Infrastructure Investments, Regional Trade Agreements and Agricultural Market Integration in Mozambique

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Abstract

Integration of agricultural markets has been a topic of great interest in Mozambique. Numerous studies have been conducted to assess both domestic and regional integration of maize markets in the country, though with some contradictory results. In this study domestic and regional market integration in Mozambique is assessed, focusing on maize markets as the main crop in the country. In contrast to previous work, this study takes into account new investments in infrastructure as well as changes in regional trade policies, using vector autoregressive (VAR) and vector error correction (VEC) models. The main findings suggest that maize markets in Mozambique are not efficiently integrated. This is particularly true between the deficit markets in the South and the surplus markets in the Centre and North of the country. At the regional level, market integration is also inefficient in many cases. Nonetheless, investments in infrastructure, such as the Zambezi River Bridge, linking the north to the rest of the country, as well as changes in trade policies over the years are shown to be significantly impacting to maize price changes, particularly in the north. The overall results suggest there is room for improvements in the maize value chain performance, particularly there is scope for farmers to engage more in trade and for reducing food loss. Action may include investments on training programs and incentives to shift farmers from the current subsistence farming to a more commercial farming system approach.

1. Introduction

Spatial integration of markets and efficient price transmission are important to reduce price volatility of commodities and to lead to gains from trade (Baulch, 1997). However, despite advances in information technology systems, agricultural markets in Africa are still seen as islands isolated from the world. Conforti (2004) and Minot (2011) found overall poor short-term and long-term price transmission from world agricultural markets to domestic markets in Africa. Together, these two authors have evaluated around 11 agricultural markets in Africa (including Mozambique), all from the Sub-Saharan region with the exception of Egypt.

Recently, Davids et al. (2016) examined market integration for maize within the Eastern and Southern Africa region and the relationship between different markets across the three main regions (South, Centre and North) of Mozambique and markets in the cross-border countries. However, they did not test for integration across the markets in Mozambique.

In general, the results from past studies have been contradictory. Some studies point to poor integration of maize markets between the domestic surplus and deficit regions, while others suggest a highly efficient spatial arbitrage condition that leads to market integration (Alemu & Biacuana, 2006; Penzhorn & Arndt, 2002; Tostão & Brorsen, 2005; Van Campenhout, 2012). The reality, however, is that maize trade between the domestic surplus and deficit markets is limited. Most of the maize consumed in the South is sourced from imports, particularly from South Africa (AFF, 2012; Cirera & Arndt, 2008; Traub et al., 2010). Findings from Traub et al. (2010) and Davids et al. (2016) point to a long-run price relationship between Maputo and South Africa with regard to maize and maize meal price transmission. Likewise, maize

markets from the Central and Northern provinces are integrated with markets from Malawi and Zambia (Paulo, 2011).

With regard to Mozambique, price transmission and market integration have been topics of great interest over the last two decades. Apart from the study by Minot (2011), a considerable number of other studies have been undertaken in relation to Mozambique agricultural commodities (Alemu & Biacuana, 2006; Davids, Schroeder, Meyer, & Chisanga, 2016; Paulo, 2011; Penzhorn & Arndt, 2002; Tostão & Brorsen, 2005; Traub, Myers, Jayne, & Meyer, 2010; Van Campenhout, 2012). In many of those studies the focus has been on domestic and regional price transmission for maize. This is not surprising since maize is an important crop in the Southern Africa region, and it is the most grown and consumed crop in Mozambique. Penzhorn and Arndt (2002), Tostão and Brorsen (2005), Alemu and Biacuana (2006) and Van Campenhout (2012) focused on domestic spatial integration of maize markets across the surplus and deficit regions for maize in Mozambique. Others have concentrated on cross-country price transmission analyses. Traub et al. (2010) focused on market integration between Maputo (South of Mozambique) and South Africa, whilst Paulo (2011) analyzed the spatial integration between the markets in the surplus region (North and Centre) of Mozambique and markets in neighboring countries (Malawi and Zambia) where informal exports frequently occur.

The limited domestic trade of maize (and other commodities) between the surplus and deficit regions in Mozambique has been associated with overall poor marketing conditions that lead to excessive transfer costs between these regions (Alemu & Biacuana, 2006; Cirera & Arndt, 2008; Penzhorn & Arndt, 2002; Tostão & Brorsen, 2005; Van Campenhout, 2012). This is also likely the case with nearby markets. Despite some investment in road rehabilitation in the post-civil war period (after 1992), Cirera and Arndt (2008) found a weak positive impact of such investments on integration of nearby markets (24 km to 243 km away).

Further investments in transport infrastructure and road rehabilitation across the country have continued over the years. The most significant investment was the construction of the Zambezi River Bridge, opened in August 2009. At 2.4 km long it is one of the largest in Africa and it ensures a complete road connection between the North and South of Mozambique (Reis, Pedro, & Dalili, 2012). Other investments in road infrastructure and rehabilitation have also been made, particularly through projects funded by the World Bank and other donors (AfDB, 2006; IFAD, 2016; World Bank, 2018a). The main expected outcome from such investments is improved domestic markets integration, which is crucial to boost domestic agricultural production and minimize food loss, particularly at the farm level. The rationale is that, even for markets that are not directly trade related, market integration between them is important to reduce arbitrage that is important for fairer prices, particularly at the farm level. However, to date, no study has been carried out to assess the impact of the Zambezi River Bridge on domestic or regional agricultural markets integration.

The aim of this study is to assess the integration of domestic and regional markets for maize in Mozambique and it contributes to the literature in three key ways. Firstly, it is an updated study on

domestic market integration in Mozambique. Secondly, it assesses the impact of the Zambezi River Bridge and changes in trade policies on domestic and regional markets' integration. Thirdly, it is broader in scope than previous studies in that it tests for market integration considering simultaneously domestic markets across the three regions of Mozambique and markets from countries where regional trade is prevalent. Outcomes from this study provide key information on the status of market integration domestic and regionally, that can assist with policy decisions aimed at improving the maize value chain performance in the country.

2. Theory Of Market Integration And Price Transmission Analyses

Market integration and price transmission are interrelated, though different concepts. Different markets are said to be spatially integrated if tradability of a particular good (or set of goods) exists between them, and (or) price shocks from one market are transmitted to the other market (Barrett & Li, 2002). Price transmission, however, is limited to the reaction of price in one market (or level) as a response to changes in prices in another market (or level) (Bunte, 2006; Minot, 2011). Price transmission is then a form of market integration and, in many cases the two terms are used interchangeably.

Transmission of price shocks (or price co-movement) across markets, and hence market integration, can be driven by different factors such as trade network infrastructures, volatility of transport costs and common climatic conditions (Fackler & Goodwin, 2001; Ravallion, 1986). Other factors such as *"domestic and border regulation policies, market power, product heterogeneity and perishability, exchange rate risks, imperfect flow of information and expectations"* (Listorti & Esposti, 2012, p. 84) are also regarded as drivers of spatial arbitrage and price transmission.

Price shock transmission can also occur between markets not directly connected through trade. For instance, two markets (A and B) not directly connected through trade can be strongly integrated if they both are connected directly in trade to a common third market (C) (Fackler & Goodwin, 2001).

Common approaches to assess market integration are based on the "Law of One Price" (LOP) (Baulch, 1997; Rapsomanikis, Hallam, & Conforti, 2006). This law states that, under trade and arbitrage conditions, the price differential of a homogenous good between two different markets is equivalent to the transfer costs of that particular good from the lower price market to the higher price market (Listorti & Esposti, 2012; Rapsomanikis et al., 2006). Assumptions behind LOP are very strong and restrictive as noted by Listorti and Esposti (2012) and Rapsomanikis et al. (2006). An alternative to LOP is the spatial arbitrage condition, which states that a condition for market integration requires the price differential of a homogenous commodity between two markets to be at most (and not necessarily) equal to the transfer cost (Fackler & Goodwin, 2001; Rapsomanikis et al., 2006).

$$\text{LOP: } P_i + r_{ij} = P_j$$

$$\text{Spatial arbitrage condition: } P_j - P_i \leq r_{ij}$$

Where, P is the price of the commodity in markets i and j , and r_{ij} is the commodity's transfer cost from market i to j .

The spatial arbitrage condition is regarded as a “weak LOP”. Despite the inequality sign, the weak LOP is viewed as an equilibrium concept. Accordingly, even if actual prices diverge from the weak LOP, in well-functioning markets actions from arbitrageurs will tend to move the price spread towards transfer costs (Fackler & Goodwin, 2001).

Over the years, different approaches to market integration and price transmission analyses have been developed based on the LOP and the spatial arbitrage condition definitions. These include correlation analysis, static and (several variations of) dynamic regression models and the parity bounds model (Abdulai, 2000; Baulch, 1997; Fackler & Goodwin, 2001; Ravallion, 1986).

Dynamic regression models are the most widely used approaches, with many being based on autoregressive distributed lag (ARDL) models. The vector autoregressive (VAR) model is a good example of ARDL models used for this purpose. As the name suggests, VAR is a matrix of multiple regression models with different related and simultaneously treated endogenous variables, with lagged variables included to capture the dynamic and long-term market integration relationships (Popat, Griffith, & Mounier, 2017). This model is also based on the correlation among a set of variables, however, it also allows for the analyses of causality and impulse response relationships between endogenous variables (Lütkepohl, 2005). VAR is appropriate to describe the relationship between stationary (or integrated) series. In cases where series cannot be made integrated, a variant of this model, a restricted VAR also called the Vector Error Correction (VEC) model, is often suggested for cointegrated series (Hill, Griffiths, & Lim, 2012).

Examples of past studies relying on ARDL models for price transmission analysis for agricultural crop commodities include Ravallion (1986), Abdulai (2000), Conforti (2004), Alemu and Biacuana (2006), Traub et al. (2010), Paulo (2011), Minot (2011) and Davids et al. (2016). Alemu and Biacuana (2006) and Van Campenhout (2012) for instance, have used the threshold autoregressive (TAR) model. This model, unlike some other variants of ARDL (e.g., VAR and VEC models), is extended to include information on transfer costs. Traub et al. (2010) used the switching error correction model, which allows the inclusion of other set of variables. Others like Chang and Griffith (1998), Taha and Hahn (2014) and Popat et al. (2017) have relied on ARDL model approaches to non-crop agricultural commodities.

An alternative to ARDL models for market integration assessment is the parity bounds model (PBM) proposed by Baulch (1997). In addition to the price data required for ARDL models, PBM demands information on transfer costs to assess spatial arbitrage efficiency – the validity of the spatial arbitrage condition – between markets. Particular advantages of this model are its explicit consideration in the analysis of the possibility of trade flow discontinuity and simultaneity of price determination between markets, as well as the issues related to stationary and cointegration of time-series (Baulch, 1997). Penzhorn and Arndt (2002), Tostão and Brorsen (2005) and Cirera and Arndt (2008) have used PBM to

assess the spatial arbitrage efficiency between maize markets in Mozambique. Some limitations of PBM, however, include the model's inability to account for the time-series properties of the data, and its results being dependent on distributional assumptions, which are not based on economic theory (Cirera & Arndt, 2008; Van Campenhout, 2012).

3. The Maize Trade Environment In Mozambique

Domestic trade of maize and other agricultural commodities is limited domestically, particularly between the surplus and deficit regions in Mozambique. Figure 1 below displays the maize value chain behavior in the two markets. The limited trade has been attributed to the excessive transfer costs derived from the long distances and existing poor road infrastructure conditions between the regions. In contrast, the proximity to regional markets in neighboring countries has favored imports (by the South) and exports (from the North and Centre).

Current regional trade policies also seem to be favoring maize imports. Since 1997 maize (grain) import tariffs have settled at a low 2.5 percent (*ad valorem*) for Most Favored Nations (MFN), and have been waived (in some years) for specific countries or regions (Table 1). For maize flour import tariffs are much higher.

Although the current import duty rates on maize and maize flour aim at protecting and promoting the development of the domestic milling industry, the goal of achieving self-sufficiency in maize supply is adversely affected. Maize import volumes have responded positively to import tariff suspensions. The long-term free trade agreements (FTAs) established between SADC countries beginning in 2012 seem to be linked to the increasing trend in maize imports observed in the following years (Fig. 2). Over the last 3 years (2015 to 2017), however, the rapid depreciation of the national currency (Metical) as a result of the economic downturn (FAO, 2017; World Bank, 2018b), aligned with other factors, seems to have dampened other incentives for the increasing imports.

Table 1
Maize and maize flour import tariff duty rates per line over the period 1997 to 2016

Period	Maize (corn) (HS ^a 1005) duty rates ^b per line of preference				
	MFN	South Africa	Malawi	SADC (other countries)	EU
1997–2000	2.5%	—	—	—	—
2001	2.5%	0%	—	0%	—
2002–2003	2.5%	0%	—	0%	—
2004–2006	2.5%	—	—	—	—
2007–2011	2.5%	—	—	—	—
2012	2.5%	0%	—	0%	—
2013	2.5%	0%	—	0%	—
2014–2016	2.5%	0%	—	0%	0%
Period	Maize (corn) flour (HS 11022000) duty rates per line of preference				
	MFN	South Africa	Malawi	SADC (other countries)	EU
1997–2000	35%	—	—	—	—
2001	30%	—	—	—	—
2002–2003	25%	—	—	—	—
2004–2006	25%	—	—	—	—
2007–2011	20%	—	—	—	—
2012	20%	15%	—	10%	—
2013	20%	15%	0%	10%	—
2014–2016	20%	15%	—	15%	—
^a HS stands for the harmonized system nomenclature from 2007					
^b where not specified, duty rates preference to a particular country (or region) are assumed to be similar to the regional (or MFN) agreements					

Source: World Trade Organization (WTO, 2018)

4. Methods

In this study a VEC model is used to assess maize market integration in Mozambique. The main advantage of this model is the relatively low demand for data. Usually data on prices are sufficient to effectively assess the relationship across markets.

The majority of past studies on maize market integration in Mozambique have relied solely on maize prices (Davids et al., 2016; Paulo, 2011) and transport costs (Penzhorn & Arndt, 2002; Tostão & Brorsen, 2005; Van Campenhout, 2012). Others have extended their models to capture seasonal variations (Alemu & Biacuana, 2006) or the impact of road rehabilitation (Cirera & Arndt, 2008), while a few studies (e.g., Traub et al., 2010) have included other variables such as tariffs and traded volumes. In this study, the impacts of the Zambezi River Bridge, macroeconomic changes in trade policies and seasonal variations are taken into account. Some of these are nonlinear models, whose usefulness are highlighted by Sexton, Kling and Carman (1991).

4.1. Model Specification

The standard form of the proposed VEC model for this study is described in Eq. 1. This equation derives from Johansen's methodology for error-correction models as described by Johansen (1995) and Mukherjee and Naka (1995). Chang and Griffith (1998) used a similar VEC model with dummy control regressors. For Eq. 1, the proposed set of dummy control regressors is summarized in Table 2.

$$\Delta x_t = \pi_0 + \pi x_{t-1} + \sum_{i=1}^{p-1} \pi_i \Delta x_{t-i} + \sum_{j=1}^J B_j Z_{j,t} + \varepsilon_t \quad (1)$$

where $\pi = \left(I - \sum_{i=1}^p A_i \right)$ and $\pi_i = - \sum_{j=i+1}^p A_j$

p = the lag length;

$x_t = (n \times 1)$ vector of endogenous variables;

$\Delta x_{t-i} = (n \times 1)$ vector of x_{t-i} in first differences;

$I = (n \times n)$ the identity matrix;

$A = (n \times n)$ matrices of the unknown parameters for the endogenous regressors;

π = matrix rank;

$\pi_0 = (n \times 1)$ vector of intercepts;

$B = (J \times J)$ vector of the unknown parameters for the exogenous (dummy) regressors;

$Z_t = (J \times J)$ matrices of the exogenous (dummy) variables;

$\varepsilon_t = (n \times 1)$ vector of the white-noise disturbance term (assumed to be independently and identically distributed with zero mean and variance matrix $\Sigma\varepsilon$).

Table 2: List of variables used to VEC model

Variable	Description
x_1	Log of (real) maize (retail) price for Maputo (South of Mozambique)
x_2	Log of (real) maize (retail) price for Chimoio (Centre of Mozambique)
x_3	Log of (real) maize (retail) price for Nampula (North of Mozambique)
x_4	Log of (real) maize (retail) price for Lilongwe (Malawi)
x_5	Log of (real) maize (wholesale) price for Randfontein (South Africa)
Z_1	Dummy control regressor for the investments in road infrastructure (the Zambezi River Bridge). $Z_1 = 1$ since August 2009, and $Z_1 = 0$ otherwise.
Z_2	Dummy control regressor for the changes in trade policy as displayed in Figure 2. $Z_2 = 1$ for periods of FTA (with South Africa), and $Z_2 = 0$ otherwise.
D_{1-11}	Seasonal dummies (January to November). D is a subset of the Z defined in Equation 1.

VEC are appropriate models for data series that are not stationary but cointegrated (Enders, 2015). A rapid diagnosis on the data suggests that maize prices (in most markets) are random walk nonstationary processes moving closely in the same direction for the majority of the sampling period. Therefore, VEC seems appropriate compared to VAR. Formal unit roots tests are also performed to confirm the stationary condition.

In VEC models, the right-hand side in Equation 1 is usually of primary interest. It displays information of the matrix rank (π), which represents the long-run impact in the model (Chang & Griffith, 1998). The order of π (also called matrix rank order, r) is important to determine the number of cointegrating vectors in the system. If $r = 0$, the VEC model is equivalent to a VAR in first differences and variables are not cointegrated, i.e., they do not share the same stochastic trend and the long-run relationship cannot be established from this model (Enders, 2015). If $r = n$, all variables are stationary and VEC is again equivalent to VAR, though in levels. Intermediate cases where the rank order is between 1 and n imply the existence of a single (if $r = 1$) or multiple (if $1 < r < n$) co-integrating vectors (Chang & Griffith, 1998; Enders, 2015).

The matrix rank order can be determined by the characteristics roots tests (Equations 2 or 3). Critical values from these tests derive from the Monte Carlo approach and are dependent on degrees of freedom

equivalent to the “number of nonstationary components under the null hypothesis (i.e. $n - r$)” and the presence of a constant and (or) drift terms in the model (Enders, 2015).

$$\lambda_{trace}(r) = -T \sum_{i=r+1}^n \ln(1 - \hat{\lambda}_i) \quad (2)$$

$$\lambda_{max}(r, r+1) = -T \sum_{i=r+1}^n \ln(1 - \hat{\lambda}_{r+1}) \quad (3)$$

Where,

$\hat{\lambda}_i$ = the estimated values of the characteristic roots obtained from the estimated π matrix;

T = the number of observations.

Another property of π is that it can also be used to determine the speed of adjustment parameters (α), which is a measure of the long-run dynamics (Chang & Griffith, 1998; Enders, 2015). As described in Johansen’s methodology, the matrix rank order can be viewed as a product between the matrices α and cointegrating parameters (β), i.e., $\pi = \alpha\beta'$ (Enders, 2015). Chang and Griffith (1998, p. 372) summarizes that:

A large (small) value of α means that the system will respond to a deviation from the long-run equilibrium with a rapid (slow) adjustment. On the other hand, if the α s are zero for some equations, it implies that the corresponding variables do not respond to the disequilibrium error and, hence, may be weakly exogenous.

Equation 1 is estimated as a bivariate model for each pairwise market using Eviews 8. If market pairs are not cointegrated, Eq. 1 is reduced to the appropriate VAR form.

The VEC model is estimated using Johansen’s methodology. Overall, four main steps are required to implement VEC models, and parameters can be consistently estimated by the maximum likelihood estimator (Enders, 2015). The steps include:

- Variables pretesting (for lag length and order of integration);
- Model estimation (as in Eq. 1), rank determination and white-noise properties test;
- (if white-noise properties are satisfied) Analyses of the normalized cointegrating vector(s) and the speed of adjustment coefficients;
- Assessment of the model adequacy (causality tests).

4.1.1. Lag Length and Stationary Tests

The first step in estimating VEC (and VAR) models includes the pre-tests to determine the variables lag length and order of integration. Appropriate lag order selection, in particular, has the property of returning the minimum mean square errors (Lütkepohl, 2005) and, hence, (*ceteris paribus*) leading to more consistent parameter estimates and robust post-estimation tests. Different procedures for lag order selection can be found in the literature. According to Lütkepohl (2005), the Schwarz Bayesian information criterion (SBIC or SC) is more consistent compared to others. Hence, SBIC is chosen for this study.

Although VEC models can reveal the presence (or absence) of cointegration among series regardless of their integration order, Enders (2015) recommends testing for series order of integration. Augmented Dickey-Fuller (ADF) and Phillips-Perron are some of the tests used for this purpose (Enders, 2015; Hill et al., 2012). The former is constructed under the assumption of residuals independence with constant variance whilst the “*Phillips-Perron test* [, which is a modification of the Dickey-Fuller test,] *allows the disturbances to be weakly dependent and heterogeneously distributed*” (Enders, 1994, p. 239). Both ADF and Phillips-Perron tests are performed in this study.

4.1.2. Model’s Assessment

Validation of the results from Eq. 1 is subject to the properties of the residuals. Consistent results and valid post-estimation statistic tests are ensured if residuals from the model are at least independently distributed and display time invariant variance. Autocorrelation is tested using the Lagrange multiplier (LM) test as proposed by Johansen (1995). For time invariant variance (homoskedasticity), the White test with cross-product terms is performed.

4.2. Post-estimation Tests

Significance tests on the α 's are important to identify weakly exogenous variables in the system (i.e., if there are any $\alpha = 0$) whilst on the β 's statistics tests are relevant to identify the system and establish r linear combination of variables necessary to construct meaningful parameters of α 's through appropriate normalization of β 's (Johansen, 1995). The test statistic for the purpose of testing individual (or a linear combination of the same) parameter type is described as a likelihood ratio test (LR). This test involves comparing restricted to unrestricted models, and it follows a chi-square distribution with degrees of freedom equal to the number of restrictions. In the case of a single cointegrating vector ($r = 1$) LR is asymptotically equivalent to a t -test for a single coefficient test (Enders, 2015).

Other tests such as the impulse response function are also recommended as complementary to VEC analysis. Lütkepohl (2005, p. 262) supports that “*impulse responses may give a better picture of the relations between variables*”. Chang and Griffith (1998), Listorti and Esposti (2012) and Popat et al. (2017) are some examples of past studies that applied impulse response function as complementary to VAR or VEC model analyses. Broadly speaking, impulse response functions are useful to assess the adjustment response from a variable to shocks on other variable within the system (Hill et al., 2012; Lütkepohl, 2005). For this study, however, the focus is limited to the degree of integration between

markets and the significance of the estimated coefficients. Assessing the response of one market to shocks on the other market is beyond the scope of this study.

4.3. Data

This study is based on monthly price series from January 2007 to December 2015. Prices from Mozambique (Maputo, Chimoio and Nampula) were gathered from the Ministry of Agriculture and Food Security (MASA) and converted to USD using the monthly exchange rate obtained from the Central Bank. FAO GIEWS was the source of price data from Malawi (Lilongwe) and South Africa (Randfontein). The selected markets are similar to those used in previous studies. All maize prices are at the retail level, except from South Africa where wholesale prices are the only prices reported. All prices are converted to real terms by the Mozambique's consumer price index provided by the Central Bank and the National Institute of Statistics (adjusted to the base period of December 2010), and used in log-forms. The trends of these prices over time for each market are displayed in Fig. 3. Descriptive statistics of real prices are presented in Table 3. Overall, price series variability range from 20 to 35 percent, with the series for Maputo being the most stable.

Data availability and access is a major limitation for this study. Only price data could be accessed for this study. Some (10) cases of missing data were observed on the dataset, all for Lilongwe from January to October 2011. The missing data was replaced with information from the closest market from which data was available. Nsanje (in Malawi), was used as a proxy for Lilongwe and information was gathered from February to October 2011. A linear interpolation with the months in between was then used to estimate a price for January.

Another important feature of the dataset is the timing of coverage. Prices gathered from MASA were up to December 2015. This captures the initial period of the Metical rapid depreciation as shown in Fig. 4. However, it is unlikely that this has much impact on the model since the dataset used does not extend to following years.

Table 3
Descriptive statistics of maize prices (\$ USD/MT) in real terms

Market	N	Mean	Std. Deviation	Min	Max	CV
Maputo	108	406.88	79.88	217.01	646.22	0.20
Chimoio	108	287.34	101.98	148.94	687.81	0.35
Nampula	108	307.59	90.20	181.47	580.96	0.29
Lilongwe	108	286.54	100.63	142.64	611.74	0.35

Source: Data from the Central Bank of Mozambique

5. Results And Discussion

5.1. Estimated Bivariate Models

Based on the outcomes from the preliminary tests, VAR(2) and VEC(2) models are estimated in this study. For the sake of simplicity, full results from the preliminary and post-estimation tests are presented in the Supplementary Materials. Overall, the estimated VAR and VEC models display consistent results. LM and White tests reveal no issues with autocorrelation and heteroskedasticity, respectively, for each of the 10 bivariate models at the lag order selected. The only issue is the violation of the normality assumption. However, *“in large samples the maximum likelihood estimator [...] has a probability distribution that is approximately normal”* (Hill et al., 2012, p. 723). Results from the bivariate models are reported in Table 4.

5.1.1. Domestic Market Integration

Most recent data suggest that Mozambique is still a net importer of maize despite the surpluses produced in the Northern and Central provinces. Annually, over \$USD 25 Million is spent on maize imports (UN COMTRADE, 2018). In contrast, maize surplus is often partly lost at the farm level and traded informally to neighboring countries such as Malawi, Zambia and Zimbabwe (Cugala et al., 2017; FEWSNET, 2018; Hugo, 2008).

Nevertheless, the results in Table 4 suggest that Maputo is integrated with markets from the Centre (Chimoio) and North (Nampula). The integration, however, is not symmetric. For instance, a 1 percent increase in maize prices in Chimoio has a significant impact in Maputo, leading to a 0.20 percent maize price increase in the latter market. Conversely, a 1 percent increase in maize prices in Maputo has no significant causality impact on maize prices changes in Chimoio and Nampula. Whilst such an outcome is generally expected given that Maputo is a deficit market for maize and others are described as maize surplus markets, the magnitudes of the significant coefficients reported are curious.

Table 4
Outcomes from the bivariate models

Markets	Coef.	t-statistic	Integrated	Bridge	Policy
Maputo - Chimoio	0.20 (0.06)	3.17***	Yes	-0.01	-0.01
Maputo - Nampula	2.38 (0.49)	4.87***	Yes	-0.00	-0.02
Chimoio - Maputo	0.06 (0.20)	0.31	No	-0.02	0.00
Chimoio - Nampula	2.00 (0.33)	6.06***	Yes	0.00	-0.01
Nampula - Maputo	0.42 (0.26)	1.59	No	-0.09***	0.06**
Nampula - Chimoio	0.50 (0.13)	3.55***	Yes	-0.09***	0.06**
Maputo - Randfontein	-0.03 (0.07)	0.42	No	-0.01	-0.01
Chimoio - Randfontein	0.00 (0.12)	0.02	No	-0.02	0.00
Nampula - Randfontein	0.22 (0.27)	0.83	No	-0.07**	0.04*
Randfontein - Maputo	-0.14 (0.17)	0.80	No	0.02	-0.02
Randfontein - Chimoio	-0.04 (0.10)	0.42	No	0.02	-0.01
Randfontein - Nampula	4.47 (1.18)	3.78***	Yes	0.01	-0.01
Maputo - Lilongwe	0.02 (0.05)	0.44	No	-0.01	-0.01

Markets	Coef.	t-statistic	Integrated	Bridge	Policy
Chimoio - Lilongwe	1.08 (0.22)	4.99***	Yes	-0.01	-0.00
Nampula - Lilongwe	0.64 (0.09)	7.32***	Yes	-0.07**	0.06**
Lilongwe - Maputo	0.12 (0.26)	0.45	No	-0.03	0.01
Lilongwe - Chimoio	0.93 (0.23)	4.01***	Yes	-0.06*	0.01
Lilongwe - Nampula	1.56 (0.18)	8.43***	Yes	-0.00	-0.02
Randfontein - Lilongwe	0.03 (0.07)	0.42	No	0.02	-0.01
Lilongwe - Randfontein	0.09 (0.16)	0.60	No	-0.03	0.01

Given the excessive transportation costs between the North and South of Mozambique (Coughlin, 2006), one would expect Maputo to be more integrated to Chimoio than to Nampula. Nonetheless, the findings from this study suggest the opposite.

One explanation relates to the expansion of the milling industry from the South to the Central and Northern provinces of Mozambique, which happened during the same period. One of the biggest millers operating in the Central region was launched in 2005 (Agriterro Ltd, 2019; World Bank, 2012), and a number of others operating in the Northern provinces were launched about the same time. This expansion of the milling industry has potentially increased the North's demand for maize. This may have led to some degree of competition between the North and South for the maize produced in the Centre. This is likely the classic example of two apparently unrelated markets being integrated from sharing a third and common market supplier.

The Central region of Mozambique (where Chimoio is located) is the major producer of maize, contributing around 60[1] percent of national production (MASA, 2015, 2016). With the Central region presumably playing an important role as a common domestic maize supplier for both the North and South, the positive and significant relationship between Maputo and Nampula seems acceptable. Since Maputo (and the South in general) is by far the major consumption market for maize domestically (Alemu & Biacuana, 2006; Penzhorn & Arndt, 2002), a larger response to price changes in Nampula would be expected as an incentive to attract sellers from the Centre. In contrast, price changes in Maputo are

likely to have a minimum (or no significant) effect to price changes elsewhere since the North is also an important production region for maize.

Chambo (2013) also found a positive and significant impact of maize price changes in Nampula to prices in Maputo. That study used weekly data between January 2007 and May 2013 to assess maize price transmission at the wholesale level across Maputo, Nampula and South African markets using a similar methodology. To explain these findings Chambo (2013) points out that “a considerable part of the domestic maize consumed in Maputo is sourced from Nampula”, which is stated to be “the major producer province of maize in Mozambique” (Chambo, 2013, p. 60). This view, however, does not match with the data reported by MASA (2015, 2016) for the years 2012, 2014 and 2015, which suggests Tete, Zambezia and Manica (all in the Central region) were the top three producers of maize, respectively. Santos and Tschirley (1999) also suggest infrequent trade of maize between the two regions due mainly to excessive transaction costs. Even though data on maize trade across the domestic markets could not be accessed, Chambo’s arguments are hardly convincing.

Van Campenhout (2012) using monthly data from January 2000 to February 2011 also studied the maize price relationship between Maputo and Nampula, using autoregressive, TAR and flexible TAR models. The author found a negative relationship with estimated coefficients ranging from about -0.10 to -0.06. This inverse relationship is not clearly discussed by the author.

Maize markets integration between Maputo and Chimoio is the most studied relationship in recent years. Penzhorn and Arndt (2002), Tostão and Brorsen (2005), Alemu and Biacuana (2006) and Van Campenhout (2012) are some examples of past studies focusing on market integration between these two markets. Past results, however, are not congruent. The findings from this study point to Maputo being integrated to Chimoio (and not the opposite) in accordance with findings from Penzhorn and Arndt (2002) and Alemu and Biacuana (2006). Conclusions from other studies have been contradictory. For instance, using the PBM approach with weekly data, Penzhorn and Arndt (2002) point to market integration between Maputo and Chimoio more than 75 percent of the time during the period 1993–1998. In contrast, Tostão and Brorsen (2005), in analyzing the relationship between the same markets using the same methodological approach, found market inefficiency (and hence non-integration) over 80 percent of the time using monthly data over the period 1994–2001. Results from other studies are also intriguing. Whilst overall results from Alemu and Biacuana (2006) point to a strong integration and a positive price relationship between the two, Van Campenhout (2012) using a similar approach (TAR model) identified a negative relationship.

With regard to Chimoio and Nampula, a similar outcome to Maputo and Chimoio integration would be expected since the Centre is likely a maize supplier to the North and South. Nonetheless, the results from Table 4 point to a symmetric significant price transmission between Chimoio and Nampula, with Chimoio’s responsiveness being about twice the price changes in Nampula, and Nampula’s responsiveness being about 0.50 percent to a 1 percent price changes in Chimoio. This outcome suggests one of two things: either (i) buyers from Nampula have low bargaining power, or (ii) excessive

transfer costs exist between the two markets. The latter seems more plausible. Overall access to production centers in the country is difficult due to poor infrastructure, and until mid-2009 the road connection between the North and the rest of the country was interrupted, and access was only be possible by ferry (Reis et al., 2012).

Overall, the results suggest that domestic maize markets are poorly integrated. Whilst prices are transmitted from the North and Centre to the South, the opposite doesn't hold. Between the North and Centre, a symmetric significant price transmission is observed. However, market inefficiency is still an issue, with price transmission not being proportional. If the LOP holds, the price differential between markets should only be explained by changes in transfer costs, in which case symmetric and proportional price changes (in relative terms) would be expected unless access costs display some volatility. The main likely outcome from such poor market integration is the overall low domestic trade, which may have some implications to food losses, mainly at the surplus markets, and to the South's strongest reliance on imports. Considering the current downturn in the domestic economy (World Bank, 2018b), the Government of Mozambique should seek to reduce the dependence on overall imports by better linking the surplus and deficit regions. Alternatively, to avoid (or minimize) food losses efficiently, surplus markets should at least be price integrated with regional markets with trade occurring between them.

5.1.2. Regional Market Integration: Mozambique and South Africa

In small-scale producing countries such as Mozambique, regional market integration is crucial to ensure that domestic markets are not islands isolated from the world or region, and that changes in domestic prices are fairer in an open economy context. With regard to the relationship between Mozambique and South Africa, a number of interesting and intriguing results are identified from Table 4. Overall, domestic markets don't respond to price changes in South Africa in the long run. Whilst these results would seem reasonable for the Central and Northern markets domestically, it may not be so for Maputo. Almost all maize processed in Maputo is imported, mainly from South Africa (World Bank, 2012). That being the case, it is likely that domestic maize grain traded in Maputo goes to a different market segment, which is smaller and non-responsive to price changes in South Africa. Traub et al. (2010) also found a non-significant long-run price relationship between Maputo and South Africa. Nonetheless, these authors found some evidence of a significant relationship between maize meal prices in Maputo and maize grain prices in South Africa.

Possibly the most interesting result on the maize price relationship between the two countries is the significant impact of price changes in Nampula to South Africa. There is no apparent trade connection between Nampula and South Africa and they don't share a common trade partner that would explain such an outcome. Also, considering the relative size of the markets in terms of maize production, it seems intuitive that price changes in South Africa would cause price changes in Nampula and not the opposite. Closer inspection to Fig. 3 shows that maize prices in Chimoio, Nampula and Randfontein (South Africa) move closely together for most of the sampling period. Outcomes from the significant price relationship

between South Africa and Nampula can be an indication of other (market or non-market related) factors that lead to price co-movements across these markets that are not effectively captured in this study.

5.1.3. Regional Market Integration: Mozambique and Malawi

The outcomes from the maize prices relationships between Mozambique and Malawi in this study are consistent with theory. As shown in Table 4, markets in Central and Northern Mozambique are the only ones that display a significant and symmetric price relationship with Malawi. With Malawi being the main destination of Mozambique's informal exports of maize, this outcome is clearly consistent. However, whilst market integration between Chimoio and Malawi seems more efficient, with almost proportional price transmission between the two, the same does not seem true for Nampula and Malawi. Prices in Nampula react by almost 0.6 percent to a 1 percent price changes in Malawi, whilst prices in Malawi react by around 1.6 times to price changes in Nampula. This is likely an indication of lower trade frequency between Malawi and Nampula compared to Malawi and Chimoio, and/or higher access costs for the Malawian imports from Nampula compared to Chimoio.

Results from Davids et al. (2016) also point to a significant and symmetric maize price transmission between Nampula and Lilongwe. In either direction (Nampula – Lilongwe or Lilongwe – Nampula) Davids et al. (2016) found that price changes in each market react similarly (between 0.54 and 0.58) to a 1 percent change in prices from the other market. This is close to the findings in Table 4 regarding the impact of price changes in Lilongwe to Nampula. These authors' model, however, did not account for any control regressors, which could have improved the magnitude of the estimates, particularly with regard to the impact of prices changes in Nampula to Lilongwe.

5.2. Impact of Infrastructure Investments and FTA

The overall results in Table 4 suggest that the Zambezi River Bridge and FTAs have mostly significant impacts on maize price changes in Nampula. The negative coefficient for the Zambezi River Bridge suggests that such investments may have lowered the access costs to the Northern markets (Nampula), which in turn may have contributed to lower prices in those markets. In contrast, in terms of FTAs there are positive and significant impacts for every price equation for Nampula. On one hand this could seem to be counter intuitive, however, on the other it may reveal some preference for maize produced in the North by regional importers such as Malawi. That being the case, FTAs are effective in promoting regional trade particularly from that region of the country, which may have a substantial role to minimize food loss and improve maize farmers and traders' welfare.

[1] Average for 2012, 2014 and 2015

6. Conclusion

The results from this study indicate that maize markets in Mozambique are becoming more integrated domestically and regionally. However, integration is not symmetric in some instances, as is the case for

the South. Whilst Maputo seems to be integrated with the Centre and North, domestically these two markets are only integrated with each other. Even in this case of the Centre and North, market integration is not yet efficient as the coefficients suggest some non-proportional price transmission. At the regional level, even where market integration is found to be significant, it is also inefficient. The only exception is for the Centre (Chimoio) and Malawi. The investments in road infrastructures such as the Zambezi River Bridge have had significant impacts on maize pricing in the North (Nampula), contributing to lower prices from these markets. In contrast, FTAs have impacted positively and significantly to increase maize prices from these markets. This may be an indication of some regional preference for maize produced in the North. This is also highlighted by the positive and significant market integration identified between Nampula and Lilongwe.

With maize markets becoming more integrated domestically and regionally, it is likely that efficiency in the overall maize value chain in Mozambique will be improved, with farmers engaging more in trade and food loss being minimized. However, for this to happen investments in training programs and incentives should be provided to shift farmers from subsistence farming to a more commercial farming system approach. Incentives should target improvements in infrastructure to promote trade and market linkages as well as minimize postharvest losses.

Overall results from this research are based on a linear modelling approach. In future research, other models that account for the nonlinearities in the market integration status for many agricultural commodities, should also be considered. Nonlinear models could reveal other features of the integration status not efficiently or effectively captured by linear models. These models could be integrated with other techniques to estimate other useful, though unavailable, information (e.g., transaction costs) that is required for implementing the nonlinear models. Outcomes from that new proposed research could be important to reassess the current results.

Declarations

Compliance with Ethical Standards

All secondary datasets used in this article were gathered online (from websites or documents) and public institutions. Consent has been given to the use of datasets from public institutions which are not available online.

Conflict of Interest

Authors of this article declare that there are no conflicts of interest related to this publication.

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Supplementary Material

Due to the file size of the supplementary materials, interested readers should contact the authors for access to that information.

Figures

(a)

(b)

Figure 1

Maize value chain in the deficit (a) and surplus (b) regions of Mozambique Source: Popat, Griffith, Mounter, and Cacho (2020) (a) South of Mozambique (b) Centre and North of Mozambique

* Data on maize import tariffs for 2017 could not be accessed from WTO. It is assumed that no change has been made to the SADC FTA protocol

Figure 2

Volume of maize imports by Mozambique Source: Data from USDA (2018)

Figure 3

Log of real prices of maize over the period January 2007 to December 2017

Figure 4

Exchange rate (MZN/USD) over the period December 1999 to December 2018 Source: Data from the Central Bank of Mozambique