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Spatial price premium transmission for Meat Standards Australia-graded cattle: the vulnerability of price premiums to outside shocks*

Luis Emilio Morales, Nam Hoang and Eric Stuen†

Studies of market integration show that price changes are transmitted spatially through arbitrage. Transmission across differentiated agricultural products is important to investigate, but it has not been explored given its complexities for assessment. Using data from Australian cattle markets, we examine the dynamics of Meat Standards Australia price premium transmission between states. An impulse response function analysis using Bayesian vector autoregression with sign restriction identification shows that shocks to prices and price premiums are partially transmitted contemporaneously between markets and it takes several weeks to complete transmission. In addition, we find an asymmetry of price and price premium shocks originating in Southern Queensland that have an inverse immediate impact in New South Wales, and take months to transmit the usual price response. This outcome may be explained by differences in cattle availability in each state, which can be related to forage availability due to weather conditions. Based on these results, producers can forecast fluctuations on price premiums and adjust their cattle supply accordingly.

Key words: Bayesian vector autoregression (BVAR), cattle markets, market integration, Price premiums, sign restriction identification.

1. Introduction

Volatility in the premiums paid for high-quality agricultural products is a risk that discourages their production. To encourage producers, the expected price premium in competitive market equilibrium should be at least equal to the additional cost of producing the high-quality product (Lapan and Moschini 2007). Under a competitive market structure, with prices for base-

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† Luis Emilio Morales (e-mail: emilio.morales@une.edu.au) is Lecturer in Agricultural Economics at UNE Business School, University of New England, Armidale, Australia. Nam Hoang is Senior Lecturer in Econometrics at UNE Business School, University of New England, Armidale, Australia. Eric Stuen is Associate Professor of Economics at Department of Business, University of Idaho, Moscow, Idaho, USA.

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quality and high-quality grades determined by market supply and demand, price premiums need to be transmitted to maintain incentives for farmers selling high-quality products. Market integration also implies that a shock to anyone market has symmetric impacts on all related markets. However, to our knowledge, no previous empirical studies have examined the dynamics of adjustment and spatial transmission of quality-grade price differentials. In this paper, we connect the topics of quality-grade price premiums and spatial price transmission by studying a context in which the transmission between local cattle markets in Australia varies among quality grades. Higher-quality grades are represented by Meat Standards Australia (MSA) cattle, but it is unclear how effectively shocks to supply and demand factors are transmitted through markets, the time periods involved, and whether price premiums for MSA-grade meat are maintained.

The Australian beef industry supplies the domestic market and exports live animals, frozen and chilled beef with different attributes, depending on the requirements of each market (Mulley *et al.* 2014). Within the domestic market, a grading system is used to signal meat quality and address declines in domestic consumption (Polkinghorne *et al.* 2008). Using the MSA scheme, the industry can predict the eating quality of each cut, classifying them in one and two stars (unsatisfactory), three stars (MSA graded), four stars (premium quality) and five stars (supreme quality) (Meat and Livestock Australia (MLA) 2017a). Lyford *et al.* (2010) reported consumer preferences in Australia, Ireland, Japan, and USA. On average, consumers were willing to pay 0.5, 1.7 and 2.5 times the value of three star samples for two, four and five star ones, respectively. These preferences explain the MSA price premiums across major cuts, which on average were AUD1.73 per kilogram during 2014–2015, and the average cattle premiums of 0.24 Australian cents per kilogram of carcass weight (AU cents/kg cwt) during 2015–2016 (MLA 2017b).

Meat Standards Australia-graded and MSA-ungraded cattle can be processed and sold in domestic and export markets, according to specifications of each market made in contracts with abattoirs and exporters. In addition to MSA, there are other grading systems that support branding schemes to indicate meat quality for domestic and international markets, including organic and OBE beef from the Channel Country grasslands. In this scenario, with several alternative specifications of attributes required in different markets, this research focuses on the dynamics of MSA price premium transmission between local markets, given the increasing number of MSA-graded live cattle traded by Australian farmers (MLA 2017b). During 2015–2016, Queensland (QLD) had the largest number of MSA-graded cattle with 1.3 million head, followed by New South Wales (NSW) with almost 1 million head, which represent approximately 35 and 56 per cent of the state cattle slaughter, respectively (Australian Bureau of Statistics (ABS) 2016a).

Meat Standards Australia price premiums fluctuate under competitive conditions in cattle markets in Australia, where there is no grid pricing for MSA-graded cattle that fixes the price premium with respect to the MSA grade. In these markets, MSA-graded (high-quality) and non-MSA prices vary due to changes in demand and supply for each grade, which captures variations in production and demand in domestic and export markets, affecting the MSA price premiums. In this situation, producers base the decision over whether it is worth incurring the extra costs to produce high-quality cattle on current and expected MSA price premiums.

While price premiums have been investigated within single local markets, and spatial price transmission has been studied in terms of geographic price convergence, based on the law of one price (LOP) and market integration, the dynamics of the spatial transmission of price premiums have not been previously examined. Spatial price transmission has been studied in several contexts to test market integration and to inform companies' selling decisions (e.g., Williams and Bewley 1993; Fackler and Goodwin 2001; Kaspersen and Foyn 2010; Esposti and Listorti 2013; Aruga and Li 2016). In addition, different degrees and speeds of spatial price transmission have been identified between markets in different agro-food chains, including cattle in Queensland, Australia (Williams and Bewley 1993), sorghum and coffee in Uganda (Kaspersen and Foyn 2010), durum wheat in Italy (Esposti and Listorti 2013) and seafood in Japan (Aruga and Li 2016). Price premiums are expected to differ for each local market (Tomek and Kaiser 2014), reflecting differences in attributes and variations in regional supply and demand for products of each quality grade. At the same time, under a competitive market structure and market integration, such that arbitrageurs can easily buy and sell across locations, price differences for a particular quality level are expected to be transmitted between local markets until the price differential between locations equals the transfer costs. Two studies that theorise about such transmission but do not test for it directly are Fackler and Goodwin (2001), and Tomek and Kaiser (2014).

There are several motivating reasons for conducting this research. Given that price transmission for physical commodities tends to be imperfect, whether and how fast price premiums for cattle are spatially transmitted are empirical questions that we aim to address and add to the body of knowledge of price transmission. Second, this research is relevant to analysing and forecasting the behaviour of prices in the Australian beef market, and assessing the viability of producing MSA-grade beef. The examination of whether price premiums freely fluctuate is also relevant to antitrust policy, as any finding of fixed premiums or nontransmission would be suggestive of price fixing in the market.

Market integration is usually less than perfect, so that price transmission could be inhibited due to one or more of the following factors: market failure, government intervention, transport, processing and marketing costs, and consumer preferences in cases when products offered in one market are imperfect substitutes of products traded in other markets (Rapsomanikis and Mugera 2011; Greb *et al.* 2013). Examples of disparities in price transmission due to differences in product quality were found by Norman-López *et al.* (2013) in Australian rock lobster, and by Li and Saghaian (2013) in coffee beans in Colombia and Vietnam. These variations in price transmission between different quality grades could lead to fluctuations in price premiums for high-quality products, which is the focus of this study. To test this, NSW and Queensland South (QLDS) live cattle markets were studied; given they represent a high proportion of the cattle traded in Australia, there are some variations in supply and demand drivers, and due to data availability.

In this article, we first discuss the theory of price premiums and price transmission, and by extension spatial price premium transmission. We then describe the data used in this study and the fluctuations in MSA price premiums during the period under analysis. After that, we introduce the theoretical model used to test spatial transmission of prices and MSA price premiums, and the Bayesian Vector Autoregression (BVAR) method of estimation. The next section discusses impulse response functions (IRF) that we estimated using the BVAR model, which first reviews the size and dynamics of price transmission between different quality grades, and then analyses the spatial price premium transmission between geographically separate cattle markets. Finally, we discuss the implications of our analysis for understanding market integration and price premium transmission, and its implications for agricultural companies supplying high-quality grade products.

2. Determinants of price premiums and spatial transmission theory

A considerable amount of literature has investigated the sources of price differentials paid for high-quality products. According to Ding *et al*. (2010), price differences can be related to disparities in quality that could increase consumer utility. In addition, variations in price premiums have been found for different forms of product differentiation, including fair trade, branded, eco-labelled and organic products. Roheim *et al*. (2011) estimated a premium of 14% for eco-labelled seafood products in the UK, while Batte *et al*. (2007) found a range of price premiums from 4 to 17 per cent for a cereal box with different attributes, including organic. Therefore, disparities in price premiums could be explained as the result of differences in consumer utility and product differentiation related to attributes of each product. In addition, variations in prices of different quality grades could alter price premiums paid in different locations. But, according to Lapan and Moschini (2007), in equilibrium the farm-level premium for the high-quality product should at least compensate for the difference in production cost.

Fackler and Goodwin (2001) stated that spatial arbitrage will guarantee that the difference between prices of a homogenous good at any two local markets will be equal to the cost of moving the good between locations, a property known as the LOP. Therefore, in competitive markets without trade barriers, prices should differ only by transfer costs. Goodwin and Piggott (2001) highlighted the need to include transaction costs in price transmission models to get more reliable inferences about market integration. Consequently, they utilised threshold autoregression and cointegration models to test price transmission when there are barriers that might inhibit price adjustments; thus, commodity prices could differ between markets due to the effects of these thresholds. Greb *et al.* (2013) extended the threshold regime and indicated that price transmission between markets will materialise between thresholds under a 'regime-dependent' price transmission, when variations in prices in each market exceed transfer costs between markets. In cases where farmers are dispersed and can trade their products in each market, they face variable transfer costs depending on the farm and point of delivery location; therefore, farmers will maximise their profits by selling their cattle in the market that offers them the higher net price after deduction of transfer costs. Variations in the volume traded in each market due to the response by farmers to the net price received will lead to price transmission.

According to Norman-López *et al.* (2013) and Tomek and Kaiser (2014), variations in prices of different quality grades are correlated with variations in price differentials between quality grades, attributes and types of products. In the case of the Australian beef industry, Chang and Griffith (1998) found that prices at farm, wholesale and retail levels tend to move together over time and respond to the same shocks in different degrees. Figure 1 presents an example of the net prices that Australian cattle companies supplying two markets could receive. These costs influence their decision to supply a specific market with cattle of a particular grade, creating boundaries between supplying areas (Tomek and Kaiser 2014).

More than one boundary will exist when premiums differ between markets. In the example presented in Figure 1, which assumes similar transfer costs, two boundaries are highlighted, one boundary for the non-MSA (ungraded) cattle and another for the MSA (high-quality) grade cattle certified by MSA. The maximum difference in the premium paid between markets is twice the transfer costs, considering the maximum potential differences in prices paid in both markets at each quality grade.

When prices of the different grades vary in a similar proportion and they are transmitted in an equivalent way between markets, the price premiums will remain constant. Under this scenario, MSA prices will vary in the same proportion as non-MSA cattle prices, and price premiums will remain constant in each market as presented in Equation (1):

$$\begin{aligned}\text{Price Premium} &= \left[\frac{\text{Price}_{\text{MSA}kt} - \text{Price}_{\text{NON-MSA}kt}}{\text{Price}_{\text{NON-MSA}kt}}\right] \times 100 \\ &= \left[\frac{\text{Price}_{\text{MSA}kt}(C_{\text{MSA}kt}) - \text{Price}_{\text{NON-MSA}kt}(C_{\text{NON-MSA}kt})}{\text{Price}_{\text{NON-MSA}kt}(C_{\text{NON-MSA}kt})}\right] \times 100 \\ &\text{for } C_{\text{MSA}kt} = C_{\text{NON-MSA}kt},\end{aligned} \tag{1}$$

where $\text{Price}_{\text{MSA}kt}$ is the price of MSA cattle in a particular market place k at time t; $\text{Price}_{\text{NON-MSA}kt}$ is the price of non-MSA cattle in a particular

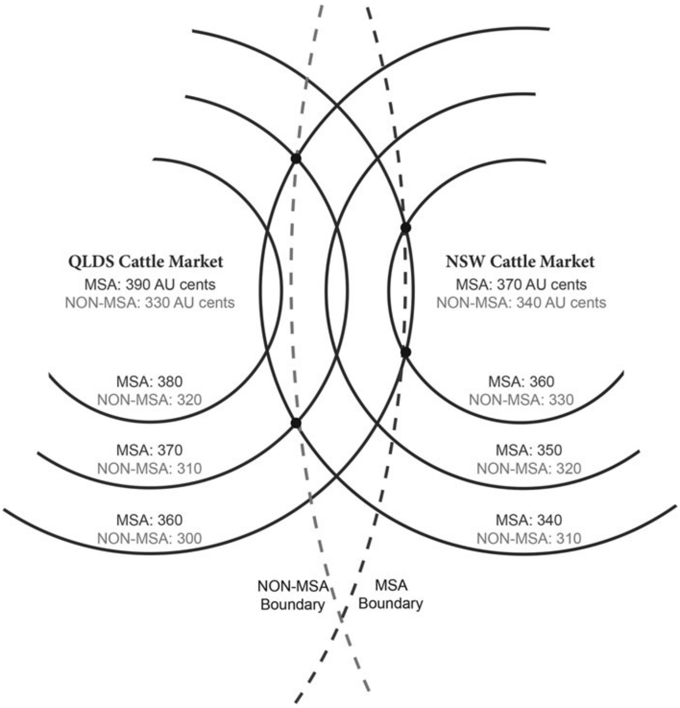

Figure 1 Example of different grade boundaries between supplying areas.
Source: Adapted from Tomek and Kaiser (2014).

market place k at time t; $C_{\mathrm{MSA}kt}$ is a coefficient that adjusts the price of the MSA cattle in a particular market place k at time t after a shock; and $C_{\mathrm{NON\text{-}MSA}kt}$ is a coefficient that adjusts the price of the non-MSA cattle in a particular market place k at time t after a shock. Therefore, in the case of Equation (1) $C_{\mathrm{MSA}kt}$ is equal to $C_{\mathrm{NON\text{-}MSA}kt}$, and the price premium will remain constant. Alternatively, $C_{\mathrm{MSA}kt}$ and $C_{\mathrm{NON\text{-}MSA}kt}$ could be different due to variations in the transmission of shocks, and as a consequence, price premiums will fluctuate and might be transmitted between markets in different locations.

3. Data

We collected weekly average prices of non-MSA and MSA-grade live cattle sold in NSW and QLDS between July 2011 and December 2015. We obtained the data from reports of direct selling of livestock to processors from over-the-hook sales, prepared by MLA (2016). We use for both non-MSA and MSA prices the reported values of 260–280 kg steers in AU cents/kg cwt, given their availability. Additionally, we deflated all prices to July 2011 values using the quarterly Consumer Price Index (CPI) obtained from the ABS

Table 1 Average non-Meat Standards Australia (MSA) prices, MSA prices, MSA premiums and MSA price premiums

		2011	2012	2013	2014	2015
Non-MSA Cattle Prices	QLDS	339.13	318.21	297.17	320.87	431.31
(AU cents b07-2011/kg cwt)	NSW	338.74	325.22	308.67	327.21	433.99
MSA Cattle Prices	QLDS	358.91	352.13	328.90	363.29	462.31
(AU cents b07-2011/kg cwt)	NSW	347.49	346.82	332.09	348.76	464.84
MSA Cattle Premium	QLDS	19.78	33.92	31.73	42.42	31.00
(AU cents b07-2011/kg cwt)	NSW	8.75	21.60	23.42	21.54	30.85
MSA Cattle Price Premium	QLDS	5.87%	10.74%	10.79%	13.52%	7.45%
(as a Proportion of Base-Grade Cattle Prices)	NSW	2.56%	6.65%	7.61%	6.61%	7.11%

Note: 2011 values cover only the period July to December.
Source: Meat and Livestock Australia (MLA) (2016). Available at http://www.mla.com.au/Prices-and-markets.

(2016b). The evolution of prices and price premiums through the period under analysis is presented in Table 1.

Even though prices fluctuated in a similar pattern in both states during the period under analysis, there are variations in the magnitude of changes in prices between locations, leading to wide divergence in the MSA price premiums of NSW and QLDS; that is, there are clear differences in the amount and proportion of the premiums paid for MSA certified cattle compared to non-MSA cattle prices. There are several factors that could affect MSA price premiums in each local market, including seasonal conditions, herd dynamics, and competition from export markets. However, under market integration conditions, it is expected that these fluctuations in price premiums would be spatially transmitted between states and so tend to converge over time. The fluctuations in price premiums in each state during the period under analysis are presented in Figure 2.

Figure 2 shows continual variation in the price premium in each state throughout the period studied due to changes in the non-MSA and MSA-grade prices. Contrary to expectations, it is not clear from the figure that there is a specific pattern of correlation between the price premiums of each state. Since it is not clear from casual examination that changes in the price premium are spatially transmitted, there is need for formal analysis that investigates the degree of spatial price premium transmission between local markets.

4. Spatial transmission testing framework

A period of time may pass for prices in a specific agricultural market to adjust to shocks in other markets due to previous contracts and transport delays. Therefore, dynamic models including lagged endogenous and exogenous variables have been used to assess spatial price transmission, including

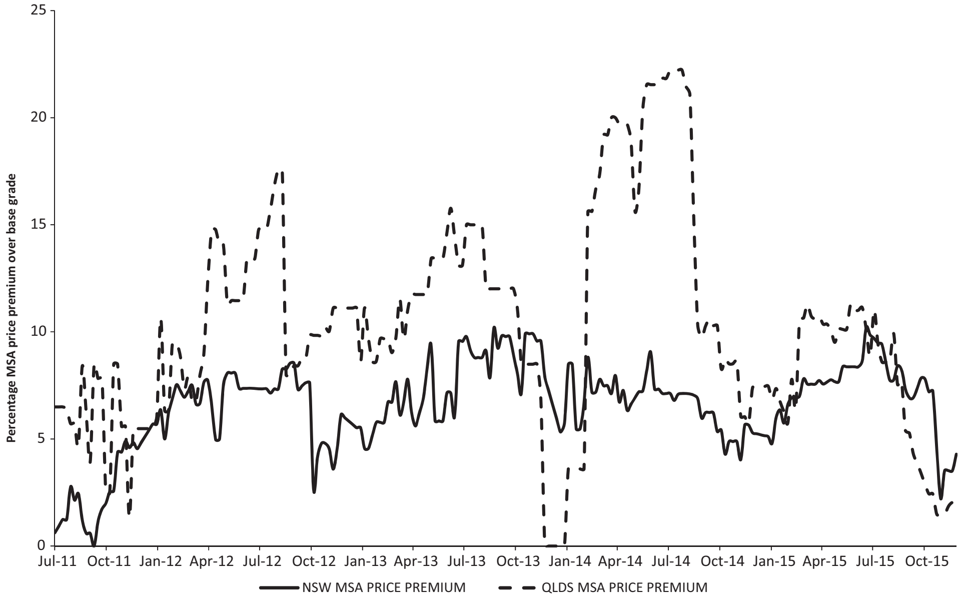

Figure 2 Meat Standards Australia (MSA) price premium fluctuation (July 2011 to December 2015). Source: Meat and Livestock Australia (MLA) (2016). Available at http://www.mla.com.au/Prices-and-markets. Note: During the period December 2013 to January 2014, cattle prices were high in QLD, with non-MSA prices similar to MSA prices, which made MSA price premiums close to zero.

different versions of vector autoregression (VAR) models (Williams and Bewley 1993; Fackler and Goodwin 2001). The spatial price transmission dynamic model used in this study has the following form:

$$A_0 P_t = C_0 + \sum_{s=1}^{S<T} C_s P_{t-s} + u_t, \tag{2}$$

where P_t is a matrix of prices at time t that includes non-MSA-grade and MSA-grade prices in different markets. Moving the matrix A_0 to the right-hand side of Equation (3), the term $A_0^{-1} u_t$ presented in Equation (3) is the random stochastic residuals matrix ϵ_t estimated from the residuals u_t of the unrestricted VAR, where $A_0^{-1} u_t = \epsilon_t$.

$$P_t = A_0^{-1} C_0 + \sum_{s=1}^{S<T} A_0^{-1} C_s P_{t-s} + A_0^{-1} u_t. \tag{3}$$

Similarly, if we apply the spatial transmission dynamic model for prices shown in Equation (3) to price premiums, the model used in this study to test the dynamics of spatial price premium transmission is as follows:

$$\mathrm{PP}_t = A_0^{-1}C_0 + \sum_{s=1}^{S<T} A_0^{-1}C_s\mathrm{PP}_{t-s} + A_0^{-1}u_t, \tag{4}$$

where PP_t is a matrix of price premiums at time t, presented in percentage premium over non-MSA-grade price. Using variables in levels is only appropriate when price series are stationary. A stationary series is one that has a constant mean, constant variance and constant autocovariances for each given lag. When nonstationary series are regressed, the result could be a spurious regression, where there appears to be a significant relationship among unrelated variables trending over time (Granger and Newbold 1974). The models presented in Equations (4) and (5) are structural VAR (SVAR), and can be transformed into VAR in standard or reduced form when there is no simultaneity between the endogenous variables. The reduced form includes only predetermined values on the right-hand side of the equation, assuming that there are no contemporaneous effects. That form can be validly used when the error terms are uncorrelated, and then, their contemporaneous covariances are equal to zero (Lütkepohl 2005).

In cases where contemporaneous effects arise, it is possible to use the vector moving average (VMA) representation of the SVAR model and analyse its IRF or innovations, as indicated by Sims (1980). In the case of the VAR model of price premiums, the VMA representation will be as presented in Equation (5):

$$\mathrm{PP}_t = \mu + \sum_{s=0}^{\infty} \emptyset_s e_{t-s}. \tag{5}$$

Using this representation, prices and price premiums, which are the endogenous variables in this study, are presented as functions of current and past values of independent structural shocks or impulses, tracing out the impact over time of shocks on prices and premiums in each market included in the VAR system. To fully identify the structural shocks, restrictions on the errors can be imposed according to theory (Fackler and Goodwin 2001; Lütkepohl 2005).

Contemporaneous effects can be tested using causal ordering of shock propagation through Cholesky decomposition. This technique imposes recursive restrictions on the direction of the shocks using a lower triangular variance–covariance matrix with restrictions applied to the residuals. Therefore, Cholesky decomposition only allows estimating the contemporaneous response to shocks on one direction. To estimate the SVAR, we need to find a matrix A_0 such that $\epsilon_t = A_0^{-1}u_t$, which is equivalent to $u_t = A_0\epsilon_t$, and $E(u_t u_t') = I$, to be able to identify the structural shocks. This is equivalent to $E(A_0\epsilon_t\epsilon_t' A_0')) = E(A_0\Sigma' A_0') = I$. Cholesky decomposition gives $A_0 = P^{-1}$, where $P = Chol(\Sigma)$ is the Cholesky decomposition of Σ. There is an orthogonal matrix H called the 'given matrix', such that $HH' = I$, where $Q = PH$ and $A_0 = Q^{-1}$. There will be an infinite number of given matrices H. In all cases, $u_t = A_0\epsilon_t$ will also be satisfied and the orthogonal condition of the shocks will be:

$$QQ' = PHH'P' = PIP' = \mathrm{PP}' = \Sigma, \tag{6}$$

which means

$$E(u_t u_t') = Q^{-1}E(u_t u_t')(Q^{-1})' = Q^{-1}\Sigma(Q^{-1})' = Q^{-1}QQ'(Q')^{-1} = I. \tag{7}$$

In this study, we follow a sign restriction identification procedure similar to the one used by Uhlig (2005) and Fry and Pagan (2011), where Cholesky identification is initially used for the VAR model and then the recursive restriction is relaxed, to estimate all possible impulse vectors and calculate their response functions. This procedure considers the effects of the variables as unknown, which allows the data to speak about the relationships between the variables included in the model. The result obtained should be compared against theory, and then, the researcher decides whether or not to impose *a priori* sign and zero restrictions on the parameters.

We can generate a large number of matrices A_0, allowing the data to speak about the relationships between the endogenous variables. In this paper, we use the mean-target (MT) methodology suggested by Fry and Pagan (2011) to determine the matrix A_0, with the purpose of finding a model with impulses closest to the mean of the impulses from all models. There are five steps required to decide the matrix A_0: (i) subtract the mean of each impulse, (ii) divide the subtracting mean impulses by their standard errors to get standardised impulses, (iii) place the standardised impulses in a vector Θ^k, (iv) choose k that minimises $(\Theta^k)(\Theta^k)'$ and (v) use this k to determine the model.

5. Bayesian VAR estimation

Vector autoregression is a popular model for studying the interdependency between time series variables. It is not a parsimonious model and usually contains a large number of parameters to be estimated. Estimation of a VAR model by ordinary least squares (OLS) is inefficient relative to the Bayesian VAR approach, which is growing in popularity. By including the out-of-sample information through the prior, Bayesian estimation uses more information when estimating the VAR parameters (Koop 2003; Koop and Korobilis 2010).

Bayesian VAR estimation uses out-of-sample information to estimate the distributions of the unknown parameters of the VAR model, which are called the prior distributions. When data become available, the prior distributions are adjusted to the posterior distributions using the Bayes' theorem. The posterior distributions are then used to make inferences about the true parameters of the model. In the case of the VAR(2) model of price premiums (PP), the posterior distributions are as follows:

$$\pi(\theta|\mathrm{PP}) = \frac{f(\mathrm{PP}|\theta)\pi(\theta)}{f(\mathrm{PP})}, \tag{8}$$

where θ represents the model parameters; $\pi(\theta)$ is the hypothesis about their prior distributions; $\pi(\theta|\mathrm{PP})$ represents posterior distributions; $f(\mathrm{PP}|\theta)$ is the distribution of PP given θ, which is the likelihood function; and $f(\mathrm{PP})$ is the marginal distribution of PP, which is the unconditional distribution of PP. The posterior density function is equal to the likelihood function multiplied by the prior density function and divided by the marginal density function of PP. Since the marginal density function of PP is constant, we can write the posterior distribution as a fraction of the likelihood function multiplied by the prior distribution:

$$\pi(\theta|\mathrm{PP}) \propto f(\mathrm{PP}|\theta)\pi(\theta). \tag{9}$$

In this analysis, we use the 'Minnesota Priors' which were developed by Litterman (1979). They were selected due to their ability to produce shrinkage coefficients which fit well to the nature of VAR models, improving the efficiency of the estimations. In a VAR with all variables endogenous, the efficiency of the model is affected by the inclusion of the variables' own lags and the lags of other variables. It is widely agreed that the longer the lags, the smaller the impacts on endogenous variables, that is the smaller the size of the coefficients in probability. Bayesian estimation fits better than OLS in this context using out-of-sample information through the priors (Doan *et al.* 1984). Consequently, BVAR estimations are more efficient compared to the classical VAR estimations, which results in more accurate inference of impulse responses.

6. Estimation results

Previous studies working with time series in economics demonstrated that the series were incorrectly categorised as nonstationary when they were actually persistent with nonlinear trend series (Christiano *et al.* 2005; Uhlig 2005; Canova 2007; Kilian 2009). Those studies show that most of the price time series contain a nonlinear trend; therefore, they are trend-stationary. According to Canova (2007), most of unit root tests could not detect persistent trend-stationary series. In this scenario, we first de-trended the series using the band-pass filter with 12 lags proposed by Baxter and King (1999). This filter was selected based on its power and better performance for small size samples (Pedersen 2001). Using the Baxter-King filter, the low and high frequency trend components in an economic series are suppressed as it shuts down all fluctuations outside a chosen frequency band (DeJong and Dave 2011). After the series were de-trended, we undertook unit root tests proposed by Elliot *et al*. (1996), and Ng and Perron (2001) to determine whether or not the de-trended series are stationary. Both tests were selected due to their relatively better power and small sample size properties in comparison with other unit root tests. The results of the unit root tests for the series in levels are presented in Table 2.

The results of the unit root tests indicate that it is possible to reject the hypothesis that the de-trended cattle price series have unit roots at 5% significance when they are in levels. Hence, we used the de-trended variables in levels in the estimations of BVAR models and conducted a sign restriction identification procedure for the BVAR models of prices and price premiums using 10,000 simulations of different identifications. The results confirm the presence of contemporaneous price and MSA price premium effects between Australian cattle markets when there are shocks to prices and price premiums. Under this scenario, the impact of shocks on prices and premiums may be analysed using IRF (Sims 1980).

Figure 3 presents the confidence interval and mean-target IRF of prices due to shocks on non-MSA prices for a horizon up to 40 weeks after the shock, allowing the data to speak about the relationships between prices of different grades in both states.

In Figure 3, Panels (A) to (H) present the impulse responses of non-MSA-grade and MSA-quality grade prices to shocks on non-MSA prices in NSW and QLDS cattle markets, from our estimated BVAR(4) model for prices. The results show that in all possible response functions, a positive shock on non-MSA prices in NSW is associated with a contemporaneous increase in prices of different grades in NSW and QLDS markets, as shown in Panels (A), (C), (E) and (G), in all cases with a decaying effect that takes several weeks. These findings are consistent with the economic theory of market integration and previous results reported by Williams and Bewley (1993) between cattle auctions in QLDS. Conversely, a positive shock on QLDS non-MSA prices is affiliated with an increase in non-MSA prices in NSW as

Table 2 Unit root tests results of de-trended series

	Elliot *et al*. (1996) test statistic		Ng and Perron (2001) MZα test statistic	
	NSW	QLDS	NSW	QLDS
Non-MSA Cattle Prices (AU cents b07-2011/kg cwt)	0.5223***	0.4215***	−177.8140***	−117.7160***
MSA Cattle Prices (AU cents b07-2011/kg cwt)	0.2548***	1.2579***	−277.3740***	−126.4610***
MSA Cattle Price Premium (AU cents b07-2011/kg cwt)	3.3334***	0.8222***	−27.8900***	−71.9482***

Note: Null hypothesis: Series has unit root. (***), (**) and (*) indicate that the parameter is significant at the 1%, 5% and 10% levels, respectively.

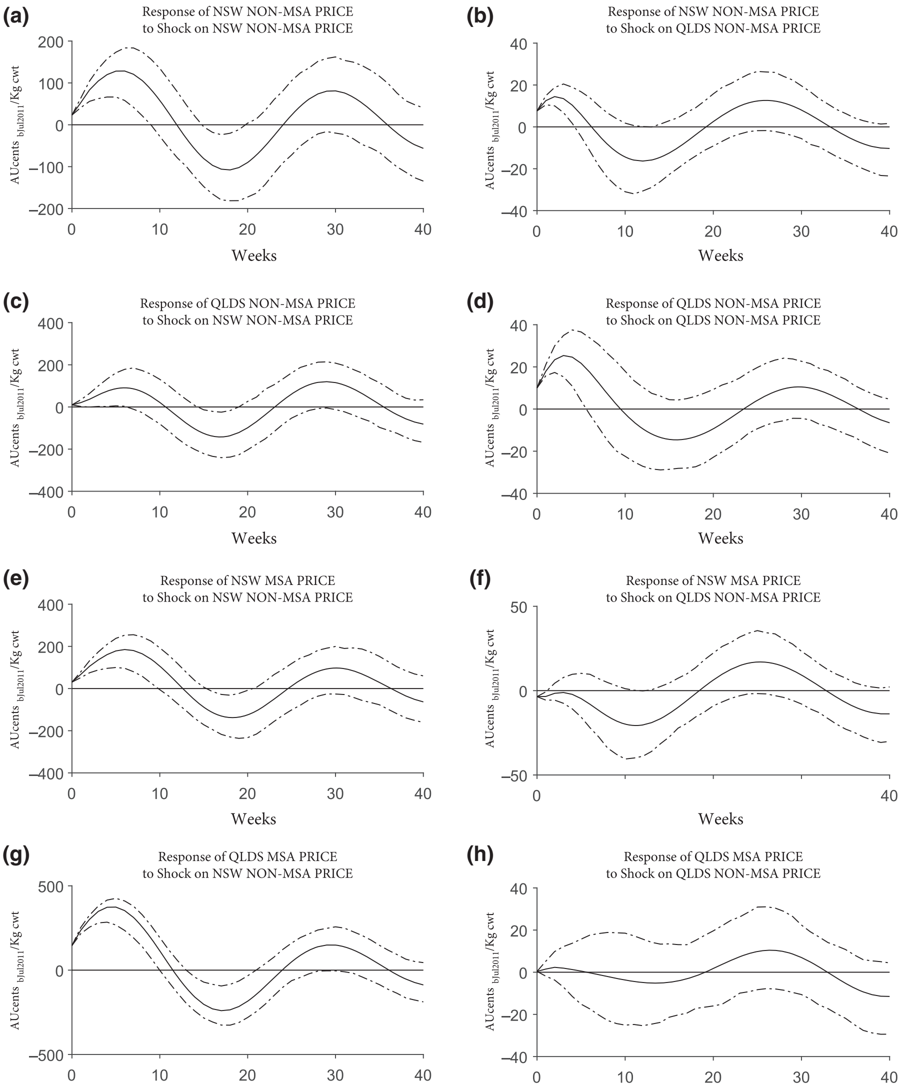

Figure 3 Ranges for impulse response to shocks on non-Meat Standards Australia prices. Graphs present the impulse response functions and its 95% CI.

shown in Panel (B), and with a slight decrease in MSA prices in NSW as presented in Panel (F). In the latter case, the negative contemporaneous response of NSW MSA-quality grade prices to positive shocks on the QLDS non-MSA-grade price is followed by a positive variation in the second week. This result is contrary to the theory of market integration, given the process of arbitrage assures that an increase in price in one location is quickly met by an increase in the other. Here, we see that a price increase for non-MSA cattle in QLDS results in a slight contemporaneous decrease in price for MSA cattle in NSW, which may be due to several reasons. Firstly, a high proportion of

QLD meat is exported to different markets, some of them with high-quality requirements that are met with MSA-graded beef, for example EU and Saudi Arabia markets. Exports to some of those export markets are not possible all the time due to limited quotas, so the demand factors switch on and off. In contrast, NSW beef production is mostly oriented to domestic consumption, which is much more stable. Evidence of this is in Figure 2, where there are larger variations in QLDS MSA price premium, which probably represent moments when there was more competition from high-quality export markets, such as the EU, and the trough in late 2013 is probably associated with the close of the EU market when the quota was filled. Second, QLDS tends to have more volatile market forces due to shocks from export markets, including live exports, and more extreme seasonal conditions than in NSW. Droughts in QLD result in reductions on forage availability and, consequently, in spikes in the cost of raising cattle and in the supply of cattle. Producers sell stock to avoid overgrazing and negative effects on animals, as found by Gillard and Monypenny (1990) who assessed the effects of drought and stocking rate on beef cattle properties in Northern Australia. Third, variations exist in competition at the processing sector level between geographic regions, with NSW cattle being slaughtered in both regions and most of the QLDS cattle being processed at local abattoirs. Finally, movement of feeder cattle tends to be from north to south between QLDS and NSW, given that the conditions in Northern QLD and Northern Territory are mostly suitable for breeding.

Panels (I) to (P) present the impulse responses of both grades to shocks on MSA-grade prices. The results are similar to those response functions to shocks on non-MSA-grade prices, with positive shocks on MSA-grade prices in NSW related to contemporaneous increases in prices of different grades in NSW and QLDS cattle markets, as revealed in Panels (I), (K), (M) and (O). However, positive shocks on QLDS MSA prices are associated with contemporaneous increases in prices of both grades in QLDS, as presented in Panels (L) and (P), and also with contemporaneous decreases in prices of both grades in NSW, as shown in Panels (J) and (N).

Finally, Figure 5 presents the unrestricted range and mean of estimated IRF for MSA price premiums for a horizon up to 40 weeks after the shock.

Based on our estimated BVAR(2) model for price premiums, Figure 5 Panels (A) to (D) present the impulse responses of MSA price premiums to shocks on price premiums in NSW and QLDS cattle markets. The IRF presented in Figure 5 have a similar transmission pattern to those exhibited by cattle prices, where a 4% shock on MSA price premiums in NSW is contemporaneously associated with a 10% increase in MSA price premiums in QLDS, as shown in Panels (A) and (C), with effects decaying gradually over 10 months. In contrast, a 10% shock on MSA price premiums in QLDS is contemporaneously related to a 4% decrease in MSA price premiums in NSW, which is followed by positive variation in the later weeks, as presented in Panels (B) and (D). Therefore, these results demonstrate that under competitive conditions, shocks on MSA price premiums are transmitted between locations; however, price shocks of different quality grades are not spatially transmitted independently, and there are adjustments to keep the incentives to produce the high-quality product. Most shocks are partially contemporaneously transmitted and take several weeks to complete transmission. The magnitude and signs of the contemporaneous transmission are not reciprocal and vary depending on the origin and direction of the shocks.

As noted above, the inverse relationship between shocks originating in QLDS and the resulting price or price premium in NSW (as seen in Figure 3, Panel F; Figure 4, Panels J and N; and Figure 5, Panel B) is contrary to what would be expected given the LOP, or market integration.

This inverse contemporaneous relationship may be explained by the following scenarios. First, a high value export order or international market opens, which is pursued by large processing firms, which in most of the cases are based in QLD. Second, abattoirs offer a price premium in QLDS to attract cattle, which depending on the requirements of the international market, could push up more MSA cattle prices than non-MSA ones. Third, QLDS abattoirs restrict their volume slaughtered of other cattle in order to meet the requirements of export markets, including their slaughters of NSW cattle that are transported to South-East QLD for being processed and supply beef to domestic markets. Finally, lower demand in QLDS for cattle from NSW could lower prices in NSW, including NSW MSA cattle.

7. Conclusions

When markets fail to offer attractive price premiums, companies do not have an incentive to produce high-quality products. As a consequence, they should focus their efforts on cost management rather than on certification or branding. However, what would be the case when agricultural markets have variable price premiums? In that scenario, companies may be uncertain about whether they should incur additional costs to produce high-quality products and whether they should sell their products in local markets. This article contributes to the literature by studying the existence of spatial transmission of MSA price premiums and the way they are transmitted between markets under competitive conditions. In the case study of MSA cattle price differentials in Australia, there are fluctuations in prices and price premiums that alter the boundary at which it is profitable to transport each grade, thus limiting the supplying areas for different markets and allowing spatial transmission as described by Tomek and Kaiser (2014).

This study demonstrates that there are lags and variations in the transmission of cattle prices and MSA price premiums between markets in Australia, but they tend to adjust over time. We found partial contemporaneous price and MSA price premium transmission between cattle markets, but the effects vary depending on whether the price shock originates in NSW or QLDS, with shocks from the latter generating unusual price responses at first and only later

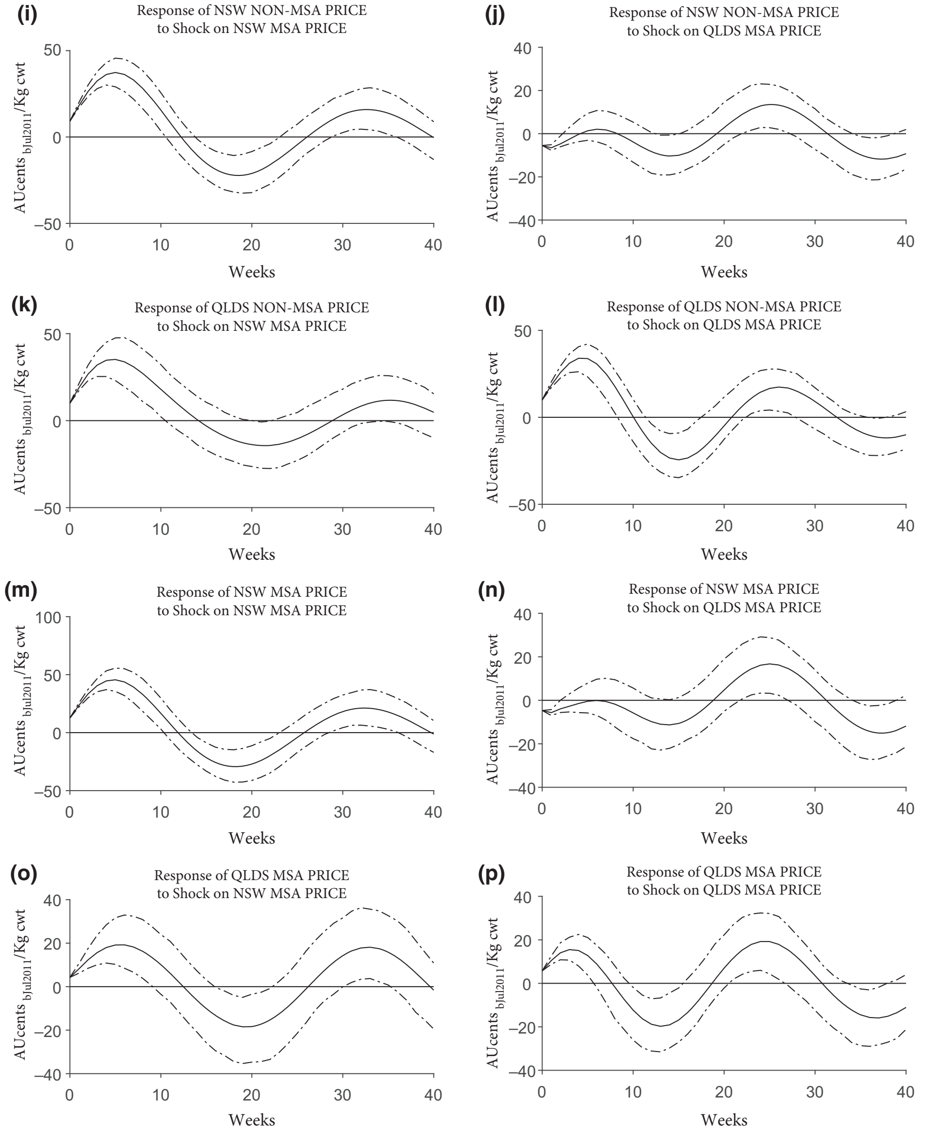

Figure 4 Ranges for impulse response to shocks on Meat Standards Australia prices. Graphs present the impulse response functions and its 95% CI.

reverting to the typical pattern of price adjustment. This may be explained by a concurrent decrease in cattle availability in QLDS and increase in NSW due to several reasons, including differences in the markets served by both regions, variable demand from export markets, more seasonal and extreme weather conditions in QLDS than in NSW, variations in competition from the processing sector, and movement of feeder stock between both regions.

In addition, we found that it takes several weeks for the shocks in prices and MSA price premiums to be fully transmitted, and fluctuations of prices of

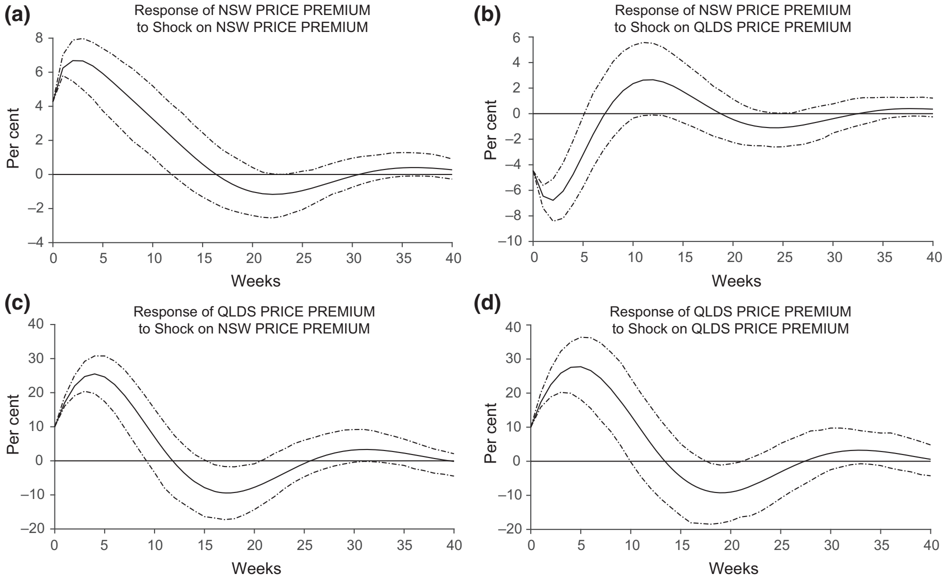

Figure 5 Ranges for impulse response to shocks on Meat Standards Australia price premiums. Graphs present the impulse response functions and its 95% CI.

different quality grades in each market do not always vary in the same proportion. These results explain the volatility exhibited of price premiums during the period under analysis and demonstrate imperfect market integration despite the competitive characteristics of the Australian beef industry. The results do confirm that there is transmission of cattle prices between Australian states, which is consistent with the findings reported by Williams and Bewley (1993) on cattle auctions. In addition, the results also identify that spatial transmission of MSA price premiums between cattle markets follows a similar pattern to that of prices. These findings can be considered to be evidence that under competitive conditions, price premiums are sensitive to shocks from neighbouring regions, which affects the incentive for companies to produce high-quality products. These results confirm that the markets for both non-MSA and MSA-grade cattle in NSW and QLDS are integrated, although imperfectly.

Given our results, in order to maximise their profits, companies commercialising their MSA cattle in different markets should decide their selling location and moment according to the adjustment of prices and premiums, and associated transfer costs, considering these variations in the degree of market integration. The differences found in the transmission of price premiums presented in Figure 5 Panels (B) and (C) explain the disparities in MSA price premiums between markets over time shown in Figure 2. Even though MSA price premiums continually vary, as presented in the case study, under competitive conditions they adjust over several periods.

Further research should study the transmission of price premiums between different quality grades. Additionally, further studies should be conducted to analyse the vertical transmission of price premiums received at retail level and its effects on the volume of the high-quality product offered in different markets. This issue has great relevance for retailers in maintaining a reliable supply of a high-quality product for their customers. We anticipate that this study will be useful for managerial decisions in agricultural companies currently selling or considering the production of high-quality products under fluctuating price premium conditions, by revealing the degree to which the price premium for cattle is sensitive to shocks originating in other locations, and hope it will encourage future research on the dynamics of price premiums in agricultural markets.

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