in vector autoregression form of price series $P_{1,t}$ and $P_{2,t}$ as being equal to a sum of their past values. $\begin{pmatrix} a_1 \\ a_2 \end{pmatrix}$ is a vector of the intercept terms and $\begin{pmatrix} g_{11} & g_{12} \\ g_{21} & g_{22} \end{pmatrix}$ is a matrix of coefficients to lagged price series, $\begin{pmatrix} P_{1,t-1} \\ P_{2,t-1} \end{pmatrix}$. In addition, $\begin{pmatrix} v_{1,t} \\ v_{2,t} \end{pmatrix}$ is a vector of residuals.

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$$\begin{pmatrix} P_{1,t} \\ P_{2,t} \end{pmatrix} = \begin{pmatrix} a_1 \\ a_2 \end{pmatrix} + \begin{pmatrix} g_{11} & g_{12} \\ g_{21} & g_{22} \end{pmatrix} \begin{pmatrix} P_{1,t-1} \\ P_{2,t-1} \end{pmatrix} + \begin{pmatrix} v_{1,t} \\ v_{2,t} \end{pmatrix} \qquad (3)$$

Extending Equation (3) by allowing each matrix of coefficient for lagged values of P to be represented by $G_1, \dots G_k$, and adding k lags gives VAR(k) Equation (4)

$$\begin{pmatrix} P_{1,t} \\ P_{2,t} \end{pmatrix} = \begin{pmatrix} a_1 \\ a_2 \end{pmatrix} + G_1 \begin{pmatrix} P_{1,t-1} \\ P_{2,t-1} \end{pmatrix} + \dots + G_k \begin{pmatrix} P_{1,t-k} \\ P_{2,t-k} \end{pmatrix} + \begin{pmatrix} v_{1,t} \\ v_{2,t} \end{pmatrix} \qquad (4)$$

In terms of vector error correction modelling notation Equation (4) is represented as

$$\begin{pmatrix} \Delta P_{1,t} \\ \Delta P_{2,t} \end{pmatrix} = \begin{pmatrix} a_1 \\ a_2 \end{pmatrix} + (G_1 + \dots + G_k - I) \begin{pmatrix} P_{1,t-1} \\ P_{2,t-1} \end{pmatrix} + \begin{pmatrix} v_{1,t} \\ v_{2,t} \end{pmatrix} \qquad (5)$$

$(G_1 + \dots + G_k - I)$ is the rank of the matrix which is equal to the number of cointegrating vectors b. If $b = 1$, then the price series are cointegrated. If $b = 0$ or 2, then the price series are not cointegrated or stationary respectively. The cointegrating vector is tested, using the maximum eigenvalue and trace tests. In order to put Equation (5) in error correction form, Johansen(1991) defined the rank of the matrix as $(G_1 + \dots + G_k - I) = \alpha\beta$', where α is the speed of adjustment parameter and β is the cointegrating parameter and measures the long-run relationship.

Finally, the LOOP suggests that price adjustment should be instantaneous. In reality, however, price leadership may occur from a source of new information or a larger market. Granger causality and impulse response functions are used as the final and supplementary step to cointegration. The Granger causality test measures, if added past values of the other market price, say $P_{1,t}$, improves the explanation of the current price in $P_{2,t}$. Granger causality indicates the direction of information flow and precedence between the markets, but not causality of the price. Impulse response functions are then applied which aim to quantify the speed of adjustment in the price in one market from a shock in the other price. That is, Granger causality attempts to detect the direction of information flows while impulse response functions measure the speed of information flow.

6. Results

Despite promising results in the form of high bi-variate correlation findings shown in Table 1, the main testing procedure rejects the proposition that the LOOP is satisfied between Adelaide and Melbourne markets. Granger causality testing generally indicates that the Melbourne prices leads the Adelaide prices, while arbitrage opportunities generally are eliminated in about a month's time frame.

Large Western Australian carton of carrots and washed white cocktail South Australian potatoes have a high correlation of almost 0.8 which implies that they are close to satisfying the LOOP. The LOOP is considered to hold, if prices are correlated with a coefficient of one. This means that prices in the two markets are perfectly positively synchronised. The correlation results of this analysis suffer from spuriousness which leads to an upward bias in the correlation coefficient. This is because only one price series was stationary without the need for differencing. Based on the ADF and PP tests for stationarity, all price series were non-stationary

except for washed white cocktail potatoes from South Australia sold in Melbourne which was I(0). All the price series were found to be stationary after first differencing, I(1), except for washed white cocktail potatoes from South Australia sold in Melbourne. Prices may be correlated because of common factors such as inflation, seasonality, supply and demand shocks or environmental factors simultaneously (Delgado 1986;Harriss 1993). It is possible that they could also independently vary within the band of inactivity which is the size of the transfer costs.

Based on the Johansen cointegration and Engle Granger tests, the hypothesis that the LOOP is satisfied in the Adelaide and Melbourne wholesale vegetable markets is rejected. Table 2 shows the Johansen cointegration test findings which suggest that the result of non-rejection of the null hypothesis for the trace and maximum eigen value tests at the five per cent level of significance, leading to the conclusion that the LOOP is not satisfied in these markets for the products examined. Engle Granger cointegration testing was also completed and confirmed that the LOOP was not satisfied at all reasonable levels of significance. Although high correlation coefficients suggested satisfaction of the LOOP was possible, post the elimination of spuriousness issues in the price series, the hypothesis that the price series were cointegrated was rejected, yielding, the conclusion that the LOOP does not appear to hold in these markets.

Granger causality provides results to imply that information flows from the larger market Melbourne to the smaller market Adelaide. The results of the Granger causality tests are presented in Table 3. They show that the Melbourne price precedes Adelaide's for washed white cocktail potatoes from South Australia. This suggests that demand shocks from the larger market impact on the smaller Adelaide market. Supply shocks would lead to Granger causality in reverse, from the source of supply to the market of demand. Furthermore, through the use of impulse response functions, which traces out the response of one price series to a shock in the other price series, we see that speed of the information flow is estimated to takes approximately five weeks to complete for potatoes from Adelaide to Melbourne and vice versa. Cherry red tomatoes from Queensland are relatively faster adjusting in four weeks, while large carrots from Western Australia take a long time respond to price shocks between these markets. Granger causality testing of the potatoes is significant, as the potatoes are sourced from South Australia, although the Melbourne prices precede the Adelaide prices which suggest that the information flows from Melbourne, the demand market, to Adelaide, the supply market. The speed of information flow was estimated, using impulse response functions which show that it takes about a month for the tomatoes and potatoes to complete information flows.

Promising correlation results did not translate into the price series being cointegrated. It was concluded that the high correlation coefficient results in Table 1 were biased upward due to the effects of spuriousness. Cointegration findings from the use of both the Engle Granger and Johansen tests led to the same result. The conclusion was that the price series for the potatoes, carrots and tomatoes sold in the Adelaide and Melbourne Wholesale markets were not cointegrated and, therefore, did not satisfy the LOOP. Granger causality tests and impulse response functions testing resulted in the finding that information flows from the larger demand market to the supply market.

Table 2 Johansen cointegration test findings

Product	Series	No of cointegrating equations	Lagged intervals	Degrees of freedom	Trace test	Maximum eigenvalue	0.05 Critical value for trace test*	0.05 Critical value for max eigen test*	Remarks
Large WA carrots carton	MEL-ADE	None	1 to 2	72	14.35	10.69	15.49	14.26	Non-rejection of null indicates no cointegration at the 0.05 level
		At most 1	1 to 2	72	3.66	3.66	3.84	3.84	Non-rejection of null indicates no cointegration at the 0.05 level
Cherry red QLD tomatoes	MEL-ADE	None	1 to 2	66	12.51	9.1	15.49	14.26	Non-rejection of null indicates no cointegration at the 0.05 level
		At most 1	1 to 2	66	3.41	3.41	3.84	3.84	Non-rejection of null indicates no cointegration at the 0.05 level

* Critical values are taken from MacKinnon-Haug-Michelis (1999) p-values.

Table 3 Granger causality findings

Product	Null hypothesis	Degrees of freedom	F-statistics	Remarks
Large WA carrots carton	Adelaide Granger causes Melbourne	70	4.24***	Do not reject null
	Melbourne Granger causes Adelaide	70	1.93	Reject null
Washed white cocktail SA potatoes 15kg bag	Adelaide Granger causes Melbourne	87	0.49	Reject null
	Melbourne Granger causes Adelaide	87	2.88***	Do not reject null
Cherry red QLD tomatoes 250gm punnet	Adelaide Granger causes Melbourne	59	0.48	Reject null
	Melbourne Granger causes Adelaide	59	1.27	Reject null

* Denotes significance at 10%,** at 5% and *** at 1%

7. Policy implications

The LOOP appears useful in evaluating the pricing efficiency of markets. If the LOOP is not satisfied it implies that pricing signals are inefficient. These signals are transmitted vertically and horizontally throughout the supply chain, implying that market agents are acting on less than informative market signals resulting in a misallocation of resources and ultimately higher prices for consumers. Using weekly average wholesale price data for three popular vegetable products in the Adelaide and Melbourne markets, the LOOP was tested using cointegration. The key finding from this study is that the LOOP does not appear to hold in the Adelaide and Melbourne markets.

These findings lead to the conclusion that these markets are not priced efficiently, as there is no sign of cointegration between the wholesale price series. The findings of this analysis are, therefore, in contrast to the findings presented by the ACCC (2008) which was based on analytics and anecdotal evidence from market agents. Pricing efficiency is promoted by the effective and timely communication of market information. A policy recommendation stemming from this study is that the general level of market information should be improved. Particularly volume and trade flow information needs to be enhanced. It has been demonstrated elsewhere in the past, with experimental simulation, that reduced public information leads to decreased pricing efficiency (Anderson *et al.* 1998), while mandatory price reporting has the opposite effect (Bastian *et al.* 2001). Mandatory price reporting by wholesalers constitutes one possible way to increase market information. The development of information communication technology such as the internet should be a central tool in any information dissemination mix developed. The internet provides information instantly, is easily accessible and happens to be cost effective.

Although this study contains limitations regarding the empirical procedures and the short time span of the price series, it does highlight the need for greater emphasis on empirical analysis of market performance in Australia. There is great potential value and opportunities for future research in applied market performance analysis in Australian supply chains. Further research can extend this study by incorporating the entire network of Australian wholesale vegetable markets into the analysis. What also may be done is to use the superior switching regime modelling approach to testing the LOOP. If explicit transfer cost and tradeflow data are unavailable, it is suggested that simulation techniques might be used.

8.   Concluding comments

Australian vegetable wholesale markets face challenges regarding the levels of market information. There is very limited empirical literature regarding pricing efficiency in these markets. By testing whether or not the LOOP holds in the Adelaide and Melbourne markets, we were able to test the pricing efficiency of these markets. Using cointegration and wholesale average price information, we conclude that prices do not appear to satisfy the LOOP. This indicates a less than efficient allocation of resources in these markets, implying that the general level of market information should be increased.

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