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TOMATO MARKET INTEGRATION: A CASE STUDY OF THE DURBAN AND JOHANNESBURG FRESH PRODUCE MARKETS IN SOUTH AFRICA

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Abstract. In a market-driven economy, price indicators guide and regulate production, consumption and marketing decisions over time, form and place. Identifying the causes of price differentials across markets is important for understanding markets. This study analyzes the market price integration of tomato in Durban and Johannesburg fresh produce markets in South Africa, using secondary monthly time series of wholesale price data for the period 2008–2012. Cointegration was tested using the Augmented Engle-Granger (AEG) test, while the direction of causality between Johannesburg and Durban prices was tested using the error correction model (ECM). The results showed that the two markets were integrated. Furthermore, the results also revealed that following a shock to the market that causes disequilibrium, economic agents take about a month to adjust back to equilibrium; the response to the shock is faster in the Durban market than in the Johannesburg market. The high degree of market integration suggests that the South African fresh produce market is quite competitive and provides little justification for government intervention designed to improve competitiveness or to enhance market efficiency. Policy implications for an improved and effective tomato marketing program were also discussed.

Keywords: market integration, fresh produce, cointegration; error correction model (ECM)

INTRODUCTION

Markets are important determinants of food availability and food access (WFP, 2007). It is also argued that market integration is a prerequisite for successful economic integration (Artingi-Ego et al., 2006). The extent to which markets make food available and keep prices stable depends on whether they are integrated with each other (Nyange, 1999). Spatial market integration occurs when commodity markets in geographically separated locations share a common long-run price equilibrium relationship on a homogenous good (Goletti et al., 1995; Negassa et al., 2003). According to Barrett and Li (2002), two markets are integrated if there is tradability and contestability between them. They described tradability as the physical flow of a commodity between markets and contestability as a situation where arbitrage between the markets is fully exploited, leaving market agents indifferent about trading. Fackler and Goodwin (2001) defined market integration as the extent to which supply and demand shocks arising in one market location are transmitted to another market. Therefore, price transmission is at the core of integration analysis (Goodwin and Schroeder, 1991; Goletti et al., 1995; Kabbiri et al., 2016), and hence the two terms are used interchangeably. Price transmission occurs when a change in

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the price of a good in one market causes a price change of a similar good in another market.

Market integration has become a major issue over the past few decades because of price stabilization and food security concerns (Akhter, 2016). While a well-integrated market system will ensure regional balance between deficit and surplus zones and between food and non-food producing regions, in the absence of market integration, price signals will not be transmitted between food deficit and food surplus areas (Baulch, 1994; 1997; Muyatwa, 2000), agricultural producers will fail to specialize according to their comparative advantage (Baulch, 1997), macro-level price stabilization policies will not effectively influence micro-level decisions and most policy objectives in the agriculture sector will be undermined (Baulch, 1994; Muyatwa, 2000). The importance of integration analysis has been hinged on the fact that it explains how long a localized scarcity can be expected to last (Ravallion, 1986); the extent to which a country (or a region) is vulnerable to external market shocks, and spatial market efficiency (an economic equilibrium condition whereby all potential profitable arbitrage opportunities are exploited) (Barrett and Li, 2002; Negassa et al., 2003).

Hence, knowledge about market integration is crucial for planning and implementing government and other non-governmental organization food programs. The degree of market integration informs the analysis of food security and appropriate responses to a crisis while also reflecting the extent of possible negative effects of food aid and local procurement possibilities. High degree of market integration implies a competitive market and provides little justification for government intervention designed to improve competitiveness or to enhance market efficiency (Mushtaq et al., 2008).

In South Africa and other developing countries, the lack of cointegration between prices of agricultural products is more likely due to inefficient marketing service, lack of infrastructures, less developed market institutions, barriers to entry and inefficient information services (Shrestha et al., 2014). The lack of cointegration between prices of agricultural commodities is more likely to affect the fresh produce industry than any other agricultural industry in South Africa, because of its high perishability which requires immediate marketing to ensure quality produce to consumers and beneficial prices to growers. It has been reported that a large gap exists between the price received by producers and that paid by consumers; prices of commodities are lower in production areas while market prices are generally high. According to Shrestha and Pandey (2010), this is because agricultural marketing is quite complicated, since a large number of marketing arbitrators are involved, which increase the marketing cost and consequently raise the price.

Given the importance of tomato in household food security and in the economy of South Africa, and the importance of integrated markets in bridging intra-country supply/demand gaps, it is imperative that an investigation into the spatial integration of tomato markets be conducted. Therefore, this study analyzes the market price cointegration of tomato in Durban and Johannesburg fresh produce markets in South Africa.

TOMATO PRODUCTION AND MARKETING STRUCTURE IN SOUTH AFRICA

Tomato (*Solanum Lycopersicon*) is the second most important vegetable crop after potato worldwide. It is nutritionally categorized as a vegetable, but botanically classified as a fruit (Peralta and Spooner, 2001). Tomato is highly perishable and is consumed raw, or as an ingredient in many dishes, sauces, stew and also in drinks.

Tomato is produced in all provinces of South Africa. The Limpopo province is the major production area with 3590 ha (i.e. more than 75% of the total area planted to tomatoes in the country). This is followed by Onderberg area of Mpumalanga Province with 770 ha and Border area of Eastern Cape Province at 450 ha (DAFF, 2012). South Africa is self-sufficient in tomato production and there are comparatively low levels of tomato imports compared to exports. The tomato industry's contribution to GDP increased by 42% in 2009 compared to 2008. The highest contribution to GDP was recorded in 2010 and was 3% higher than in 2009 (DAFF, 2014).

Historically, the marketing of fresh produce, including tomatoes in South Africa, has mainly been done through National Fresh Produce Markets (NFPMs). As a result, the prices determined in these markets provide a standard for the national business in fresh produce markets. In South Africa, the tomato industry uses four existing channels for marketing, namely the local channel through the NFPMs, exports, processing and direct marketing.

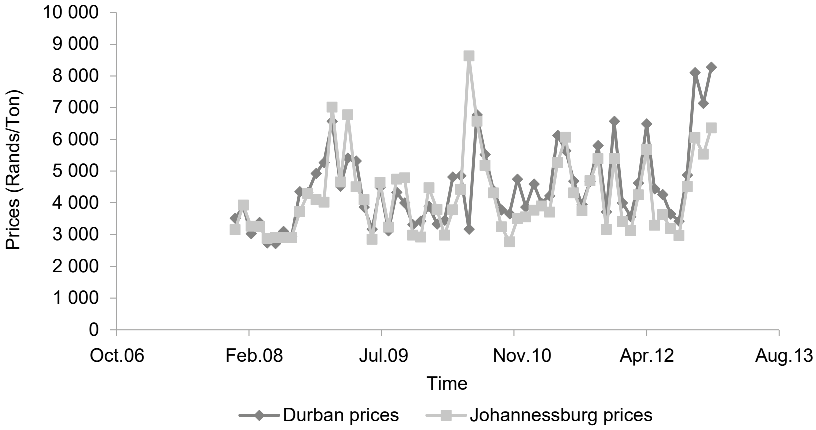

Fig. 1. Trends in tomato prices for both the DFPM and JFPM.
Source: DAFF, 2014.

The Johannesburg fresh produce market (JFPM) is South Africa's major center for the marketing of fresh produce. It is the largest in South Africa and in Africa, controlling about 50% of the market share of the total NFPMs. A private company wholly owned by the City of Johannesburg, it was incorporated as a limited liability company in 2000 as part of the IGoli 2002 plan. It is a commission market where producers deliver their produce to any of the 14 market agents who sell it to the buyers on their behalf. It handles about 32% of all fresh produce marketed through formal channels in the Gauteng province. The total capacity of the JFPM is estimated at 65,000 m^2. As a value-adding service, there are fruit ripening chambers and about 40 cold rooms which can accommodate 4,100 pallets of fresh produce. About 10,000 farmers send their produce to the JFPM. It handles an average of over 16,000 transactions per trading day, with a buyer base estimated at 6,000 at any given time. The market realizes an estimated average daily turnover of ZAR 10.8 million and more than ZAR 1.8 billion a year. The JFPM makes a 5% non-negotiable commission on all fresh produce sold in the market, while the market agents receive a negotiable 7.5% commission on the selling price of all the fresh produce (DAFF, 2014).

The Durban Fresh Produce Market (DFPM) has been operational since the late 1800s and has gone through several transformations over the years. Currently, the DFPM is run by the Metro Council and controls about 7% of the market share of the total NFPMs. According to DAFF (2014), the highest increase in the DFPM's revenue from tomato was in 2006, and it increased to ZAR 425.2 million, a growth of 16.7% compared to the previous year.

The changes in tomato prices in both the JFPM and DFPM are presented in Figure 1. Major declines in prices were experienced in June 2009, August 2009, November 2010 and July 2012. Major increases, in turn, were recorded in March 2009, July 2010 and October 2012. The major peaks and troughs in prices are influenced by the seasonality of production of tomatoes in South Africa (DAFF, 2014).

MARKET INTEGRATION: THEORETICAL CONSIDERATIONS

Market integration occurs when prices among different locations or related goods follow similar patterns over a long period of time (Goletti et al., 1995; Negassa et al., 2003). Groups of prices often move proportionally to each other; when this relation is very clear among different markets, they are said to be integrated. At times, integration may be intentional, with the government implementing certain strategies as a way to control the direction of the economy. At other times, market integration may be due to factors such as shifts in supply and demand that have a spillover effect on several markets (Goletti et al., 1995).

Spatial market integration implies the co-movements of prices in the long run. It is described as a smooth or continuous transmission of price signals and information between spatially distinct markets. Trade flows across markets are a sufficient but not necessary condition for some degree of spatial market integration (Negassa et al., 2003). However, markets are still considered to be integrated if they are connected by the process of arbitrage. Thus, integration between two markets implies that a supply or demand or price shock in one market will be transmitted to the other one (Negassa et al., 2003; Mushtaq et al., 2008; McNew and Fackler, 1997). Integrated markets show evidence of a long-run relationship between their prices. Spatial prices can therefore deviate in the short run and still be considered as integrated (Vollrath, 2003).

Transaction costs and location are key aspects in marketing decisions as participants prefer low transaction costs in selecting one market over another. Transaction costs consist mainly of transportation, handling fixed costs and the immeasurable costs such as contract monitoring and costs of time spent in identifying and negotiating transactions, risk associated with opportunistic behavior of trading partners, enforcement etc. (Penzhorn and Ardnt, 2002).

Prices. Prices have an important role as a competitive tool in determining the efficient allocation of resources in a marketing system. They are used as effective signals for allocating scarce resources and in effect stimulate agricultural productivity and economic growth (Barrett, 1996). Serra and Goodwin (2002) assert that prices are the key instrument by which markets are linked. Expected prices (and profits) propel production and planting decisions made by farmers. Hence, prices play an important role in any economic study of markets. The long-term functioning of a market can be better analyzed by understanding spatial or vertical price transmission between markets (Du Preez, 2011). Goodwin and Harper (2000) stated that the vertical transmission of shocks between various market levels is an important feature in describing the long-term operation of the market. Such price transmissions imply a smooth flow of price signals and information across spatially separated markets, which bring such market analyses closer to efficiency state of perfect competition.

Arbitrage. Arbitrage refers to the simultaneous purchase and sale of equivalent assets or of the same asset in multiple markets in order to exploit a temporary discrepancy in prices (Faminow and Benson, 1990). It is the other reason why prices of the same good in different markets move together and reach potential equilibrium (Vollrath, 2003). McNew and Fackler (1997) define arbitrage as the error correction system that moves prices of a similar good in two markets towards equilibrium. Prices between markets move towards equilibrium after small fluctuations and variations in prices that can be due to capital constraints, interest rates, transaction costs and execution risk which will limit trading if potential expected profits are small (Tsay, 1998). Arbitrage is the mechanism that shields the movement of prices on concurrent markets. In cases when the price differences between markets exceed transaction costs, arbitrage opportunities open up; profit-seeking market participants would seek to seize such opportunities by buying from the low-priced surplus market and reselling in the higher-priced deficit market (Uchezuba, 2005). Arbitrage opportunities can only occur when the deviation in prices is substantial enough for potential profit to exceed the cost of trading, thus raising the prices in the surplus region and reducing them in deficit regions (Tomek and Robinson, 1990). Imbedded in the intuition of arbitrage is that it occurs when there are large differences in prices, such that the potential costs of trading are offset by the potential profits. Thus, prices of related goods may deviate from each other in the short term but in the longer term, arbitrage will be the mechanism which ensures that the prices reach some equilibrium relationship (Du Preez, 2011).

The law of one price (LOP). The law of one price (LOP) states that efficient trade and arbitrage activities will ensure that prices in spatially separated markets, (i.e. one adjusted for exchange rates and transportation costs) will be equalized. Assuming compliance with the LOP, a single "representative price," which is common to all trade regions, may be defined (Goodwin, 1992). Zanias (1999) cited by Du Preez (2011) states that, in agricultural markets, the LOP maintains some importance at national and international level. However, in investigating the LOP, Padilla-Bernal et al. (2003) found that it fails when there are disjointed trade flows, pricing-to-market, exchange rate risks and a significant geographical separation of markets. In other literature, Ardeni (1989) reported that the LOP is a long-run concept as it fails to hold in the short run. No evidence was found by Ardeni (1989) to support the LOP as a long-run relationship; it was suggested that institutional factors, transaction costs as well as prices and time-specific problems were the main reasons for its failure, as supposed by the concept of LOP itself. In light of the short-term limitations of the LOP, more focus needs to be placed on the LOP in the long run. Having considered the above, the LOP has a significant role in defining the extent of the market and in measuring market integration (Ghoshray and Lloyd, 2003).

CONCEPTUAL FRAMEWORK

Economic theory suggests that certain pairs of economic variables should not diverge from each other by too great an extent in the long run (Granger, 1986). According to Granger (1986), such variables may drift apart in the short run or in function of seasonal factors, but they should not continue to be too far apart in the long run. These variables are said to be cointegrated if they have a long-term or equilibrium relationship (Gujarati and Porter, 2009). Based on economic theories of supply and demand, co-movements in prices are expected to bear some persistent and long-term relationship. Consequently, a measure of long-term co-movement of prices gives a good indication of the degree of interconnectedness between local markets (Badiane, 1999). Co-integration techniques may be used to test whether a constant linear relationship can be established between local prices over time. Granger (1986) asserts that even though individual variables may not be stationary, linear combinations of them can be. Thus, the theory of cointegration helps to reconcile findings of non-stationarity with the possibility of testing relationships, such as the Law of One Price (LOP) among economic variables (Ardeni, 1989).

Market cointegration has a positive relationship with market efficiency and market competitiveness, i.e. as the market is cointegrated, it tends to be efficient and competitive (Shrestha et al., 2014). Fama (1970) defines an efficient market as one where all available information is fully reflected in market prices. According to Enders (2010), cited by Shrestha et al. (2014), price cointegration of two markets can be tested if the price in one market display in same order with the other market. Therefore, the following hypotheses were tested in this study:

There is no positive relationship between tomato prices in Durban and tomato prices in Johannesburg.

There is no stationarity between tomato prices in Durban and those in Johannesburg.

There is no linear cointegration between tomato prices in Durban and those in Johannesburg.

RESEARCH METHODS

Data

Time series data spanning from January 2008 to December 2012 was used in this study. Data on average monthly tomato prices in Durban and Johannesburg was obtained from the Department of Agriculture, Forestry and Fisheries (DAFF). The study uses nominal average monthly tomato prices for Durban and Johannesburg markets in the period 2008–2012. Prices in the South African currency (Rands/ton), were deflated by consumer price index. The number of observations was 60 which is an acceptable amount to undertake research and is considered a large sample.

Empirical model

In order to analyze the market price integration of tomato in Durban and Johannesburg fresh produce markets in South Africa, the study employed the cointegration technique and the Error Correction Method (ECM). This involved three separate procedures which are: (i) evaluating the stationarity of tomato prices in Durban and tomato prices in Johannesburg, (ii) investigating whether there is a cointegration relationship between tomato prices in Durban and tomato prices in Johannesburg and (iii) investigating the short-run relationships between tomato prices in Durban and tomato prices in Johannesburg.

The Augmented Dickey-Fuller (ADF) test of unit roots

A unit root test assesses whether a time-series variable is non-stationary using an autoregressive model. The data series in this study was tested for stationarity using the ADF test proposed by Dickey and Fuller (1981) which consists in detecting whether a time series has unit roots or not. The null hypothesis that there is a unit root (i.e., time series data is non-stationary) was tested against the alternative hypothesis that data series are stationary.

The ADF test builds on the Dickey-Fuller test, which tests for the null hypothesis that $\delta > 0$ against the alternative hypothesis that $\delta > 0$ in the following equation:

$$\Delta Y_t = \delta Y_{t-1} + \varepsilon_t \quad (1)$$

where: Δ is the first difference operator, Y_t is time series data and ε_t is a random error term. If δ is found to be zero, the conclusion is that the time series Y_t is non-stationary. If δ is negative, Y_t is stationary (Dickey and Fuller, 1979). The DF test assumes that the error terms are independently and identically distributed. However, this is an assumption that is not frequently satisfied in economic time series data. Therefore, it is a limited/low power test (Gujarati and Porter, 2009). The ADF test adjusts the DF test to account for possible autocorrelation in the error terms by adding the lagged difference terms of the regression as shown in equation (2).

$$\Delta Y_t = \alpha + \delta Y_{t-1} + \gamma t + \Sigma\lambda_i \Delta Y_{t-1} + \varepsilon_t \quad (2)$$

where Δ is the first difference operator, Y_t is time series data; α is the intercept; the product value of γ and t denotes a deterministic time trend; ΔY_{t-1} are the lagged difference terms of the time series data; and ε_t is a random error term.

The Augmented Engle-Granger (AEG) Cointegration test

The Augmented Engle-Granger (AEG) approach was used to examine the cointegration relationship between tomato prices in Durban and Johannesburg fresh produce markets. The first stage of the AEG two-step procedure involves the estimation of the following static cointegrating regressions:

$$\ln T_{dt} = \alpha_0 + \alpha_1 \ln T_{jt} + \mu_{1t} \quad (3)$$
$$\ln T_{jt} = \alpha_0 + \alpha_1 \ln T_{dt} + \mu_{2t} \quad (4)$$

where: $t = 1, 2..., T$; ln is natural logarithm; T_{dt} and T_{jt} are average monthly tomato prices in Durban and Johannesburg, respectively; α_0 is a non-zero drift; α_1 is the slope coefficient of data series; μ_{1t} is the residual series.

The second stage of the AEG cointegration test involves testing the stationarity of the residuals. These are calculated as T_{dt} and T_{jt}.

$$\mu_{1t} = \ln T_{dt} - (\alpha_0 + \alpha_1 \ln T_{jt}) \quad (5)$$
$$\mu_{2t} = \ln T_{dt} - (\beta_0 + \beta_1 \ln T_{dt}) \quad (6)$$

where t; ln; T_{dt}; T_{jt}; α_0; β_0; α_1; β_1; μ_{1t} and μ_{2t} are defined as above.

The stationarity of the residuals was tested in the second stage of the AEG cointegration test. The corresponding residual series were calculated as:

$$\mu_{1t} = \ln T_{dt} - (\alpha_0 + \alpha_1 \ln T_{jt}) \quad (7)$$

where t; ln; T_{dt}; T_{jt}; α_0; α_1; μ_{1t} are defined above.

The AEG test was estimated as follows:

$$\Delta\mu_t = \alpha + \delta\mu_{t-1} + \gamma t + \Sigma\lambda_i \Delta\mu_{t-1} + \varepsilon_t \quad (8)$$

where α symbolizes a non-zero drift, and the product value of γ and t denotes a deterministic time trend, μ_t is the estimated residual series, Δ is the first difference operator, while ε_t is white-noise residuals. A cointegration relationship occurs if the residual series is stationary (i.e. $\delta < 0$). Otherwise, there is no long-term relationship between the two series. Lag order selection was also done using the SBIC selection method.

The Error Correction Model (ECM)

The Error Correction Model (ECM) corrects for short-run disequilibrium between variables. The Granger representation theorem states that if two variables are cointegrated, then their relationship can be expressed as an ECM (Gujarati and Porter, 2009). Error correction is a way of capturing adjustments in a dependent variable that do not depend on the level of the explanatory variable, but on the extent to which an explanatory variable deviated from an equilibrium relationship with the dependent variable (Townsend, 1998). The ECM was specified as follows:

$$\Delta\ln T_{dt} = \alpha_0 + \alpha_1 \Delta\ln T_{jt} + \alpha_2 \mu_{1t-1} + \varepsilon_{1t} \quad (9)$$
$$\Delta\ln T_{jt} = \alpha_0 + \alpha_1 \Delta\ln T_{dt} + \alpha_2 \mu_{2t-1} + \varepsilon_{2t} \quad (10)$$

where Δ is the first difference operator; $\ln T_{dt}$ and $\ln T_{jt}$ are logged average monthly prices in Durban and Johannesburg, respectively; μ_{1t-1} is the lagged value of the error term in equation (3) and ε_t is a white noise error term. ECM was used to determine the Granger-causality relation between average monthly prices in Durban and Johannesburg. The term Error Correction Model is derived from the fact that it has a self-regulating mechanism: after deviations, it returns automatically to its long-run equilibrium. Granger causality means that a lead-lag relationship between variables in the time series is evident. However, this does not mean that if a structural change in one series occurs, the other will change as well, but rather that the turning point in one series precedes the turning points of the other (Granger and Weiss, 1983).

EMPIRICAL RESULTS AND DISCUSSION

Augmented Dickey Fuller (ADF) test results

The Augmented Dickey Fuller (ADF) test results revealed that the acceptance of the null hypothesis of

Table 1. Augmented Dickey Fuller (ADF) unit root test results

Variable		ADF statistic	Critical values			Lags
			1%	5%	10%	
Level form	$\ln T_{dt}$	–3.619	–4.132	–3.492	–3.175	1
	$\ln T_{jt}$	–3.82	–4.132	–3.492	–3.175	1
First difference form	D $\ln T_{dt}$	–5.424	–4.137	–3.494	–3.176	2
	D $\ln T_{jt}$	–6.881	–4.135	–3.493	–3.176	1

non-stationarity is achieved at 1% level of significance. The unit root test results obtained using the ADF test procedure are presented in Table 1.

The ADF test statistics for both price variables at their level form were significant at least at 1%. This means that the null hypothesis of non-stationarity (or the presence of a unit root) could not be rejected at the 1% significance level, implying that both variables were non-stationary at their level form. However, the null hypothesis was rejected at all levels of significance for both variables in their difference form. That is, both variables were stationary at their first difference form. Cointegration requires that variables be non-stationary in their level form and stationary in their first difference form. This result is consistent with that of Yusuf et al. (2006) and Adeoye et al. (2011) that commodity could be stationary at first difference.

Augmented Engle Granger (AEG) Cointegration test results

After testing for unit root, cointegration was tested using the Augmented Engle Granger (AEG) Cointegration test. The AEG cointegration test results for stationarity in the residuals are presented in Table 2.

Table 2. Cointegration models without the time variable (i.e. without trend)

Dependent variable	Constant	Independent variables		Model
		$\ln T_{jt}$	$\ln T_{dt}$	
$\ln T_{dt}$	2.2578	0.7358		4.1
	(0.002)	(0.000)		
	{3.24}	{8.77}		
$\ln T_{jt}$	1.8244		0.7746	4.2
	(0.017)		(0.000)	
	{2.47}		{8.77}	

Model 4.1: $R^2 = 0.57$, Adj$R^2 = 0.56$, $F = 76.8$, p value = 0.000, $d = 1.5229$
Model 4.2: $R^2 = 0.57$, Adj$R^2 = 0.56$, $F = 76.88$, p value = 0.000, $d = 1.6551$
where:
R^2 = coefficient of variation, AdjR^2 = Adjusted coefficient of variation, d = Durbin Watson test statistic, values in parentheses are p values and values in braces are t-statistics

Models 4.1 and 4.2 are double log models of average monthly tomato prices in Durban as a function of average tomato prices in Johannesburg, and average monthly tomato prices in Johannesburg as a function of average tomato prices in Durban, respectively. The results show that overall, the coefficients in both regressions are statistically significant as indicated by the statistically significant F-statistics at all levels of significance. This implies that at least one of the variables included in each model is significant in explaining the dependent variable. Both models explain 57% of the variation in the dependent variable. The result presented in Table 2 shows that a 1% increase in average monthly tomato prices in Durban causes an about 0.74% increase in average monthly tomato prices in Johannesburg, while a 1% increase in average monthly tomato prices in the Johannesburg market causes an about 0.78% increase in average monthly tomato prices in the Durban market, *ceteris paribus*.

The models were re-estimated and the time variable was included. The results indicate that both models show no sign of serial correlation with Durbin Watson statistics of 1.84 and 1.77 (d~2). This is also supported by the BG-test at all levels of significance. Further tests also show that the series had no sign of multicollinearity with a VIF of 1.05, which is below 10. Overall, the coefficients in both models were statistically significant at all levels. Thus, at least one of the variables included in each model was important in explaining the dependent variable.

The decision rule for significance is that *p*-values must be less than the significance levels of 1%, 5% and 10%, i.e. for the variables to be significant at 5%, for example, the *p*-value must be less than 0.05; otherwise, it is insignificant at this level. Table 3 shows the cointegration model regression results, taking into account the effects of time.

Table 3. Cointegration models with the time variable (i.e. with trend)

Dependent variable	Constant	Independent variables			Model
		$\ln T_{jt}$	$\ln T_{dt}$	time	
$\ln T_{dt}$	2.6731	0.6692		0.0045	4.3
	0	0		0	
	{4.18}	{8.61}		{3.78}	
$\ln T_{jt}$	1.3069		0.8449	–0.0023	4.4
	–0.109		0	–0.123	
	{1.63}		{8.61}	{–1.57}	

Model 4.3: R^2 = 0.65, AdjR^2 = 0.64, F = 54.4, p value = 0.000, d = 1.84
Model 4.4: R^2 = 0.59, AdjR^2 = 0.57, F = 40.63, p value = 0.000, d = 1.77
where:
R^2 = coefficient of variation, AdjR^2 = Adjusted coefficient of variation, d = Durbin Watson test statistic, values in parentheses are *p*-values and values in braces are *t*-statistics.

In model 4.3, time and the average monthly tomato prices in Johannesburg are both significant in explaining changes in average monthly tomato prices in Durban. This implies that a 1% increase in average monthly tomato prices in Johannesburg causes a 0.67% increase in average monthly tomato prices in Durban, while a one-month increase in time results in a 0.45% increase in average monthly tomato prices in Durban, *ceteris paribus*. While in model 4.4, the inclusion of the time variable causes the intercept to be insignificant at all levels of significance. Table 4 summarizes the results from the AEG cointegration test.

Table 4. Summary results for the AEG cointegration test

Variable	AEG τ value	Critical τ values			Lags
		1%	5%	10%	
$\ln T_{dt}$	–6.93	–4.13	–3.491	–3.175	0
$\ln T_{jt}$	–6.749	–4.13	–3.491	–3.175	0

The absolute value of the AEG τ value was higher than the absolute critical values at all levels of significance. Therefore, the null hypothesis of non-stationarity in the residuals and of the absence of cointegration was rejected; it was concluded that the average monthly tomato prices in Durban move together with the average monthly tomato prices in Johannesburg in the long run. That is, there is a cointegration relationship between the two variables. These results provide empirical evidence that tomato prices in both markets do not represent separate or independent markets; instead, they form part of one integrated market with a common price determination process. This suggests that even though regional markets are geographically dispersed and spatially segmented, spatial pricing relationships show that tomato prices are linked together indicating that all the tomato exchange locations exist within the same economic context.

Granger and Weiss (1983) demonstrated that if a set of variables are cointegrated, they could be regarded as being generated by an Error Correction Model, which is called the Granger representation Theorem.

Error Correction Model (ECM) results

Even though it has been concluded that there is market integration through cointegration, there could be disequilibrium in the short run, which implies that price adjustment across markets may not occur instantaneously. It may take some time for spatial price adjustments. Engel and Granger (1987) showed that when price series are integrated and cointegrated, their short-run dynamics can be examined using the Error Correction Model (ECM), which takes into account the short-run and long-run disequilibrium in the markets and the time taken to eliminate disequilibrium.

After the residuals were found to be stationary (that being a sign of cointegration), the residuals from the cointegration regression were then used in the second stage as estimates of true disequilibrium errors in an ECM. The

ECM gives the short-run dynamics within the framework of the long-run stable relationship established by the cointegration between the variables (Nkoro and Uko, 2016). The results of the ECM are presented in Table 5.

The ECM was used to determine whether there is a causal relationship between average monthly prices in Durban and average monthly prices in Johannesburg. The results showed that for both models (i.e., 4.5 and 4.6), the intercepts were not important in explaining the causal relationships. However, all explanatory variables including the ECMs were significant at all levels, implying that a percentage change in the average monthly prices in the Durban market is important in explaining the percentage changes in average monthly tomato prices in the Johannesburg market.

When prices are cointegrated, the coefficient EMC_{t-1} (which is known as the attractor and helps to absorb the effects of shocks and keeps prices in a long-term equilibrium relationship) is often negative and statistically significant. The higher the value of the attractor, the faster the adjustment of price towards its equilibrium level. The results presented in Table 5 show that the coefficients on the lagged error terms were both negative as expected, and statistically significant at 1% and 5% levels. The significant *F*-values for both models indicate the presence of bi-directional Granger-Causality between average monthly tomato prices for the Durban and Johannesburg markets. The coefficient for the lagged error term indicate the speed at which the dependent variable adjusts to equilibrium. Thus, the rate at which average monthly tomato prices in Durban move back to equilibrium is 92.89% (model 4.5) and the rate at which average monthly tomato prices in Johannesburg adjust to equilibrium is 87.25% (model 4.6). This implies that following a shock to the market which causes disequilibrium, economic agents take about 1 month to adjust back to equilibrium. Thus, the response to the shock is faster in the Durban market compared to the Johannesburg market. The relatively low speed of adjustment for the Johannesburg market, as reflected by the ECM, can be attributed to the fact that the Johannesburg market serves a relatively larger area than the Durban market (Abdulai, 2000). It can also be due to a greater number of government policy interventions which affect the Johannesburg market more than the Durban market. Another possible cause of the difference in rates of adjustment between the Johannesburg and Durban markets could be the differences in transaction costs and other distortions within the respective markets.

Table 5. Results from the Error Correction Model (ECM)

Dependent variable	Constant	Independent variables			Model
		$\Delta \ln T_{jt}$	$\Delta \ln T_{dt}$	EMC_{t-1}	
$\Delta \ln T_{dt}$	0,0038	0,6181		–0,9289	4.5
	(0,854)	(0,000)		(0,000)	
	{0.19}	{8.70}		{–6.78}	
$\Delta \ln T_{jt}$	0,0014		0,7560	–0,8725	4.6
	(0,951)		(0,000)	(0,000)	
	{0.06}		{8.74}	{–6.61}	

Model 4.5: R^2 = 0.67, AdjR^2 = 0.65, F = 55.97, p value = 0.000, d = 1.96
Model 4.6: R^2 = 0.65, AdjR^2 = 0.64, F = 53.14, p value = 0.000, d = 1.97
R^2 = coefficient of variation, AdjR^2 = Adjusted coefficient of variation, d = Durbin Watson test statistic, values in parentheses are p values, values in braces are t-statistics.

CONCLUSIONS AND POLICY RECOMMENDATIONS

From the results of the study, it can be concluded that the average monthly tomato prices in the Durban and Johannesburg fresh produce market move together in the long run, implying a cointegration relationship in tomato prices in the two markets. Hence, the "Law of One Price" holds as Durban prices can be expressed in terms of Johannesburg prices.

The high degree of market integration observed in this study leads to some policy recommendations. Since the tomato market is highly integrated and price signals are transmitted within a month, this suggests that market stabilization policies can be planned at national level, which could help in achieving food security for the consumers. Also, for a highly perishable product like tomato, which tends to be sensitive to market crises, a public intervention at local level – aimed at ensuring adequate management of sudden market prices – would be appropriate. This could include an improvement in economies of scale in tomato marketing operations and an improvement in transportation and information infrastructures, which could reduce transaction costs and thus increase market integration.

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