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The dynamics of price adjustment and relationships in the formal and informal beef markets in Namibia

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ABSTRACT
Beef prices have increased significantly in Namibia in recent years. The main reason for the increase in beef producer prices is the high input cost and drought, leading to excessive culling of breeding herds among commercial farmers. Johansen multivariate test of co-integration and multivariate vector error correction model are used to investigate the price adjustment and the existence of long-run relationship among the beef prices at various stages of the value chain. The results show that the beef cattle prices are integrated and exhibit a long run relationship. Formal (for grade A) and informal (grade C) beef cattle prices suggest that they adjust to long-run equilibrium at different speeds. For instance, prices in the formal markets adjust to disequilibrium at about 81 per cent, while prices in informal markets adjust to disequilibrium at 63 per cent. Granger causality results indicates the log price of grade C beef cattle in the informal market does not cause Granger log price of grade A beef cattle in the formal market, log of wholesale beef price of grade A beef and log of export beef price of grade A unidirectional at the 1 per cent level of significance. The adjustment can be attributed to the objectives and the nature beef markets understudy, coupled to the lack of efficient price information linkages between formal and informal beef cattle markets.

1. Introduction

The lack of studies in price relationship in the beef sector in Namibia has led to inaccuracies in providing important measurements of the degree to which supply and demand shocks arising in one sector (formal) are transmitted to the informal sector or from the European market and South Africa to the Namibian beef market. Producers, consumers and policy makers are concerned about price relationships in the beef cattle markets in Namibia. It is believed that price relationships play a vital role in Namibia's level of beef cattle transaction and therefore has welfare implications for cattle producers in both the formal and informal markets of Namibia. In fact, Ben-Kaabia *et al.* (2005) argue that price movements at different points of transaction and along the supply chain may have important implications for producers' and consumers' welfare. Therefore, producer and retail beef price movements, disparities and formation are important to be understood for proper policy formulation. Prices are among the most followed, analysed and sometimes manipulated by role players (Ben-Kaabia *et al.* (2005). However, controlling prices could be costly and even become pointless, when informal traders and butchers continue to sell cattle and beef in open unregulated markets. It is the understanding of this study that price plays a vital role in the domestic trade

(Meyer, 2006) and should be studied carefully to provide policy issues that are important tools for developing mechanisms for price discovery in the domestic beef cattle market.

Live cattle and beef price movements in recent years have been a result of changes in both supply and demand. Changes in supply and demand dynamics have pointed to herd rebuilding patterns that takes 8 to 12 years due to the biological nature of cattle production (Sartorius von Bach *et al.* 1990), the dynamics of the land tenure system (*freehold* – with enforced property rights resulting into appropriate rangeland and grazing management systems and *non-freehold* – based on customary law and leasehold without enforced property rights, limited or restricted rangeland and grazing management systems), the occasional outbreaks of foot and mouth disease (FMD), particularly in the northern communal areas, such as the Zambezi region, input (feed and veterinary) costs and variations in slaughter weights appear to have influenced such changes (Meat Corporation of Namibia, 2014).

The study investigates the price relationships and adjustments among the prevailing prices for grade A beef cattle in the formal markets and grade C in the informal markets. The study analyses the price relationships between communal farm beef cattle prices for grade C cattle, commercial beef cattle prices (producer price for grade A), beef (wholesale and export) prices for grade A. The average prices of auction prices are used because they yield the normal profit based on the Agra Professional Vision report (2012) in this study. The emphasis is placed on the long-run relationship and dynamics of the speed of price adjustment. The question then is: What form of policies would efficiently regulate price relationship, formation and movement in the formal and informal beef cattle markets, and the kind of measures to adopt in order to improve the competitiveness in terms of pricing? Under the same principle, this article examines the short run and long run effects of the domestic live cattle and beef prices in Namibia. Emphasis is placed on the prices of beef cattle in the informal and formal beef cattle markets. In this article, prices are evaluated using the dynamic price transmission framework of applying of the Johansen multivariate co-integration (JMC) and the Vector Error Correction Model (VECM). Both the JMC and VECM frameworks are advantageous in the sense that they are versatile and provide easy interpretation of results (Lütkepohl, 2005 and Becketti, 2013). For example, the VECM displays desirable parameter estimates of short- and long-term relationships between multiple time series data such as price series in this article.

Therefore this paper attempts to bridge the knowledge gap that exists on price adjustment and the relationship between the formal and informal beef cattle markets in Namibia. Based on classical economic theory, it is also important to investigate the notion that informal beef markets are a derivative of the formal beef market and, being derivative markets, beef cattle prices are expected to behave symmetrically. Therefore, it is important to establish the kind of policies that can be recommended on price adjustment and relationship for dualistic and dynamic beef cattle markets such as those in Namibia.

It is also important to investigate whether the informal beef market in Namibia is a derivative of the formal market. Beef price movements in recent years have demonstrated changes in both supply and demand. It is argued in this article that farmers are faced with excessive production cost problems that lead to the export of more than 400,000 weaners to South Africa (Meat Board of Namibia Report, 2013). During the occurrence of drought, farmers are faced with decisions to reduce the herd size of the cattle. These decisions force prices to take a dip, due to hikes in the supply of slaughter stock. Conversely, after a drought, beef cattle producers are faced with herd rebuilding decisions, where supply reaches its lowest ebb and surges in prices are recorded due to high demand surpassing supply of slaughter cattle (Meat Corporation of |Namibia, 2013, 2014).

Table 1 shows that prices in the communal sector (characterised by thinly distributed informal cattle traders) increased by 91 per cent in real terms compared to 65 per cent in the commercial sector. Price movement from 1990 to 2014 indicates that the price gap between live cattle sold in informal market to that of cattle sold in the formal market is 25.3 per cent in nominal terms, while in real terms the gap is 0.3 per cent in absolute terms. The variation in prices can be attributed to the quality of cattle originating from the two dualistic sub-sectors, with good quality cattle coming

Table 1. Namibian beef cattle price movements (1990–2014).

	Informal price (Grade C live cattle)	Formal price (Grade A Live cattle)	Producer price (Grade A beef)	Wholesale price (Grade A beef)	Export price (Grade A beef)
Live cattle and beef price increases in nominal terms					
Price movement from 1990 to 2014:	255.10%	229.82%	377.50%	237.16%	151.94%
Live cattle and beef price increases in real terms					
Price movement from 1990 to 2014:	164.06%	164.36%	282.72%	170.24%	101.94%
Difference	91.04%	65.46%	94.78%	66.92%	50.01%

Source: Author's compilations using data provided by the Ministry of Agriculture, Water and Forestry Statistical Bulletins of 2005 and 2009 and monthly price data from the Meat Board of Namibia (2014) accessible on the portal (www.nammic.com.na).

from well managed production systems in the commercial farms and less to poor quality cattle produced from high populated (Figure 2), and often over grazed, communal areas (Agra Professional Vision, 2012).

It should also be noted that beef export price effects arise from the exchange currency impulsiveness of tradable beef. Exchange rate impulsiveness is the volatility of domestic currency expressed in terms of the currency of a trading partner/country (Meyer, 2006). It is noted that in the scenario where there is currency depreciation, an exporter is expected to have reduced earnings, but it makes exportable beef cheaper for the importing trading partner. The converse is true as well. Therefore, currency depreciation is usually not a favoured option for trading. In the case of the Namibian beef market, where Namibia is a surplus producer and net exporter of weaners and reliant on South African and European markets, policy movements in these two trading partners has implications on the retail and producer beef prices in Namibia. In particular, exchange rate volatility of the Euro has implications on profitability for beef exporters.

Price movements are synonymous with the above- or below-normal rainfall, where demand for stocking herd increases or decreases, to increase or decrease production. Therefore, economic theory suggests that in a supply response framework, the price of cattle and that of derivate product (beef) and rainfall are major determinants of production variation (Von Bach *et al.* 1990). Meanwhile exogenous factors such as demand from slaughterhouses, abattoirs and butcheries creates competition and wedge between re-stocking and slaughtering. The tug-of-war between supply response and demand response determinants eventually dictate the competitive price (Meyer, 2006; Xing, 2012)

Figure 1 is a graphical representation of real prices of live cattle and beef where IBPRICE is informal live beef cattle price (price per kilogram for grade C cattle), FBPRICE is the formal auction live beef cattle price per kilogram of slaughter weight of grade A cattle; and beef prices depicted by other exogenous variables such as PBPRICE, the producer price (N$ per kilogram of grade A) of beef, WBPRICE is the wholesale price per kilogram for beef cuts (N$ per kilogram for grade A beef) and EBPRICE is the beef export price per kilogram of beef cuts of grade A beef. Figure 1 shows the direction of the relationship between the live cattle and beef prices in the long run. This claim is validated after applying the Johansen co-integration test.

By comparison and definition, the informal market is composed of small beef cattle traders and small slaughter houses operating in small villages and settlements, who slaughter cattle on a daily basis after securing slaughter permits. Informal beef sellers do not adhere much to health standards and regulation, often selling beef carcasses in open areas with no refrigeration or cooling system (Agra Professional Vision, 2012). Therefore, they cannot compete well with the Meat Corporation of Namibia (locally known as MeatCo) and other formal market channels such as auctions, slaughterhouses and butcheries on hygiene and quality particularly for processed beef cuts. MeatCo is registered as parastatal and owned by registered cattle producers and a chief buyer of beef cattle in Namibia and offers superior quality at a high price per kilogram (Meat Corporation of Namibia,
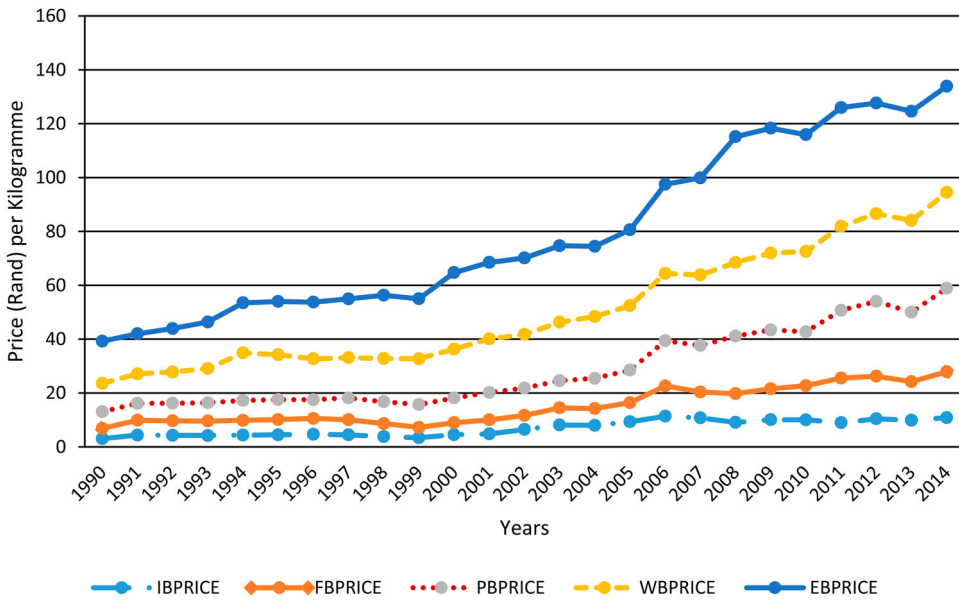
Figure 1. Shows the real live cattle and beef prices in levels (1990–2014).
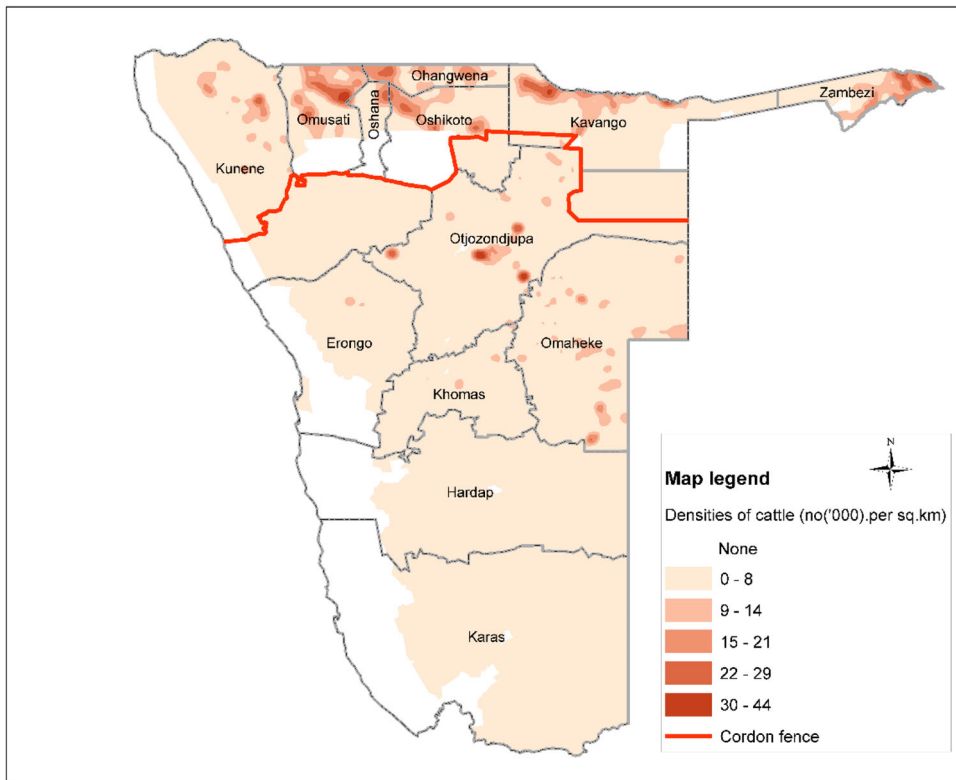

Figure 2. Map of Namibia depicting the cattle densities and distribution in 2013. Source: Ministry of Agriculture, Water and Forestry, 2013.

2013 and 2014), whilst small informal traders offer compromised quality at lower price per kilogram to a different market segment. In fact the Agra Professional Vision report (2012) indicates that the quality of cattle produced and marketed in the informal areas, particularly in NCAs is lean and mature oxen.

Figure 2 show that cattle stocking rates in Namibia depicting the existence of the veterinary cordon fence (VCF) with commercial farmers situated South-VCF and communal farmers practising their farming activities North-VCF, though a small fraction are also found South-VCF (MAWF, 2012). It is also argued that dynamism of the land tenure system in Namibia particularly in the communal area that contributes to the reduced productivity of land due to overstocking of cattle and overgrazing (Agra Professional Vision, 2012). The land tenure system affects the supply side of beef cattle production in the value chain, resulting in most of the cattle in the NCA classified as grade C0 to C1; therefore, this implies that cattle marketed in NCAs are older than 3 years and lean. In addition the report reveals that about 3.7 per cent of the land available for grazing is overstocked to point to where it exceeds the required carrying capacity for grazing.

The duality in the beef cattle sub-sector have resulted in the situation that formal and informal markets have different demand and supply dimensions, different objectives for consumers and producers and different rules and institutional attributes. Coupled to this are high transaction costs for searching and screening potential buyers, negotiating of contracts, and monitoring and enforcing the adherence to the contract.

In 2014, the Namibian government through the Ministry of Finance (MoF) gazetted a levy advocating the introduction of a value addition requirement in the domestic market. The requirement states that all market-ready beef cattle should be slaughtered and processed domestically and exported as beef cuts. Under the same requirement, if a producer exports a beef cow or ox at live weight of 450 kilograms and more, a 30 percent is levied on the selling price and a form of tax is forwarded to the Ministry of Finance (MoF, 2014), a policy seen to encourage more domestic slaughter of market ready cattle and utilization of domestic slaughter facilities. However, this requirement has implications on the supply of beef cattle to local abattoirs, where domestic prices for live cattle are observed to be low compared with prices prevailing in the South African cattle market. Another setback for the beef cattle farmers in Namibia is the cost implications of rearing weaners to the required slaughter weight of 450 kilograms. In addition, government introduced policies and regulations that prohibits animal movement from the North-VCF to the South-VCF, but beef cattle producers South-VCF can sell their cattle stock and move cattle North-VCF. This restriction has caused disparities in the dynamics of supply and demand of slaughter stock and the quality of cattle marketed in northern communal areas.

The article is structured as follows: Section 2 discusses the background on price transmission, and this informs the methodology followed in this article, which is elaborated in section 3. Section 4 explains the data in brief and the empirical results and explanation are discussed section 5. Finally, the article provides the policy implications and concludes the article.

2. Background on price relationship and adjustment

It is important to emphasize that price is a principal instrument by which various stages of the markets are linked. The nature of price adjustment and speed with which the price shocks are transmitted among beef producers, wholesale and retail channels reflects the actions of market role-players in different market segments (Mkhabela and Nyhodo, 2011). Similarly, price transmission can reflect the extent of market integration and the extent of market efficiency (Kelbore, 2013). In recent decades, producers, mostly farmers, and legislators are concerned about the efficiency and equity of price formation of beef cattle in Namibia. Producers are of the opinion that the current pricing system pitches producers at the lowest ebb, meanwhile beef processors and wholesaler and retailers are receiving high profit margins. Evaluating the efficiency of the price relationships and adjustments in the Namibian beef market is important because it helps to characterise the extent to which the beef

cattle market responds to shifts in various domestic beef prices, European market beef prices and South African weaner prices. Understanding beef price relationships and adjustment in the domestic beef sector, their relationship to European prices and South African weaner prices has not been studied and addressed well by role players in the industry. This is dealt with in this study.

In Namibia, market efficiency and price transmission of market information have attracted considerable attention because the beef market sector is seeing more government involvement in creating an allegiance with MeatCo (the main buyer and processor of cattle). Questions about price relationship between the formal market and informal market, and whether beef cattle farmers in the informal market have profited from the prices offered by MeatCo are becoming apparent. An important point to note about the beef cattle markets in Namibia is that, informal beef cattle markets are thin, spatially concentrated and are too small to compete on quality in the value chain. Meanwhile, in the formal markets, beef cattle processing and retailing is more concentrated, with MeatCo accounting for a larger share in processing and export; though it can be deduced that the market structure is more competitive at retail level than at producer level because there are few processors and many retailers selling beef. Studies of Saghaian et al. (2013), Sarmiento and Allen (2000) and Schroeder et al. (2013) infer that concentrated market structure is prevalent to providing incentive for oligopolistic behaviour. Examples of this oligopolistic behaviour include non-cooperative collusion, strategic price signalling and investment.

There are no studies conducted to evaluate the level of price transmission in the formal and informal beef market. Similarly, there are no studies conducted to determine the price relationship and adjustment in the dualistic, coupled with dynamism in land tenure and production system, like the Namibian beef cattle market. However, there are several studies on price transmission. For example, Saghaian et al. (2013) in a study on the dynamics of price transmission and market power in the formal Turkish beef sector using a vector error correction model, shows that retail prices tend to rise above equilibrium, whereas wholesale prices tend to fall, therefore creating an impact on the price margin. The same study shows that the speed of adjustment was higher for wholesale than for retail. The adjustment can be attributed to the speed of relay of market information, particularly price information. The study concluded that there exist asymmetric price transmission and a possibility of growing market concentration and inefficiency in the Turkish beef sector.

Other notable studies on pricing which involve the threshold VECM, includes Conforti (2004), Cutts and Kirsten (2006), El Benni et al. (2014). The bulk of these studies based their analysis on bivariate specification of the VECM model, whilst this study is based on the multivariate VECM framework. Examples of the bivariate VECM model includes the Jaleta and Gebermerdhin (2009) study on co-integration of wheat and teff in Ethiopia; the Minot (2011) study on transmission of world food price changes to markets in Sub-Saharan Africa and the Kelbore (2013) case study which looks at world food prices and their transmission to the Ethiopian domestic food prices. Kelbore (2013) used the VECM version and principal component approach that included the threshold aspect, but the study did not account for the presence of marketing costs. Several beef studies used co-integration and VECM model specifications to analyse pricing and transmission at different levels in the supply chain. For example, Sarmeinto (2000) looks at the dynamics of beef supply in the USA in the presence of co-integration testing of backward-bending hypothesis. Worako et al. (2008), Mkhabela and Nyhodo (2011) and Schroeder et al. (2013) formulated bivariate models to evaluate the demand for beef in South Africa and USA, respectively. Similarly, Cutts and Kirsten (2006) apply the asymmetric price transmission framework on selected commodities in South Africa to investigate the price transmission along the supply chain. However, it is important to distinguish that despite the analysis done in previous studies, both of the mentioned studies were conducted in more developed, organised markets and supply chains.

3. Methods

This section discusses the unit root testing for stationarity, the Johansen multivariate co-integration, VECM and Granger-Causality tests. The Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) are

performed to test for unit (Dickey & Fuller, 1979) among the price series. The Johansen co-integration test (Johansen, 1988, 1992) is used to determine the rank of the co-integrating matrix in the price series. By definition, co-integration describes a long-run, or equilibrium relationship between the variables (Sims, 2014). This definition makes co-integration an ideal analysis technique to ascertain the existence of a long-term relationship between the formal and informal beef cattle price series in Namibia. The dynamic behaviour of the variables can therefore be described by an error correction model. However, to aid the necessity of the error correction model, we proceed by performing the Johansen multivariate co-integration. The Johansen multivariate co-integration is a superior analysis because it requires calculating two tests to determine the number of co-integrating vectors using maximum likelihood estimation procedures. The two tests used are the *Maximum eigenvalue* (λ-*Max*) and the *Trace* (λ-*Trace*) statistic tests. The tests are important procedures to determine the number of co-integrating relations among variables (Enders, 1995). The *Maximum eigenvalue* test statistic evaluates the null hypothesis of r co-integrating relations against the alternative of $r + 1$ co-integrating relations for $r = 0, 1, 2, \ldots, n - 1$, where r is the rank of the matrix of co-integrating relationships (source). The test statistic is calculated as:

$$LR_{max}(^r/(n+1)) = -T * \log(1 - \hat{\lambda}) \tag{1}$$

where λ is the *Maximum eigenvalue* and T is the sample size, while the *Trace* statistic tests the null hypothesis of r co-integrating relations against the alternative of n co-integrating relations. In this case n is the number of variables in the equation for $r = 1, 2, \ldots, n - 1$. The *Trace* statistic equation takes the following form:

$$LR_{max}(^r/n) = -T * \sum_{i=r+1}^{K} Log(1 - \hat{\lambda}) \tag{2}$$

In most cases, *Trace* and *Maximum eigenvalue* statistics yield similar results. In scenarios where the results of the test are different, the *Trace* statistic test is more superior and preferred. In addition, the Johansen tests according to equation (1) and (2) could test both the unrestricted model (with a trend) and restricted model (without a trend). Thus, the test for co-integrating relationship between the Namibian beef cattle price series, where $n = 2$, becomes the test for the null hypothesis: $r = 0$ and $r = 1$ with and without a trend, starting without trend.

The model identified in this article is a four variable model, hence a multivariate model, which hypothesises that informal beef cattle price series is a function of beef cattle prices in the formal market, augmented by the beef price (wholesale and beef export).

$$IBPRICE_t = f(FBPRICE_t, WBPRICE_t, EBPRICE_t \tag{3}$$

where the variables are defined as given in the section preceding Table 1 and before Figure 1. The t denotes the time trend and takes the individual year (from 1990–2014). Conforti (2004) suggests that in order to reduce data variability, econometrics analysis should be carried out on the logarithms of the prices. This study has followed the Conforti (2004) advice and converted all the price series into logarithms. The additional advantage of logarithm transformation of time series processing is that, coefficients can be easily interpreted as elasticities.

As stated previously, the VECM is applied after detecting that there exists a long-run relationship between the variables. The important nature of the VECM is to detect the short-run properties of the co-integrated series (Lütkepohl, 2005). Usually, if there are no co-integrating parameters, the VECM is not required. Therefore, it is advisable to just estimate the Granger-Causality to determine the causal relationships between variables (Engle & Granger, 1987). By illustration, the VECM framework departs from the Vector Autoregression (VAR) with p lags:

$$Price_t = A_1 Price_{t-1} + A_2 Price_{t-2} + \cdots + A_p Price_{t-p} + \epsilon_t \tag{4}$$

where $Price_t$ is $K \times 1$ vector of variables (price series), v is a $K \times 1$ vector of parameters (intercept terms), $A_1 - A_p$ are $K \times K$ matrices of parameters, and ϵ_t is a $K \times 1$ vector of disturbance terms. Hence, ϵ_t has a zero mean and covariance matrix $\sum$, and is independently, identically distributed (*i.i.d.*) normal over time. It is important to note that VAR(p) presented above can be rewritten as a VECM. The expression VAR(p) to VECM follows after performing some technical manipulation of the algebra of equation (4):

$$\Delta Price_t = v + \Pi Price_{t-1} + \sum_{i=1}^{P-1} i\Delta Price_{t-1} + \epsilon_t \tag{5}$$

where $\Delta Price_t$ is a $K \times 1$ matrix of price series, representing $Price_t - Price_{t-1}$, and v is a $K \times 1$ vector of intercept terms, $\Pi = \sum_{j=1}^{j=p} A_j - I_k$ a matrix that captures the long-run relationships among the price series. If we assume that Π has reduced rank that varies $0 < r < K$ so that it can be expressed as $\Pi = \alpha\beta'$, where α and β are both $r \times K$ matrices of rank r. Then α matrix describes the speeds of the adjustment, where each price series returns to long-run equilibrium and the β matrix captures the co-integrating vectors in a long-run relationship (Lütkepohl, 2005; Becketti, 2013).

The $\Gamma_i \Delta Price_{t-1}$ term captures the short-run relationship among the elements of $Price_t$ matrix. While, the v and ϵ_t in equation (4) and (5) are similar. For example, with five variables and two co-integration vectors and ignoring v and setting $\Pi = \alpha\beta$.

4. Data and description of variables

The study used beef cattle price time data from the Meat Board of Namibia and Ministry of Agriculture, Water and Forestry. The data consists of annual average price series of beef cattle in the informal market denoted by the informal beef cattle price series (open market price per kilogram/price per head of cattle for slaughter weight of C graded cattle) and formal market; formal auction beef cattle price per kilogram of slaughter weight for A graded cattle; control variables: wholesale price per kilogram for beef cuts of A graded beef and the beef export price per kilogram of beef cuts of A grade beef. The study uses 24 observations from 1990 to 2014. Price data from the informal beef cattle trade are obtained from the Ministry of Agriculture statistical bulletins for 2005 and 2009, and Meat Board Master Plan study done by Agra Professional Service division in 2012. The consumer price index was obtained from the National Statistical Agency (NSA, 2013). All prices were deflated using the consumer price index, base year 2012, in order to account for price fluctuations over the years and obtain the real prices. Therefore, in this study price means real beef cattle prices for grade C cattle in the informal market and grade A cattle in the formal market. Prices are expressed in South African rand per kilogram (R/Kg). The South African rand and Namibian dollar are pegged one-to-one; in other words 1 South African rand is equivalent to 1 Namibian dollar and vice versa.

Price data analysis showed steady erratic movements trending with a potential for integration of order one – I(1) processes (Figure 1). In a competitive market, current and past price series contain all the information available, meaning that next year's price will be a random walk from this year's price. Evidently, the price series representing the wholesale price has been trending high over the years, while the export beef price series trended high and from 2008 the price trended downwards. This widening in the price series is not indicative of buying power, because supply shocks such as production costs and severe droughts may be the cause of this phenomenon.

Table 5 in the Appendix indicates that on the average the informal beef cattle prices are lower than that of the prices offered in other markets and about three times lower than the wholesale beef price and about four times lower than the export price. On the contrary, the informal beef cattle price is relatively comparable to the average beef cattle auction price in the formal markets. This can be attributed to the fact that live cattle are priced at live weight basis in all markets. Cattle traded in the informal market are mainly small framed cattle with an average live mass of 198 kilogramme compared with 280–325 kilograms in the formal markets (Agra Professional Vision, 2012; Meat Board of Namibia Report, 2013).

5. Results and discussion

5.1 Unit root test

This section begins with a descriptive analysis of the characteristics of individual price series displayed in Figure 1. In other words, the study examines the stationary properties of the univariate time series variables. The beef cattle price series are integrated of order one – I(1), deemed to have unit root. The results of the unit root tests in levels are reported in Table 2. It is clear from Table 2 that the null hypothesis of no unit for all the price series is rejected at their first difference because the ADF and Phillip-Perron (PP) test statistics are greater than the critical value at 1 per cent and 5 per cent levels of significance, respectively. Both the ADF and PP tests indicate that the first differenced data of beef cattle price series in Namibia is stationary in their first levels. Therefore, having the same order of integration is one requirement for co-integration, but does not necessarily mean there is co-integration relationships. Using the Johansen approach of Lagrange Multiplier (LM) and *Trace* statistics is appropriate in this study. These results therefore necessitate the need to perform the multivariate co-integration procedure.

5.2 Determination of the rank and co-integrating results

The determination of lag length is a trade-off between the curse of dimensionality and reduced models, which are not appropriate to indicate the dynamic adjustment (Sims, 2014). The information criteria function is used to determine the lag length in this study. The information criteria seek to handle the trade-off between a parsimonious model and a comprehensive model. We have included one lag so that we can check the correlogram for autocorrelation. Autocorrelation is tested with a 5 per cent confidence interval. The goal is to eliminate the presence of autocorrelation. Sufficiently enough, no autocorrelation values were observed at our confidence intervals, and we have dealt with the problem of autocorrelation. We choose to agree with Schwarz (SC) and Hanna-Quinn (HQ) Information Criterion that chose 1 lag instead of the Akaike Information Criterion (AIC) and Final Prediction Error (FPE) who indicated a lag length of three. We chose one lag length to avoid the loss of more observations and not change the information criteria.

The co-integrating matrix is estimated using the Johansen methodology, based on equations (1) *Trace* statistics and (2) *Maximum eigenvalue* statistics to determine the rank of the co-integrating matrix. Table 3 summarises the co-integrating results. The testing procedures start with testing for a zero co-integrating relationship as indicated in the maximum rank column – a maximum rank of zero. The null hypothesis is that the number of co-integrating relationship is equal to r (given by the maximum rank column of the output). The alternative hypothesis is that there are more than r co-integrating relationships among the beef cattle price series.

Table 2. Augmented Dickey-Fuller and Phillips-Perron tests for unit root on log of price series.

Variables	Augmented Dickey-Fuller test (ADF)		Phillips-Perron test statistic (PP)	
	Constant without a trend	Constant with trend	Constant without a trend	Constant with trend
Data in levels				
L_IBPRICE	−1.2643	−1.8379	−1.2643	−1.9668
L_FBPRICE	−1.3935	−2.0083	−1.4139	−2.0083
L_WBPRICE	−0.8389	−1.4136	−1.1990	−2.7086
L_EBPRICE	−1.2066	−3.8564	−1.2067	−1.9674
Data in first difference				
L_IBPRICE	−4.9678**	−4.7761**	−4.9678**	−4.7761**
L_FBPRICE	−4.8969**	−4.7255**	−4.8789**	−4.7393**
L_WBPRICE	−4.4697**	−4.8517**	−5.0914**	−5.2299**
L_EBPRICE	−3.3132**	−3.3969**	−4.5794**	−4.7500**

Note: * denotes that the null hypothesis of stationarity is rejected at 1% level of significance and ** is rejection at 5% level of significance based on Akaike Info Criterion (AIC) and Phillips-Perron (PP) test, respectively

Table 3. Johansen multivariate cointegration results.

Hypothesised number of co-integrating equations	λ-Trace statistic	Critical value (5%)	λ-Max-Eigen statistic	Critical value (5%)
$r = 0$	118.73	69.82	62.52	33.87
$r \leq 1$	56.21	47.86	28.30	27.58
$r \leq 2$	28.90**	29.78	19.47**	21.13
$r \leq 3$	9.43	15.49	9.40	14.26
$r \leq 4$	0.03	3.84	0.03	3.84

Note: ** Both the Trace and Max eigenvalues indicates that there are two co-integrating long-run relationships between the beef cattle price series. This implies that we reject the null hypothesis of no co-integration at r = 0 and r = 1, and accept that there is two (where H_0: r = 2(28.90 < 29.78 for Trace, and 19.47 < 21.13 for Max at 5% level of significance, respectively) co-integration relationship among the beef cattle price series in Namibia.

It is noted from Table 3 that both *Trace* and *Maximum eigenvalue* test statistics that the null hypothesis (H_0:$r = 0$) is rejected up to the H_0:$r = 1$, because the trace and maximum test statistics are greater than the 5 per cent critical at the level of significance (118.73 > 69.82, when $r = 0$ and 56.21 > 47.86 when $r = 1$). This implies that we reject the null hypothesis of no co-integration at $r = 0$ and $r = 1$ and accept there is 2 (where H_0:$r = 2$ (28.90 < 29.78 at 5 per cent level of significance) co-integration relationship among the beef price series in Namibia.

5.3 Vector error correction model result

Overall, the VECM output indicates that the model fits well, as supported by the stability of model process. The coefficient on informal beef cattle price in the co-integrating equation is statistically significant. Table 4 indicates that parameters in this multivariate model have the correct sign and imply mild to rapid adjustment toward equilibrium (Lütkepohl, 2005). When the predictions from the co-integrating equations are positive, informal beef cattle price is above its equilibrium value and drifts away from the equilibrium. This thus implies that when the average beef cattle price in the informal market is high, it quickly falls back towards the formal auction beef cattle price per kilogram. The estimated coefficient for formal beef cattle price implies that if the price is high compared with the equilibrium price series, the average formal beef cattle price should quickly adjust towards the informal average beef cattle price. The VECM result illustrates that, for the informal beef cattle price to be in long-run equilibrium, it will have to adjust by 63 per cent of the deviation corrected in each subsequent time period (based on the error-correction terms (ECT) in Table 4). Stated differently, about 63 per cent of disequilibrium is corrected each year by changes in log of informal beef cattle price. Similarly, the formal beef cattle price should adjust by minus 81 per cent based on the ECT.

Having determined that there is co-integrating equation between the informal and formal beef cattle price, it should be noted that the other price series (WBPRICE) were found to be insignificant at the 5 per cent level in the first and second co-integrating equation. VECM facilitates a straight forward economic interpretation, such as the existence of long-run equilibrium and how the price series adjusts to the identified equilibrium. These equations can be specified as follows:

The first co-integrating long-run equation is given:

$$L\_IBPRICE_{t-1} = -0.2655 + 0.4588L\_WBPRICE_{t-1} - 0.2078L\_EBPRICE_{t-1} \tag{6}$$

and the second long-run co-integrating equation is given as:

$$L\_FBPRICE_{t-1} = -0.2319 + 0.4443L\_WBPRICE_{t-1} - 0.2003L\_EBPRICE_{t-1} \tag{7}$$

We interpret the estimates based on Lütkepohl (2005); Baltagi (2008) and Becketti (2013). The parameters in the first and second equation as indicating an equilibrium relationship between the average beef cattle price series for the formal auction beef cattle price and the average price series for producer and export prices, respectively. Equation (6) illustrates that as the informal beef

Table 4. The results of Granger-Causality result based on VECM.

	Independent variables						
	χ²-statistics of lagged 1st differenced term					ECT$_{t-1}$ coefficient (t-ratios)	ECT$_{t-1}$ coefficient (t-ratios)
Dependent variables	ΔL_IBPRICE	ΔL_FBPRICE	ΔL_PBPRICE	ΔL_WBPRICE	ΔL_EBPRICE	Eq. 6	Eq. 7
ΔL_IBPRICE	––	0.8304	1.2505	0.1779	0.0268	−0.6394	−0.8105
		[0.3621]	[0.2635]	[0.6732]	[0.8699]	(0.6982)	(−0.8748)
ΔL_FBPRICE	1.0905	––	2.3606	0.1210	0.0796	−1.6969*	−1.9189*
	[0.2964]		[0.1244]	[0.7279]	[0.7778]	(2.0429)	(−2.2839)
ΔL_WBPRICE	0.0181	0.0305	0.0047	––	0.0086	−0.3730	−0.2761
	[0.8931]	[0.8613]	[0.9451]		[0.9261]	(0.6820)	(−0.4990)
ΔL_EBPRICE	0.4371	0.7107	0.1565	0.0136	––	−1.0583	−1.0321
	[0.5085]	[0.3992]	[0.6924]	[0.9071]		(−1.5351)	(1.4801)

Note: * denotes significant at 5% level. The figures in parenthesis (…) denote t-statistics and the figures in square brackets […] represent p-value.

cattle price are in the long-run equilibrium, it will have to adjust by 63 per cent based on the ECT for equation (6) (Table 4). By doing so, Table 4 and equation (6) illustrate that the informal beef cattle market prices are in long-run equilibrium, it will have to adjust by 63 per cent based on the ECT for equation (6). This can be stated differently, by saying that about 63 per cent of disequilibrium is corrected each year (based on the fact that annual data is used in this article) by changes in log of the informal beef cattle price, whilst equation (7) and Table 4 depict that the formal beef cattle price should adjust by minus 81 per cent based on the ECT. In equation (6), formal beef cattle price series was omitted because it was found to be insignificant, but significant in equation (7). These results are consistent with the finding in Lütkepohl (2005), Baltagi (2008) and Becketti (2013) that the parameters in the first and second equation, on finding an equilibrium relationship between the price series and the coefficients, are less than a unit. The coefficients in equations (6) and (7) are price elasticities in a long-run equilibrium.

5.4 Granger-Causality test

It is important to note that the co-integration between variables does not specify the direction of a causal relation, if any, between the variables (Sims, 2014). The chi-square statistic and probability measures the causality between the variables. The chi-square statistic and probability values are constructed under the null hypothesis of no causality. The results of pair wise analysis are shown in Table 4, where significant probability values signify the rejection of the null hypothesis. This study rejects the null hypothesis if the probability value is more than 1 per cent. Conversely, therefore, this study does not reject the null hypothesis if the probability value is less than 1 per cent. Therefore, the results indicate that the log price of grade C beef cattle in the informal market does not Granger-cause log of beef cattle price of grade A cattle in the formal market, log of wholesale beef price of grade A beef and log of export beef price of grade A unidirectional at the 1 per cent level of significance. Similarly, this applies to the log of grade A beef cattle price in the formal market to other price series. The unidirectional causality implies that past values of price series have a predictive ability in determining the present values of log price of grade C beef cattle in the informal market and log of grade A beef cattle price in the formal market.

6. Conclusion and policy implication

This article analysed the short- and long-term relationships among different price series. The VECM model specification was developed within the framework of vector error correction. The study proceeded by testing for the presence of stationarity using the ADF and PP tests. The conclusion from the ADF and PP tests is that the beef cattle price series are integrated by the same order, i.e. I(1). The

Johansen multivariate co-integration reveals that there are two co-integration equations. These are for the formal beef cattle price and the informal beef cattle price. VECM results show that price relations can alter the conclusion drawn from price relationship models. The empirical results show that informal market beef cattle prices do not adjust rapidly to equilibrium compared with the beef cattle prices in the formal beef market. Informal market beef prices takes about 63 per cent to adjust to disequilibrium while the formal beef cattle prices adjusts about 81 per cent to disequilibrium. The lack of rapid adjustment to equilibrium can be attributed to the fact that the informal beef market is a weaker derivative of the formal market and another attribute is the differences in the objectives of the two markets. This finding is consistency to the findings of Hahn (2010) and El Benni et al. (2014) who indicated in their study, which looked at the transmission of beef and veal prices in different marketing channels, that prices in downstream sectors hardly depend on producer prices.

This study is the first to unpack the price relationships and the price dynamism that exists in the beef cattle market of Namibia. Policy makers should use the results to devise policies that will enable price information to feed through to the informal market and seek institutions that can provide a favourable environment for the informal beef producers to improve their earnings from cattle farming. More importantly, by a policy aimed at improving productivity of rangelands the Namibian government should aggressively tackle the allotment of the individual land tenure system and merging the land tenure system in the dualistic beef cattle sector, with training and mentorship on rangeland management, can improve the quality of grazing in informal areas both in commercial and communal areas (Agra Professional Vision, 2012). In turn this can improve the quality of cattle coming from all the sub-sectors from grade C to AB or A grade (Meat Corporation of Namibia, 2013). The improvement in grades will ensure that cattle producers receive better prices for their live cattle and ultimately their income levels and welfare can improve in the long run.

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Appendix

Table 5. Raw price data series (1990–2014) in nominal terms.

	Live cattle prices[a]		Beef prices[b]		
Year	Informal beef price (IBPRICE) Rand/kg	Formal beef price (FBPRICE) Rand/kg	Producer beef price (PBPRICE) Rand/kg	Wholesale beef price (WBPRICE) Rand/kg	Export beef price (EBPRICE) Rand/kg
1990	3.05	3.84	6.16	10.55	15.65
1991	4.37	5.50	6.30	10.95	14.87
1992	4.28	5.39	6.54	11.60	16.11
1993	4.24	5.34	6.83	12.64	17.34
1994	4.36	5.49	7.38	17.70	18.56
1995	4.49	5.66	7.41	16.65	19.79
1996	4.67	5.88	6.98	15.18	21.02
1997	4.46	5.61	8.11	14.94	21.85
1998	3.83	4.82	8.11	16.05	23.48
1999	3.40	3.85	8.46	17.03	22.25
2000	4.54	4.43	9.18	18.18	28.39
2001	4.81	5.21	10.17	19.90	28.39
2002	6.47	6.93	15.33	20.80	28.39
2003	8.13	6.36	10.09	21.73	28.39
2004	8.00	6.23	11.23	22.90	26.08
2005	9.32	7.10	12.08	23.94	28.17
2006	11.38	11.26	16.75	25.01	33.11
2007	10.77	9.63	17.28	26.14	36.06
2008	9.06	10.69	21.40	27.31	46.71
2009	10.07	11.53	21.82	28.54	46.36
2010	10.06	12.66	20.00	29.83	43.37
2011	8.98	16.58	25.15	31.17	44.10
2012	10.43	15.80	27.79	32.57	41.08
2013	9.91	14.33	25.76	34.04	40.57
2014	10.84	17.06	31.01	35.57	39.43

Sources: [a]Prices for grade C live cattle are obtained from the Ministry of Agriculture, Water and Forestry, Directorate of Planning, Statistical Bulletins of 2005 and 2009, respectively, and are further supplemented by data obtained in the report produced by Agra Professional Service (2012) for the Northern communal areas carried out for the Meat Board of Namibia.
[b]Beef prices for grade A cattle are obtained from the several Microsoft Excel spreadsheet provided by the Meat Board data portal (2014) accessible at www.nammic.com.na and Meat Corporation annual reports. These prices are considered as average price per head of cattle and converted to price per kilogram. It is noted that auction prices are dominate prices because they yield normal profit in both markets.