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Integration and Equilibrium of Maize Markets in Southern Africa: A SADC Sub-regional Assessment

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Abstract

This paper investigates the spatial integration and efficiency between five central markets in southern Africa. The study uses data on commodity prices, trade flows, and transfer costs from central maize markets in Botswana, Malawi, and South Africa, and two in Mozambique, analyzed using the Parity Bounds Model, the Barrett-Li Model and some level 1 and non-parametric assessments. The study seeks to (1) evaluate the nature of price and trade relations, (2) establish the level of regional spatial integration, and (3) evaluate the level of efficiency in these markets.

Results from the analysis indicate various forms of integration and efficiency outcomes for the sample markets. The central markets in South Africa and Botswana are characterized by significant levels of perfect integration, with higher frequency of imperfect integration with positive returns observed on the South Africa to Botswana trade route, and some occurrence of imperfect integration with negative returns observed in the opposite trade direction. For South Africa and Mozambique, trade is bidirectional and discontinuous, with very low frequency of perfect integration. Trade between South Africa and Mozambique's Southern region generally fails to exhaust arbitrage profits, and though integrated, the market pair appears largely inefficient. South Africa and Malawi follow similar trends, although in this case perfect integration holds with higher frequency, and imperfect integration with negative return is occasionally observed from trade in the Malawi to South Africa trade route. Malawi and Mozambique's Northern region exhibit perfect integration of a relatively high frequency, although imperfect integration with positive returns appears dominant on the Mozambique to Malawi route. Trade is bidirectional and discontinuous, predominantly in the Mozambique to Malawi direction. The market interactions between Botswana and Mozambique's Southern region or Malawi follow a related trend exhibiting market segmentation as evidenced by the lack of trade. Efficiency holds with a fairly high frequency mostly in the form of segmented equilibrium, although significant segmented disequilibrium on the Botswana to Mozambique/Malawi route is also observed.

Overall, the southern Africa maize markets considered in the sample seem to exhibit significant frequency of market integration, indicating tradability commodities and contestability of markets. Efficiency holds less frequently, although non-trivially, we observe that for those markets characterized by near continuous trade returns to arbitrage are exhausted for about 25% of the time. Often however, when trade is observed, efficiency appears to be weakened by insufficient arbitrage, possibly a result of non-cost barriers to trade (infrastructural or regulatory), imperfect information, or supply side constraints. For these markets, positive trade is also occasionally observed when arbitrage returns are negative, possibly due to contracting lags, and exchange rate fluctuations. Where trade is not observed, efficiency appears to hold with a slightly higher frequency (up to 45%), so that the lack of trade is often justified by the lack of positive arbitrage returns. Significant segmented equilibrium also seems to characterize these markets, where again the lack of trade is consistent with expected arbitrage returns. For these markets, efficiency is also occasionally compromised by insufficient arbitrage, whereby trade sometime fails to occur even when the returns to arbitrage incentives appear favorable (segmented disequilibrium). Therefore in order of frequency, we observe a high frequency of imperfect integration (regimes 3) and segmented equilibrium (regime 6), a fairly regular occurrence of perfect integration (regimes 1 and 2), and irregular occurrence of segmented disequilibrium (regimes 4) and the negative returns type of imperfect integration (regime 5). In specific markets, import prices consistently exceed domestic market prices, an inefficient outcome that appears to result from the involvement of the state in grain trade, where market conduct often is driven by non-profit objectives. These results suggest a need for policy intervention in the areas of improved productivity and access to information to takes advantage of unexploited arbitrage opportunities, and in the longer term, dealing with structural barriers to trade that prevent market entry especially where positive returns are currently observed. In some cases though, the lack of trade is an efficient outcome that probably requires no immediate policy interventions.

1. INTRODUCTION

For most countries in southern Africa, food security has traditionally been addressed through self-sufficiency, normally attained through widespread government involvement in the input and output markets for major food commodities. Food policies through the 1980's have been characterized by input subsidies for farmers, fixed, pan-seasonal and pan-territorial pricing systems in commodity markets, mainly implemented through parastatal marketing boards, as well as subsidies and price controls at the wholesale and retail levels. Most of these policies have since been abandoned for more market oriented policies, either under the Structural Adjustment Programs (SAPs), or domestic reforms, of the 1990's. During the same period, most countries in the region joined the multilateral trading system, the World Trade Organization (WTO), just in time for the Uruguay Round tariff reforms, and on a regional level, two regional free trade agreements were ratified, under the Southern Africa Development Community (SADC) and the Common Market for East and Southern Africa (COMESA), and bilateral preferential trading agreements continue to be negotiated. These policy shifts have left in their wake a region characterized by a blend of food policy, with greater openness and a market-led economy in some countries, while substantial government involvement persists in others. In this policy environment, food supply volatility, price instability and weak coordination of trade policy remain fundamental problems.

Improving intra-regional trade, through reduction of tariff and non-tariff measures has been widely advocated for as a critical piece in the food insecurity puzzle (SADC FANR 2003, World Bank DTIS, Mozambique 2004, Malawi 2002, Tschirley et al 2004, Mano 2003, Arlindo and Tschirley 2003, Moepeng 2003), and a vast amount of work has already gone into monitoring cross-border trade movements of food grains in the region (WFP/FEWS 2004-2006, USAID 1995). However, it has also been shown that the extent to which the benefits expected through greater market openness will be realized, depends significantly on how well integrated and efficient the markets are, both within and across borders (Ndlela 2002, Lewis 2002, Wobst 2002, Arndt 2005, World Bank 2002 and 2004). This is because without integration and efficiency, no mechanism exists for price signals to be transmitted from food deficit to food surplus areas, prices may become volatile and fail to deliver accurate incentives, and producers may fail to specialize according to comparative advantage (Baulch 1997).

In the southern Africa region, research efforts have focused on analyzing market integration at an intra-country level (Abdula 2005, Tostão and Brorsen 2005, Alemu and Baucuana 2006, Penzhorn and Arndt 2002, Traub et al 2004, Mabaya 2003, Mutambatsere 2002, Barrett 1997). Limited work has gone into evaluating how well integrated or efficient the maize markets are at the regional level, to ascertain if in fact trade is a viable food security strategy given existing market systems. The objective of this paper is to provide disaggregated bilateral analyses for distinct maize markets in a sample of four countries: Botswana, Malawi, Mozambique and South Africa, to evaluate integration and efficiency, vis-à-vis current trade flows and existing marketing systems. The specific objectives are to: (1) evaluate the nature of price and trade relations among the sample markets, (2) establish the level of regional spatial integration, and (3) evaluate the level of efficiency in these maize markets. Data on maize prices, trade volumes and transfer costs are analyzed using several econometric procedures of evaluating market integration and equilibrium. First, the level of market price co-movements is evaluated using several level I tests, and second, market integration and efficiency is evaluated using Baulch's Parity Bounds Model and the Barrett-Li Model.

2. RESEARCH METHODS AND APPLICATIONS

The evaluation of market efficiency is one of the very well studied subjects in economics. Traditionally, market integration has been used as a proxy for measuring market efficiency, through time series price-based methods such as bivariate correlations, the Granger causality test, the Ravallion model and the co-integration coefficient method, as known as level I procedures (Barrett 1996). As the limitations of these methods became apparent, more sophisticated methods have been developed, that incorporated transfer costs data, and later trade volumes in analyzing market efficiency (called level II and level III methods respectively). Before discussing the properties and application of these econometric tools, a few key concepts are defined.

2.1 Distinguishing Integration from Efficiency

In a survey of spatial price analyses, Fackler and Goodwin 2001 distinguish among several concepts for markets interlinked in space, form or time: the spatial arbitrage condition, spatial integration and spatial efficiency. In this survey, the authors show that these terms, especially the 'integration' concept, have been 'loosely applied, such that the same word may involve distinctly different concepts in different studies' (Fackler and Goodwin 2001). Barrett 2001 proposes a clear distinction between the concepts of integration and efficiency, where integration is restricted to the flow-based notion of tradability, whereas efficiency is taken as a price-based concept that relates to the satisfaction of equilibrium conditions. In this case market efficiency holds when all the gains from trade have been exhausted, and markets are in competitive equilibrium i.e. no potential for Pareto improvements exists through trade between markets. Following Enke 1951, Samuelson 1952, and Takayama and Judge 1964, Barrett 2001 defines the spatial equilibrium concept as comprising three conditions:

$$P_i \leq P_j + \tau_{ji} \quad \text{if } q_{ji} = 0 \qquad (1)$$

$$P_i = P_j + \tau_{ji} \quad \text{if } q_{ji} \in (0, \tilde{q}_{ji}) \qquad (2)$$

$$P_i \geq P_j + \tau_{ji} \quad \text{if } q_{ji} = \tilde{q}_{ji} \qquad (3)$$

where P_i and P_j are the prices in markets *i* and *j*, τ_{ji} is the cost of transferring the good between these two markets, q_{ji} is the quantity traded and $\tilde{q}_{ji}$ is the maximal possible trade volume. From these conditions, we can see that trade is neither necessary nor sufficient for equilibrium (equilibrium without trade may occur as in condition 1, or trade without equilibrium if the left hand sides of condition 2 and 3 are not satisfied).

Market integration represents the transfer of Walrasian excess demand from one market to another, manifest in actual or potential physical flow of goods, transmission of price shocks, or both. Positive trade flows, while sufficient, are not necessary for integration. Consequently, markets are said to be segmented when a product is not tradable between them. Note that with this definition of integration, prices equalization is not necessary, it suffices that the good is tradable between the two markets. These definitions of integration and efficiency are adopted in this paper.

The following discussion briefly reviews some of the most widely employed tools for evaluating market integration / efficiency analysis, and the empirical applications of these methods, mainly to highlight some of the application challenges and the limitations of these methods as measures of market efficiency. The econometric structure of each model is summarized in Table 1.

2.2 Measures of Integration and Efficiency: Empirical Applications

Through the application of the market integration and efficiency analysis methods outlined above, the literature has revealed several merits and limitation of each of these methods. Correlation coefficients are among the earliest procedures to be used in evaluating market integration, employed first by scholars like Cummings 1967, and Lele 1967, in the evaluation of integration in Indian's grain markets. Several weaknesses have been identified in the use of this procedure as a measure of integration, especially when applied to time series analyses. First, seasonal variations of price spreads make correlations unreliable measures of integration and competition, because correlations cannot separate integration-induced co-movement of prices, from long-run time trends and seasonality effects, or parallel price movements due to common endogenous trends, thus increase the risk of spurious integration. Correlations also are unreliable measures of integration in markets where inter-seasonal trade flow reversals are prevalent (with bidirectional trade), or when price series are heteroskedastic (true for most price data of reasonably high frequency) thus results generated could be unreliable (Barrett 1996). Additionally, as Barrett 1996 points out, contemporaneous correlation tests fail to capture natural lags in price responses, hence may over-estimate segmentation in markets experiencing such lags. These weaknesses have limited the use of correlations in isolation, although they have been continually employed as preliminary analyses in combination with more advanced market integration procedures.

The Granger causality test is another price-based procedure of evaluating integrating, a result of work by Granger 1969, and Sims 1972. Granger's major contributions were defining the causality and feedback concepts in an explicit, testable manner, as well as proposing a methodology for such tests. As a measure of integration, the Granger causality tests are useful in showing what relationships between price variables, or between the contemporaneous values of a price series and its own lags, are statistically different from zero. In terms of applicability to the study of markets, especially in developing countries, the Granger causality test holds several appealing features. First, causality can be established from a set of price series data that are available at fairly high frequency (monthly or weekly) for most well developed agricultural markets, even in developing countries. Second, the econometric modeling process is fairly straight forward, requiring only basic econometric knowledge and statistical packages. As a result, application of this test procedure to the developing world markets has been fairly substantial. Some application, that also contributed to the development of the methodology, include Alexander and Wyeth 1994's work in evaluating price integration in Indonesian rice markets, and Goodwin et al 1999, in evaluating integration of regional food markets in Russia[1]. Application to the southern Africa region cereals markets includes Muchopa 2000 and Mutambatsere 2002, to the maize markets in Zimbabwe, and Mabaya 1998 to the horticulture markets in Zimbabwe. These studies seem to reveal some significant causality in the markets studied.

The Granger causality test, however, also has several limitations. First, accepting the causality hypothesis does not imply a cause-effect relationship between variables, but simply that one variable is useful in explaining/predicting another. As noted by Fackler and Goodwin 2001, causality can only show if a relationship between price variables exists, but does not say anything about the actual nature of any existing relationships. In addition, whereas the use of only price data has the advantages outlined above, the implicit assumptions made about the nature of transfer costs, by their exclusion from the analysis, may lead to inferential error. For example, in the event that transfer costs exceed price differentials, any number of results from the Granger causality tests (including lack of a causal relationship) may be consistent with efficiency (Barrett 1996). Another limitation of the Granger causality procedure is the possibility of spurious causality, often caused by missing relevant data or missing variables (Granger 1969). For example, if the data were taken to consist of two price series, but in fact a third price series existed that 'causes' both the original price series, spurious causality may be found in the original price set. Likewise, spurious causality may occur when instantaneous causality[2] is implied in a data series with missing readings (often a result of limited frequency in the data set), so that although no real causality exists, causality test results will be positive. Increasing the frequency of the data series, or widening the data set within which causality is defined would correct most of these problems.

The co-integration procedure developed as a result of work by Engle and Granger[3] in the early 1980's and was an attempt to deal with the recurrent issue of non-stationarity in economic variables. This error correction procedure deals mainly with unit-root non-stationarity, representing a major advance from preceding procedures in that it enables unbiased evaluation of linear long-run relationships among non-stationary variables. Most economic variables tend to exhibit unit root non-stationarity (seemingly common in nominal price series data) that biases conventional approaches to inference (Fackler and Goodwin 2001). This is because a stationary price series typically reverts to a long run trend after a shock has been experienced, and this trend can be accurately estimated using regression procedures such as ordinary least squares (OLS). If, however, the price series follows a random walk, its variance is not finite, and a procedure like OLS would yield inconsistent parameter estimates (Pindyck 1997). The co-integration method recognizes that non-stationary variables generally have linear combinations across space or time that are stationary, therefore can exhibit stable long-run equilibrium tendencies. Co-integration tests for this kind of long-run equilibria[4] (Fackler and Goodwin 2001).

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[1] See Fackler and Goodwin 2001 for a detailed outline of these studies.

[2] When only contemporaneous prices of one series are significant in causing another, that is, if the current value of one price series is better predicted from the present value of another

[3] Significant contributions were also made by Palaskas and Harriss-White 1993, and Alexander and Wyeth 1994.

[4] Co-integration does not say much about period by period equilibria.

The application of the co-integration procedure to Africa, and elsewhere, has been fairly extensive, including Goodwin and Schroeder 1991 in analyzing the US cattle markets, Alderman 1993 in an analysis of grain markets for Ghana, Dercon 1995 in an analysis of teff marketing in Ethiopia, Lutz et al 1995 in analyzing the maize markets in Benin, and Bopape 2002 in evaluating potato markets in South Africa. The wide application of the method is indicative of both its relevance in analyzing the unit root non-stationary variables that make up most economic data, and its relative simplicity appeal. The co-integration procedure, however, has several limitations as a measure of integration and efficiency. First, it has been shown that co-integration is neither necessary nor sufficient for market equilibrium (Barrett 1996). This is because by excluding transfer costs the procedure imposes the assumption that these are constant through time. If however transfer costs are non-stationary, co-integration inferences maybe biased. For example arbitrage between two markets may be efficient even when their prices series are not co-integrated. In other words, prices that are observed to drift apart with no apparent long term convergence may lead us to reject the co-integration hypothesis, even though the drift in prices may simply be a result of non-stationary transfer costs, rather than increasing arbitrage opportunities (Fackler and Goodwin 2001). McNew and Fackler 1997 support this observation, and show that prices in well integrated, efficient markets need not be co-integrated.

Co-integration is also not sufficient for market equilibrium because price series may be co-integrated even though markets are not directly linked with each other, especially when transfer costs always exceed the price differentials. McNew and Fackler 1997 argue that if demand and supply forces are themselves co-integrated across markets, we might be led to conclude that prices are co-integrated regardless of whether markets are actually linked by trade, or whether the arbitrage conditions are satisfied. Some noteworthy extensions of the co-integration procedure include the threshold autoregressive and the threshold co-integration methods, a result of the work of Obstfeld and Taylor 1997, Prakash and Taylor 1997, and Goodwin and Pigott 1999. These procedures attempt to cope with the existence of non-tradability bands created by nontrivial transfer costs, however, the methods have been shown to retain the major limitation of price-based integration/efficiency methods that they attempt to deduce non-price information from variations in prices, thereby make important assumptions about the efficiency that they are supposed to be testing (Barrett 2001).

Barrett 1996 shows that co-integration could be consistent with a negative price relationship, even though market integration suggests this correlation aught to be positive. Also, the ADF test normally used to evaluate co-integration imposes a common dynamic factor restriction on a static regression model, that must correspond to the properties of the data for the test to have high enough power to reject a false hypothesis. Empirical evidence however suggests limited existence of such common factors in economic variables, making the test non-optimal (Hendry and Juselius 1999). The evidence thus suggests that the co-integration method generally provides limited and potentially misleading results, especially when taken without careful consideration of underlying price-costs relations.

The Ravallion model (1986) developed as an attempt to address some of the inferential limitations of earlier integration methods such as correlations, by appropriately handling autocorrelation, common inflationary trends, and seasonality in the modeling process. This method distinguishes between short-run and long-run relations among price variables. An error-correction, dynamic regression based method, the Ravallion model assumes price shocks originating from one central market with weakly exogenous prices, where short run market integration holds if price shocks are immediately transmitted between markets, and long-run market integration holds when market prices are equalized over time. The Ravallion model extends the static bivariate method into a dynamic model by permitting each local price series to have its own dynamic structure, thus avoid the inferential dangers of the simple bivariate models arising from such properties as correlation and seasonality. The usefulness of this model, and practicality in application, has encouraged substantial application in the market integration literature. Some of the early applications of this procedure include Ravallion 1986 who used the model to evaluate spatial integration among Bangladesh rice markets, Benson and Faminow 1992 in their application of the model to the Canadian hog markets, and Jordan and Van Sickel 1995 in an application to the US and Mexican tomato markets.

One of the main weaknesses of the Ravallion model lies in its main assumption, that transfer costs are either additive or proportional and will not significantly influence integration. This assumption, if violated, may bias integration results substantially. In addition, the model restricts a radial configuration of markets, where each subsidiary or regional market must be linked directly to a pre-determined central market. In practice, however, some markets are only connected to the central market indirectly, through direct linkages to other subsidiary markets. The model does not capture this type of integration. As Barrett 1996 notes, the inter-seasonal flow reversals and direct links between subsidiary markets violate the radial markets assumption. In addition, discontinuous trade or seasonal variation of marketing margins may cause the rejection of the integration hypothesis in the Ravallion model even when markets are integrated (Baulch 1994). Finally, Ravallion 1986 consents that the model can only evaluate integration, which is itself not sufficient for the optimality of a competitive equilibrium. Thus we cannot make spatial efficiency inferences from the model's results.

Switching regimes models are level II time series procedures of evaluating spatial integration, that attempt to describe and distinguish between different forms of imperfect integration between markets. The method was developed by Spiller and Haung 1986, and Spiller and Wood 1988, who provided a framework for analyzing imperfectly integrated market networks, using a little more than just price data – by incorporating transfer costs data into the analysis. Their model identifies three different market regimes, and a framework to estimate the probability of being in each of these regimes, conditional on the size of price spreads relative to transfer costs. Sexton, Kling and Carman 1991 modified and applied this model in their study of the US celery markets, by slightly redefining the market regimes representing efficient arbitrage, relative shortage, and relative glut, and employing a regression approach. These modifications allow for the evaluation of efficiency, rather than just integration, and enable us to generate evidence on the magnitude of marketing margins, product substitutability and competitiveness of markets (Sexton, Kling and Carman 1991). Notice though that the transfer costs data is inferred from the model, and the only purely exogenous variables are still the price series. However, where implicit parity bounds[5] exist, the process of estimating transfer costs from price becomes differentials highly problematic if such costs are endogenously determined (Baulch, 1994).

Baulch 1997 also made major contributions to switching regimes modeling, by proposing the parity bounds model (PBM), a version of switching regimes that differs from the Spiller-Haung model in that in this case, regimes correspond to prices within, on and outside a defined arbitrage band. This maximum-likelihood based estimator relies on exogenous transaction cost data to estimate the probability of attaining inter-market arbitrage conditions, its main advantage over the level I procedures discussed earlier. The central idea behind the PBM is that intermarket price spreads can be compared with exact information on transfer costs for at least one time period, making it possible to establish probabilistic limits within which the spatial conditions are likely to be binding in other periods. Baulch 1997 argues that because level I tests fail to recognize the pivotal role of transfer costs, the discontinuous trade flows, and the non-linearities implied by spatial arbitrage conditions, these predominantly linear tests for market integration are often inappropriate for developing countries. The PBM takes into account all these important market properties, allowing for the possibility of discontinuous trade, simultaneous price determination, inter-period transfer costs variability, and common endogenous trends. The model also makes no a priori assumptions about the nature of marketing margins, and may be estimated using incomplete time series data (Baulch 1997).

The main problem experienced in applying the PBM though is that transfer costs are extremely difficult to measure. Barrett 2001 offers a simple decomposition of the transfer costs term including numerous

[5] Occur when two markets trade with each other infrequently but have a third regular, mutual trading partner (Baulch 1994).

components[6] of which transport is but one of a long list – this term also usually contain certain unobservable aspects such as risk and suck costs. Thus the accuracy with which transfer costs can be measured also influences credibility of results. Additionally, the PBM still fails to handle bidirectional trade and non-stationary transfer costs, and by excluding trade data, fails to take advantage of the information therein, limiting the inferential capacity of the model (Barrett, Li and Bailey 2000). Baulch 1997 also points out that the PBM though well adapted for price endogeneity and common trends does not have the flexibility of to account for lagged price adjustments.

The Barrett-Li model, discussed in greater detail in section 3.1 is an extension of parity bounds (Baulch 1997) and switching regime (Spiller and Haung 1986, Sexton, Kling and Carman 1991) procedures, due to Barrett and Li 2001. This method is an improvement on Baulch's method in that it incorporates trade volumes in the analysis of market efficiency. It is also one of the first attempts at isolating integration from equilibrium, and distinguishing conditions under which both might hold. It also enables us to deal with discontinuous and bidirectional trade data, and by allowing the identification of seasons or periods in which trade occurs, enables direct estimation of the frequencies with which a variety of market conditions occur, such as competitive and segmented equilibrium, or imperfect integrated (Barrett, Li and Bailey 2000).

Switching regimes models, in general, also have been shown to suffer from inconsistent estimation of the price spreads probability distributions, making results sensitive to choice of distributions (Fackler and Goodwin 2001). Fackler and Goodwin 2001 also argue that switching regimes models can be viewed as nothing more than flexible models of the price spread distribution, so that the accuracy of results rests much on the appropriateness of the distributional assumptions. They also argue that the assumption of no serial correlations among cost variables may not be plausible.

3. DATA AND METHODS

3.1 Methods

Level I: Price-based analyses

The paper adopts the following format of analysis: first, a comprehensive explanatory data analysis is performed using four level I procedures: bivariate correlations, Granger causality tests, co-integration, and the Ravallion model, in collaboration some non-parametric analyses. Notwithstanding limitations as measures of market efficiency, level I tests are useful in describing market interactions, without attempting to draw conclusions on integration or efficiency. For example, these methods are useful in understanding the price discovery mechanism within markets, the expected degree and direction of shock transmissions, and the long run trend in price movements. Table 1 provides a brief description of the econometric modeling process for these procedures.

Level II: Parity Bounds Model

Baulch 1997's *parity bounds model* (PBM) is used to identify regimes of perfect integration, imperfect integration and market segmentation between market pairs. This maximum-likelihood based estimator relies on exogenous transfer costs data to estimate the probability of attaining inter-market arbitrage conditions. Baulch's model is well suited for the markets under study in this paper, since it allows for discontinuous transfer costs data to be employed. The main limitation of the PBM is that it imposes restrictions of continuity on trade that, if violated, could lead to erroneous conclusions on efficiency. Therefore for those markets where reasonably frequent bilateral trade data are available, the Barrett-Li Model (BLM) analysis is applied instead. The PBM is essentially a restricted form of the Barrett-Li model (discussed in greater detail in the following section) in which trade is assumed to be continuously positive or zero between market pairs, so that only three market

[6] Barrett identifies the following components: transport costs, costs associated with insurance, financing, hedging, contracting and satisfying technical barriers to trade such as complying with safety standards, exogenous transfer costs such as underwriting fees and testing charges, duties, and a whole host of unmeasurable transfer costs associated with doing business (opportunity costs of entrepreneurial time, search costs, risk, price and exchange rate variability etc) (Barrett 2001).

conditions are identified. For conciseness, only the Barrett-Li model is discussed in detail, the structure of Baulch's PBM can be subsequently deduced.

Table 1: Measures of Integration and Efficiency

LEVEL 1	
Bivariate Correlations	$\rho(P_i,P_j) = \frac{Cov(P_i, P_j)}{\sigma(P_i).\sigma(P_j)}$ (4) where ρ is the correlation coefficient, P_i and P_j are the commodity prices in two distinct markets *i* and *j*, Cov (P_i, P_j) is the covariance of the commodity prices in markets *i* and *j*, and $\sigma(P_i)$ and $\sigma(P_j)$ are standard deviations of the respective price series.
Price Causality	$P_{i,t} = \sum_{s=1}^{n} \alpha_s P_{i,t-s} + \sum_{s=1}^{n} \beta_s P_{j,t-s} + \xi_t$ (5) $P_{i.t} = \sum_{s=1}^{n} \alpha_s P_{i,t-s} + \xi_t$ (6) where $P_{i,t}$ is the price in market *i* at time *t*, $P_{i,t-s}$ is the s^{th} lag of the price in market *i*, and *n* is the number of lags. Test if β_s is significantly different from 0.
Co-integration	$P_{i,t} = \alpha + \beta P_{j,t} + \xi_{i,t}$ (7) where $\xi_{i,t}$ follows an autoregressive process : $\xi_{i,t} = \alpha_0 + \alpha_1\xi_{i,t-1} + \ldots + \alpha_q\xi_{i,t-q} + \nu_t$. Test for the stationarity of the error term, $\xi_{i,t}$
Ravallion	$P_{i,t} = \sum_{s=1}^{n} \alpha_{is} P_{i,t-s} + \sum_{s=0}^{n} \beta_{is} P_{1,t-s} + X_{i,t}\gamma_i + \xi_{i,t}$ (8) where $P_{i,t}$ is the price in regional market *i* at time *t*, $P_{1,t}$ is the price in a central market, and $X_{i,t}$ is the vector of characteristics influencing regional markets. *Short run market integration* holds if $\beta_{i0} = 1$ and $\alpha_{is} = \beta_{is} = 0$ for all $s = 1,\ldots,n$. *Weak short-run integration* holds when $\beta_{i0}=1$ and $\sum^{n}_{s=1} \alpha_{is} + \sum^{n}_{s=1} \beta_{is} = 0$, and *long-run market integration* holds when $\sum^{n}_{s=1} \alpha_{is} + \sum^{n}_{s=0} \beta_{is} = 1$.
LEVEL II	
Switching Regimes: Spiller-Haung	Regime 1 $P_{jt} - P_{it} > r_{ijt}$, market *i* ships to market *j* (10) Regime 2 $P_{jt} - P_{it} < -r_{jit}$, market *j* ships to market *i* (11) Regime 3 $-r_{jit} < P_{jt} - P_{it} < r_{ijt}$, no trade occurs (12) where P_{jt} represents market prices in market *j* and r_{ijt} is the cost of transferring goods from market *i* to market *j,* at time *t*. Imperfect integration holds in regimes I and II, and market segmentation holds in regime III. Estimates the probability of being in each regime.
Switching Regimes: Sexton, Kling and Carman	Regime 1 $P_{jt} - P_{it} < r_{ijt}$ (13) Regime 2 $P_{jt} - P_{it} > r_{ijt}$ (14) Regime 3 $P_{jt} - P_{it} = r_{ijt}$ (15) Market efficiency holds in regime 3, and is tested by the hypothesis that the probability of being in this regime is equal to 1.
Parity Bounds Model: Baulch	Regime 1: $P_{jt} - P_{it} = r_{ijt}$ (16) Regime 2: $P_{jt} - P_{it} < r_{ijt}$ (17) Regime 3: $P_{jt} - P_{it} > r_{ijt}$ (18) If production and consumption are completely specialized, only regime 1 is consistent with integration, whereas integration would also hold under regime 2 with non-specialized production and consumption. Regime 3 implies lack of integration in either case.
LEVEL III	
Barrett-Li Model	In text

Level III: The Barrett-Li Model

The Barrett-Li model is used to establish direction specific integration and equilibrium for those market pairs for which reasonable credible trade data were available. The BLM is a maximum likelihood-based method that incorporates price, transfer costs and trade flow data to analyze market performance. This model represents major improvements from typical level II switching regimes in two ways: first, it provides a clear, testable distinction between market integration and competitive market equilibrium, and second, it uses information on trade flows, from which useful information on continuity and direction of trade can be deduced and used to estimate frequencies with which a variety of market conditions occur. In this model, market integration implies the transfer of excess demand from one market to another, manifest in the physical flow of commodity (tradability) and/or the transmission of price shocks from one market to another (contestability). Competitive equilibrium on the other hand refers to the state in which the marginal profits from arbitrage equal zero, i.e. price differentials move one-to-one with costs of spatial arbitrage. The BLM is also capable of dealing with market integration and efficiency for commodities that are not entirely homogenous, since it takes into consideration seasonal or contemporaneous bidirectional trade (normally a result of intra-industry trade) (Barrett and Li 2002).

The model identifies four distinct market conditions: perfect integration, segmented equilibrium, imperfect integration and segmented disequilibrium: let P_{it} be the price in market i at time t, C_{jit} the transfer costs between markets i and j at time t, $R_{jit} = P_{it} - P_{jt} - C_{jit}$ the marginal returns from arbitrage between markets i and j at time t, T_{jit} the volume of trade between markets i and j at time t, and λ_k the estimated probability associated with regime k. Six market regimes are identified:

Regime 1: $R_{jit} = 0$ and $T_{jit} > 0$, perfect integration with trade (19)
Regime 2: $R_{jit} = 0$ and $T_{jit} = 0$, perfect integration without trade (20)
Regime 3: $R_{jit} > 0$ and $T_{jit} > 0$, inefficient integration (21)
Regime 4: $R_{jit} > 0$ and $T_{jit} = 0$, segmented disequilibrium (22)
Regime 5: $R_{jit} < 0$ and $T_{jit} > 0$, inefficient integration (23)
Regime 6: $R_{jit} < 0$ and $T_{jit} = 0$, segmented equilibrium (24)

Competitive equilibrium prevails whenever the inter-market arbitrage condition holds with equality, or when transfer costs exceed price differentials so that no trade occurs:

$R_{jit} \leq 0$; or $R_{jit} < 0$ and $T_{jit} = 0$ (25)

Market integration holds whenever positive trade is observed or the inter-market arbitrage condition is binding:

$T_{jit} > 0$; or $R_{jit} = 0$ (26)

Under perfect integration, arbitrage rents are exhausted and trade may or may not take place – both market integration and competitive equilibrium hold. Under segmented equilibrium, trade does not occur since rents are negative – markets are not integrated, but are in competitive equilibrium. Under imperfect integration, trade occurs but either rents are not exhausted or transfer costs exceed price differentials. In this case, markets are integrated but not in competitive equilibrium. By establishing whether or not trade occurred between distinct markets, one can immediately confirm integration of markets. Segmented disequilibrium holds when trade does not occur even though rents are positive; neither integration nor equilibrium holds in this case.

A joint probability distribution can be estimated, for T_{jit} and R_{jit}, where condition (25) prevails with estimated probability $\lambda_1 + \lambda_2 + \lambda_6$, and (26) with estimated probability $\lambda_1 + \lambda_2 + \lambda_3 + \lambda_5$. The maximum likelihood method is then used to establish the probability of being in each regime. Following Baulch's logic for a parity bounds model, we use the available isolated point estimates of transfer costs to establish a confidence interval (to establish lower and upper parity bounds) within which the deflated transfer costs are allowed to vary, then assess the probability of being in each regime, given these parity bounds. The deviation of returns to arbitrage in each period from the null hypothesis of perfect integration (or zero returns to arbitrage) is captured by a systematic error term v_t, assumed to be normally distributed with mean α and variance σ^2_v, plus a positive error term u_t that is added when $R_{jit} > 0$ and subtracted when $R_{jit} < 0$. u_t is assumed to follow a half normal distribution with variance σ^2_u, and captures the extent to which price differentials deviate from the parity bounds (Baulch 1994). A non-zero α, on the other hand, captures the random components of measurement error or the unobservable component of transfer costs (Barrett and Li 2001). Following Weinstein 1964, on summing a normally and half-normally distributed variable, we can define the probability density functions for each regime as follows:

$$f_{jit}^{1} = f_{jit}^{2} = \frac{1}{\sigma_v}\varphi\left[\frac{R_{jit}-\alpha}{\sigma_v}\right] \quad (27)$$

$$f_{jit}^{3} = f_{jit}^{4} = \left[\frac{2}{\left(\sigma_u^2+\sigma_v^2\right)^{1/2}}\right]\varphi\left[\frac{R_{jit}-\alpha}{\left(\sigma_u^2+\sigma_v^2\right)^{1/2}}\right]\times\left[1-\Phi\left[\frac{-\left(R_{jit}-\alpha\right)\sigma_u/\sigma_v}{(\sigma_u^2+\sigma_v^2)^{1/2}}\right]\right] \quad (28)$$

$$f_{jit}^{5} = f_{jit}^{6} = \left[\frac{2}{\left(\sigma_u^2+\sigma_v^2\right)^{1/2}}\right]\varphi\left[\frac{R_{jit}-\alpha}{\left(\sigma_u^2+\sigma_v^2\right)^{1/2}}\right]\times\left[1-\Phi\left[\frac{\left(R_{jit}-\alpha\right)\sigma_u/\sigma_v}{(\sigma_u^2+\sigma_v^2)^{1/2}}\right]\right] \quad (29)$$

The maximum likelihood function for this parity bounds model is given by:

$$L = \prod_{t=1}^{T}\left(T_{jit}\times\left[\lambda_1 f_{jit}^{1}+\lambda_3 f_{jit}^{3}+\lambda_5 f_{jit}^{5}\right]+\left(1-T_{jit}\right)\times\left[\lambda_2 f_{jit}^{2}+\lambda_4 f_{jit}^{4}+\lambda_6 f_{jit}^{6}\right]\right) \quad (30)$$

and the parameters λ_1 to λ_6, α, σ_v and σ_u can then be estimated by optimizing In(L) with respect to each parameter. T_{jit} is a dummy variable, taking values 0 when trade occurs and 1 when trade does not occur. Φ[.] is the normal cumulative distribution function, and φ[.] the probability density function.

Baulch's PBM is similar to the model outlined above, with 2 major exceptions, first that in the PBM trade does not explicitly enter the analysis, and second that no allowance is made for measurement error in the modeling process. Consequently, regimes are defined only by the value of R_{jit}, probability density functions are distinctly defined for the three regimes, and in the original Baulch model α is set equal to zero. In the form of the Parity Bounds model used in this analysis, the α = 0 restriction is relaxed to improve precision of regime probability estimates.

A few limitations of the BLM are worth mentioning. First, this procedure is fairly data intensive, and transfers costs and trade data of the required frequency are not always readily available. Second, this model offers only static comparisons, and does not permit analysis of the dynamics of inter-temporal adjustment to short-run deviations from long run equilibrium (Barrett 2001). The model also suffers some of the weaknesses outlined earlier for switching regimes model: it also assumes serial independence of price and transfer costs data, and is sensitive to the underlying distribution assumptions (Barrett and Li 2001, Fackler and Goodwin 2001).

3.2 Data and Sources

A sample of five distinct markets in southern Africa is analyzed in this paper: Gaborone in Botswana, Gauteng in South Africa, Blantyre in Malawi, and Maputo and Mocuba in Mozambique (see figure 1). For Mozambique, two markets are included: Maputo as the central market for the southern region, and Mocuba the representative market for the northern region[7]. The differences between these two regions of Mozambique: the later a net buyer of maize and the former a net seller, as well as the supposed 'market segmentation' due to poor transport networks between the regions often highlighted in the literature[8], and the distinct regional alignment in cross-border trade with other sample markets, necessitate the individual representation of these two regions in the analysis. Generally, the choice of markets was based primarily on centrality of each market in the countries under study, each representing one of the largest consumer and/or producer markets in each country. Market choice was also based on data availability, and on diversity of trade relations among the sample markets: whereas the Botswana and South Africa markets are engaged in continuous trade with no tariffs, South Africa and southern Mozambique (Malawi and northern Mozambique) are characterized by mostly unidirectional

[7] The Northern region here comprises the four regions: Niassa, Cabo Delgado, Nampula and Zambezia, and the Southern region is made up of Maputo, Gaza and Inhambane.

[8] See Arndt forthcoming, Tostão and Brorsen 2005

continuous, protected trade, South Africa and Malawi by bidirectional discontinuous trade, and Botswana and Malawi/Mozambique by very little trade. These markets thus make up an interesting sample, in which some typical assumptions about market connectedness and efficiency can be tested.

Monthly time series data on maize wholesale prices from each of these markets P_{jt}, direction-specific transfer costs between any two markets C_{jit}, and direction-specific trade volumes for any two markets T_{jit}, are used in this analysis. The sources of these data are also summarized in Table 2.

Table 2: Data and Sources

	SOURCE					
	Price	Trade flows	Hauling costs	Tariff Rates	Exchange Rates, Consumer Indices	Fuel Prices
Botswana	BAMB	WITS, CSO, FAOSTAT	Studies*	WITS, CSO	CSO, BoB	CSO
South Africa	NDA, SAFEX	WITS, FAOSTAT, TIPS	WB, SAGIS, Studies	WITS, DTI	STATS SA, Reserve Bank	DME
Malawi	MISD	WITS, FEWS, FAOSTAT	WB, Studies	WITS, Revenue Authority	NSO, Reserve Bank	MoE
Mozambique	SIMA	WITS, FEWS, FAOSTAT	WB, SIMA, MoTI, Studies	WITS	INE	MoE

Abbreviations: Central Statistics Office (CSO), Bank of Botswana (BoB), World Bank (WB), Botswana Agricultural Marketing Board (BAMB), Food Early Warning System Network (FEWS NET), Food and Agriculture Organization's (FAO) online database FAOSTAT, Department of Market Information Services (MISD), Ministry of Energy (MoE), National Statistics Office (NSO), World Integrated Trade Solution (WITS) – World Bank trade database, Trade and Industry Policy Strategies (TIPS), Department of Trade and Industry (DTI), National Department of Agriculture (NDA), South African Grain Information Services (SAGIS), South African Futures Exchange (SAFEX), National Department of Minerals and Energy (NDME), National Institute of Statistics (INE), Agricultural Marketing System under the Ministry of Agriculture (SIMA), Ministry of Trade and Industry (MoTI). **Studies* are outlined in-text.

The complete data set comprised monthly time series wholesale price data available for each market for the time period: June 1994 to December of 2002, making up 102 observations. All of the price statistics were reported in local currency, and were converted to the US$ equivalents using the appropriate exchange rate. The US$ equivalents were used as the 'normalized' price series without further inflation adjustments. Occasionally in the analyses, reference is made to the 'trade unit values' of maize, computed as the source/destination specific per unit value of the maize traded. As shown later, these values sometimes differ from the market prices prevailing in either the source or destination markets, and may help explain perceived discrepancies in trade flows given the market price determined returns to arbitrage. Note that these 'trade unit values' are national averages (rather than market specific values), obtained by dividing the total value of maize traded between two countries as it appears at the 6-digit level of the Harmonized System of trade records, with the total quantity traded. Their use is thus restricted mainly to the discussion of results.

The transfer costs variable was challenging to construct, given incomplete and asymmetric data availability for the sample countries. The series was derived primarily from the per km hauling costs for road and rail transportation estimated in the World Bank's diagnostic trade integration studies for Malawi and Mozambique (2001), Tostão and Brorsen 2005, SADC freight studies by Vink et al 2002, Kandiero et at 2005, Erero and van Heerman 2005, the Food Agriculture and Natural Resources Policy Analysis Network (FANRPAN) 2003, and from SAGIS 2005. From these sources, several point estimates for 2001 and 2002 are obtained, and following Baulch 1997, are extrapolated to cover the study period using data of varying degrees of completeness, on fuel prices, distance between markets and transport cost indices. Often, conservative and extreme point estimates of transfer costs are offered in the literature. In this study the average of these estimates was used, allowing for variability in the transport cost index to determine seasonal fluctuations of these costs. Data on tariff rates were used to estimate the tariff costs per unit traded between specific markets, which were added to the hauling costs estimates. In some cases (specifically Mozambique), the Value Added Tax (VAT) on imported maize grain is observed to be quite high, and is often considered trade restrictive (Tschirley et al 2005). In this analysis, since

VAT is an internal tax that is often subject to exemption, we refer to it only in explaining observed trade flows, rather than as part of the transfer cost. Costs such as handling, border inefficiency, and insurance costs also could not be captured in the transfer costs estimates used here, however considering that maize is a non-perishable, low-value commodity, we might expect border losses due to spoilage, and insurance costs, to be relatively small. Note that transfer costs between any given market pair are not symmetric for the reasons that the fuel prices and consumer indices are market specific, and tariff rates differ between countries at specific time periods.

Trade statistics, though generally available from various sources for the study period, are almost exclusively available in annual form. For the sample countries, more frequent trade statistics are limited to some historic quarterly statistics for Botswana, a few recent monthly statistics for South Africa available from the Department of Trade and Industry, and for Malawi and Mozambique, monthly trade statistics for specific trade routes available from Food Early Warning System Network (FEWS NET)'s cross border trade monitoring studies. The major challenge in consolidating the trade flow variable was that the most comprehensive bilateral trade time series, available from WITS, is reported on an annual basis, whereas the monthly statistics such as those from FEWS NET were only available for recent years, often falling outside of the study period. Moreover, with the exception of FEWS NET data, trade statistics only tell country level bilateral flows, but do not identify exactly what markets the commodity originated from, or where it is destined. In this paper, the trade dummy variable used in the Barrett-Li analysis was derived from the annual statistics, using the monthly data where they exist to predict the months in which trade is likely to have occurred. To handle the issues of source and destination of reported trade, trade literature for the region[9] were referred to. Because of these numerous assumptions and adjustments made to derive frequent, reasonably accurate trade variables could only be derived for three market pairs: Gaborone and Gauteng, Gauteng and Maputo, and Mocuba and Blantyre, the only three market pairs included in the BLM analysis. For the rest of the market pairs, the PBM is used instead, in collaboration with the more accurate annual trade statistics to explain trade relations.

Overall, the maize prices series (US Dollar equivalent) for the sample markets: Gaborone, Gauteng, Blantyre, Maputo, and Mocuba are volatile, non-stationary processes, integrated of order 1. Direction specific transfer costs are also shown to be unit root processes. Higher price volatility is observed for Mocuba, Maputo and Blantyre, with Gauteng and Gaborone prices appearing to be the least volatile. The stationary, first-differenced price and transfer costs series were used with appropriate model adjustments for much of the analyses.

3.3 Description of Markets

This section offers a non-parametric description of the markets to help explain some of the trends observed in the econometric assessments that follow, and to assess the goodness of fit for the variable distributions and other statistical restrictions on the data imposed by the maximum likelihood estimations performed later. Initially, the main characteristics of each market are summarized in Tables 3 and 4, and thereafter, a description of returns to arbitrage between markets is provided (Figure 2). Figure 1 shows the location of the markets in the sample (Gauteng is the region of South Africa encompassing the cities Johannesburg and Pretoria), some of the major ports, the transportation networks linking them together and the estimated distances between the markets included in the sample. For clarity of presentation, the figure does not show most of the road networks, only those that link major ports for which rail does not exist are shown.

Figure 2 shows the cumulative distribution of returns to arbitrage between distinct markets given price and transfer costs movements. In this figure, the prevailing market prices in the central markets of the sample countries are used to compute the price spreads. Similar assessments are also performed using 'trade unit values' of maize (see Appendix 1), shown in this study to sometimes differ from the prevailing market prices in either the exporting or importing countries. This second exercise is important in that when trade occurs between

[9] FANRPAN publications, SADC publications, MSU Food Security studies, TIPS publications among others (see Reference section)

two countries, the prices received for exports may contain more accurate information on returns to arbitrage than the prices prevailing on the domestic markets. Differences between market prices and trade unit values may also have non-trivial implications on market efficiency, bearing in mind though the limitation in recording accuracy and precision of the latter, that are only national average values.

Table 3: Trade Frequencies, Annual Between Countries: 1994 to 2005

From \ To	South Africa	Botswana	Mozambique	Malawi
South Africa	-	100%	100%	89%
Botswana	100%	-	0%	0%
Mozambique	56%	0%	-	78%
Malawi	67%	0%	44%	-

Source: WITS 2005

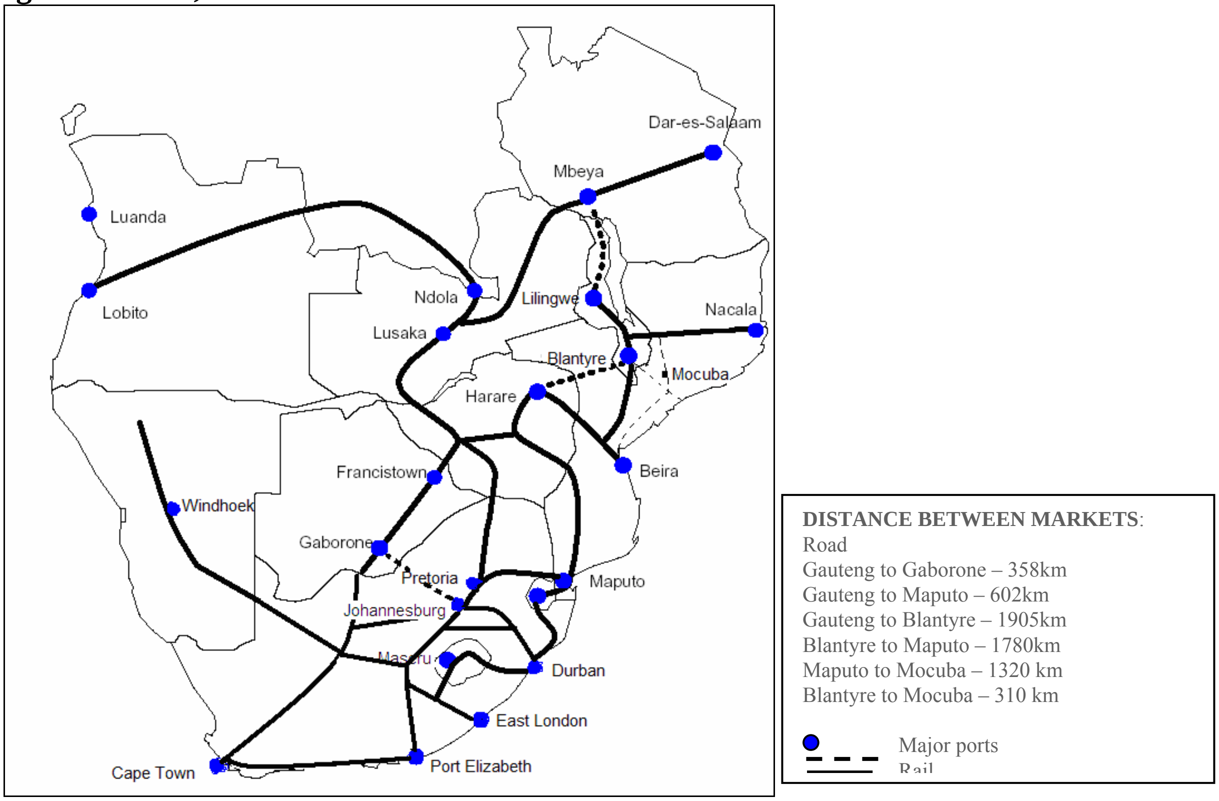
Table 4: Description of Sample Markets

	BOTSWANA	MALAWI	MOZAMBIQUE	SOUTH AFRICA
Cereal production	10% of aggregate needs	1.2-2.5 million tons per year	1.25 million tons per year	10 million tons per year
Cereals consumption	80,000 tons per year	1.5million tons per year	1.35 million tons per year	7.5 million tons per year
Imports	71,000 tons per year	125,000 tons (about 8.5% of aggregate needs) per year	200,000 tons a year	550,000 tons per year
Exports	1,000 tons per year	18,500 tons per year	7,000 tons per year	1.5 million tons per year
Major regional trading partners	South Africa (95% of imports, 75% of exports), Namibia (14% of exports), Zimbabwe (5% of imports)	Mozambique (60% of imports), South Africa (25% of total imports, 3.5% of total exports), Zimbabwe (24% of exports), Tanzania (14% of exports), Zambia (3% of total imports, 0.1% of total exports)	South Africa (80% of imports), Swaziland (3.6% of imports), Malawi (close to 60% of total exports). Limited trade with Zimbabwe, Namibia, Angola and DRC	Zimbabwe (40% of total exports, 1.5% of total imports, 75% of *regional* imports)[10], Botswana (5-7% of total exports), Malawi and Mozambique (10% of exports, ≈0.1% of imports)
Tariffs and taxes on maize	0% for SACU imports 6.7c/kg on grain, 10c/kg on maize flour	0% for COMESA imports 0% on grain, 15% on maize flour	0% on maize grain, 25% on maize flour, 17% VAT on imported grain	0% for SACU imports 6.7c/kg on grain, 10c/kg on maize flour
	GABORONE	BLANTYRE	MAPUTO	GAUTENG
Geographic Status	Capital City	Commercial Capital	Capital Province	Capital Province
Population	270,000 (15% of total)	502, 000 (1/3 of urban population, 4% of total)	> 1 million (7.5% of total)	3.2 million, 17% of total
Maize production	-	15.8% of aggregate	2% of aggregate	5% of aggregate

Sources: WITS, FAOSTAT, National statistics offices

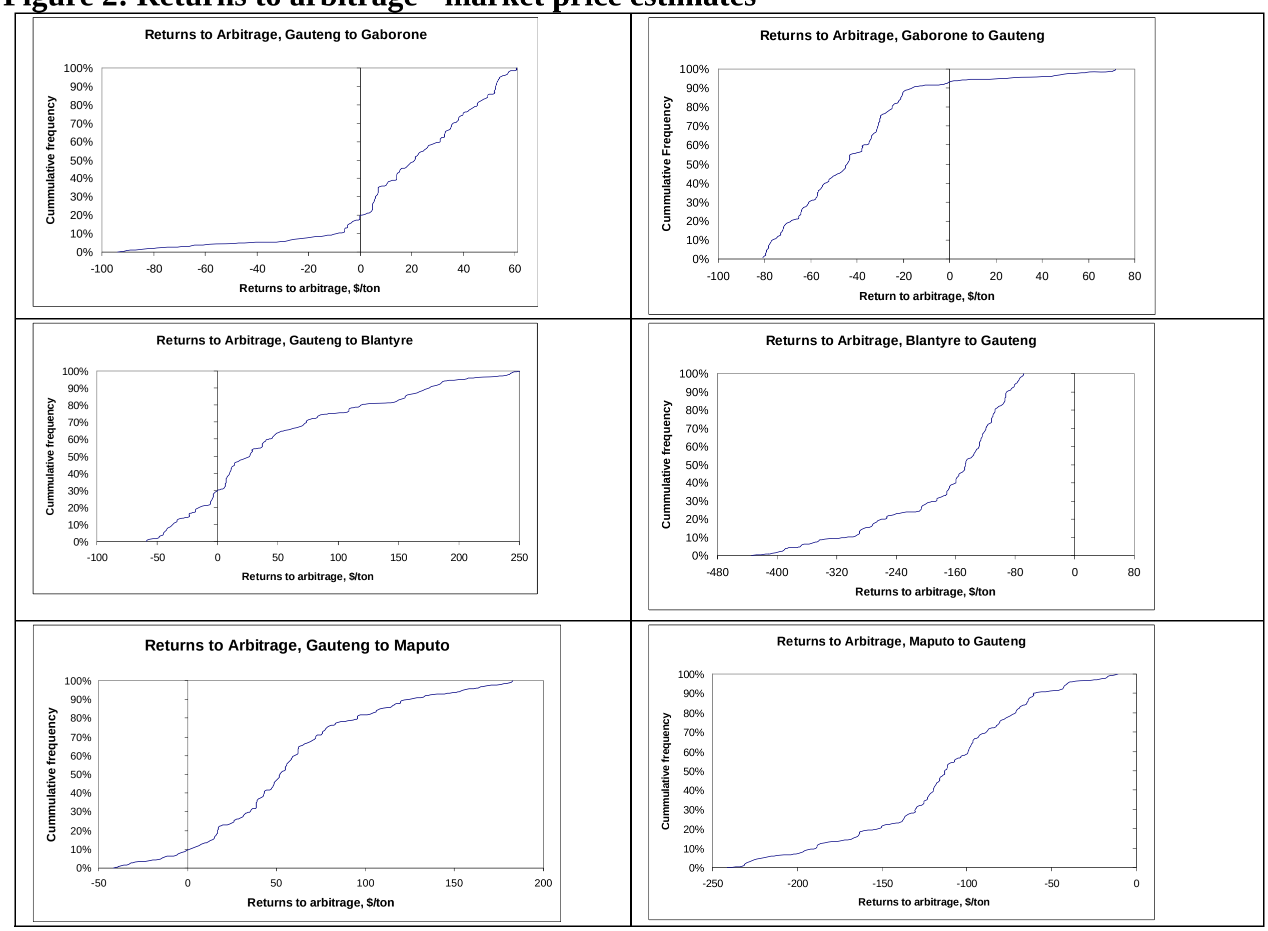
[10] Most of South Africa's imports are from the international market, and in aggregate, South Africa's imports from Zimbabwe are only 1.75% of total imports.

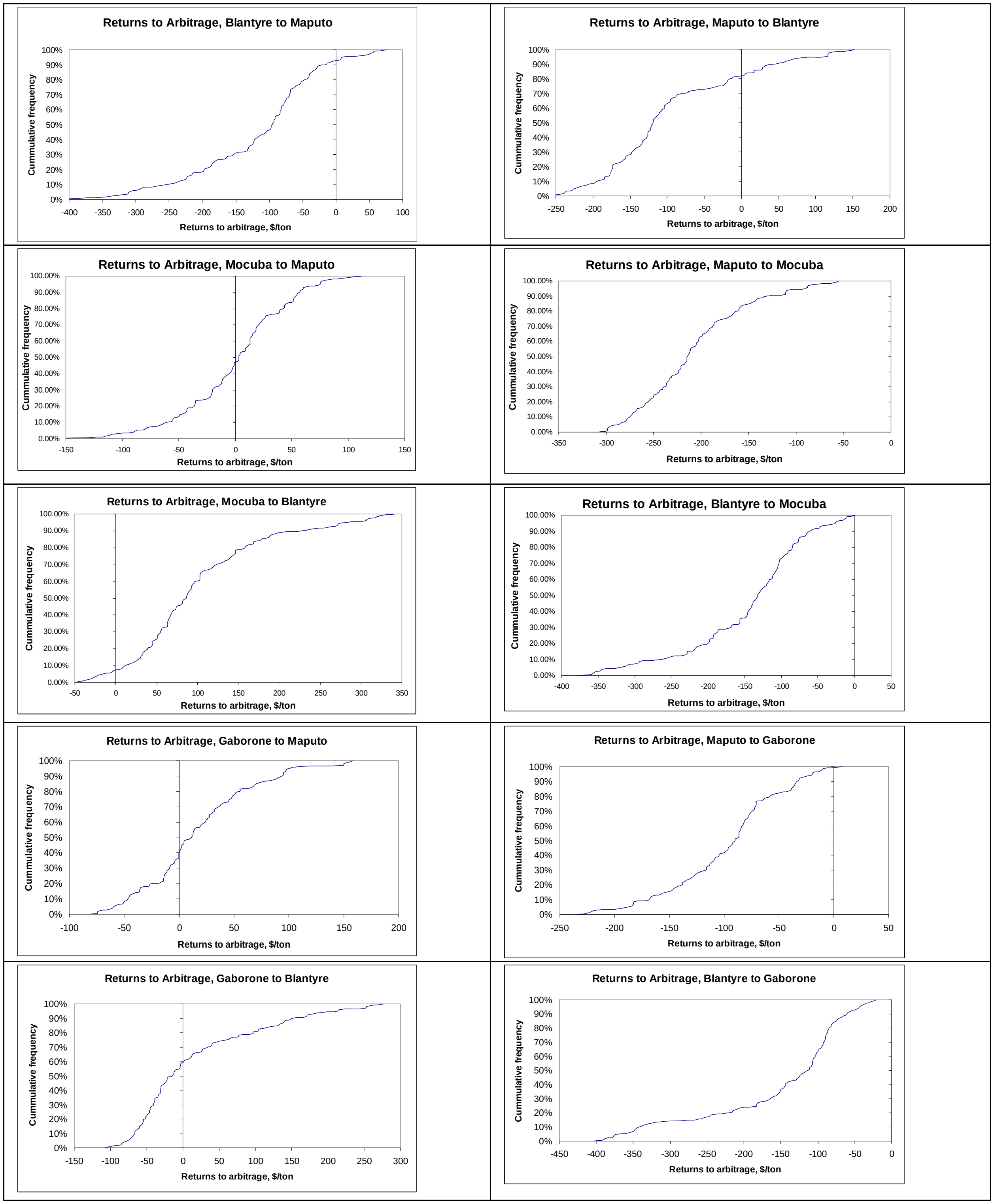
Figure 1: Ports, Inland Terminals and Main Transit Routes for SADC States



Source: FANRPAN/ MSU Maize Trade Project, 2005 (updated by authors).

Figure 2: Returns to arbitrage - market price estimates





An assessment of the sources of imports and destinations of exports for the SADC region indicates that although intra-regional trade generally contributes a small proportion of total trade volumes (around 5% of aggregate trade), the trend is significantly different for trade of maize. Statistics indicate that formal trade among SADC countries accounts for over 95% of total maize exports and about 80% of maize imports, in addition to an estimated 270,000tons (about 8.5% of total trade quantity) traded informally between neighboring states (WITS 2005, FEWS NET 2005, USAID 1995). Botswana, a deficit producer of maize, is closely linked to South Africa through tariff-free trade under the Southern African Customs Union (SACU). The southern region of Mozambique (in which Maputo is located) is also a maize deficit region (producing only 10% of national product output, compared to 40% in the Central region and 50% in the Northern region) that relies substantially on South Africa for imports. Malawi sources most of its imports from the maize surplus northern region of Mozambique, with substantial imports from South Africa, and occasional exports to parts of the region also observed. No significant trade is recorded between Botswana and either Malawi or Mozambique.

Price and transfer costs statistics indicate that the prices in Gaborone exceed Gauteng prices for most of the study period, and that the returns to arbitrage from trading grain from Gauteng to Gaborone are positive about 90% of the time. Conversely for the Gaborone to Gauteng trade direction, returns to arbitrage are almost always negative. Blantyre maize prices are higher than Gauteng prices for most of the study period, and the returns to arbitrage on the Gauteng to Blantyre trade route are positive for about 70% of the time. The Blantyre to Gauteng trade route records consistent negative returns to arbitrage. For the Gauteng-Maputo markets pair we observe again a one-sided trend in positive returns to arbitrage, with Maputo prices consistently exceeding the market prices for Gauteng.

The Maputo-Blantyre market pair is characterized by alternating positive and negative price differences, with the prices in Blantyre exceeding Maputo prices for exactly 50% of the study period. Opportunities for gainful arbitrage between these two markets appear limited, compared to the other market pairs in the sample, with the Blantyre to Maputo trade route recording non-negative returns less than 10% of the time, and the Maputo to Blantyre route for about 20% of the time. When we consider the linkage between Blantyre and Mocuba however, we observe a stark difference, whereby the prices in Blantyre now almost always exceed Mocuba prices, and returns to arbitrage in the Mocuba to Blantyre trade route are almost always positive. In-country, we notice that Maputo and Mocuba are characterized by negative returns on the Maputo to Mocuba trade route, and positive returns with a frequency of slightly over 50% in the opposite direction. Notice that due to proximity of Mocuba to Blantyre, arbitrage returns are generally higher on this trade route, compared to Mocuba-Maputo.

Market prices in Maputo almost always exceed the market prices in Gaborone, with positive returns to arbitrage on the Gaborone to Maputo trade direction expected about 60% of the time. Prices in Blantyre are also observed to exceed the Gaborone prices for most of the study period, although returns to trade on the Gaborone to Blantyre trade route are non-negative for only 40% of the time. A more detailed pair-wise description of the markets is presented in section 4 below to explain and explore further in parametric assessments, some of the observed price/transfer costs differences. For the moment, it suffices to note that these trends appear largely consistent with the observed trade frequencies presented in Table 3, with limited occasion of trade with negative returns, or the lack of trade with positive returns.

4. RESULTS

4.1 Level I Tests

Results from the Level I analyses: Bivariate correlations, Granger causality tests, Co-integration tests and Ravallion tests are presented in Table 4. For the Ravallion test, Gauteng is chosen as the central market for the reasons that first, as observed from the trade statistics, bilateral trade relations exist between South Africa and every other country in the sample (Table 3), with a trade frequency of over 80% for trade of maize from South Africa. This country also produces over 50% of the southern Africa region's maize output, is the largest source of imports for most of SADC[11] (and for all the countries in the sample), and individually supplies 75% of all the maize traded in the region (FAOSTAT 2005). In addition, though not centrally located, Gauteng is connected through either road or rail networks to each of the markets (Figure 1), and based on the price correlation and causality tests (Table 5), the market prices for Gauteng are relatively highly correlated to all other market prices, with some degree of price causality observed between Gauteng market prices and prices prevailing in the rest of the markets.

[11] Southern African Development Community: Angola, Botswana, Democratic Republic of Congo, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, South Africa, Swaziland, Tanzania, Zambia and Zimbabwe.

Table 5: Level I Test Results

Correlations

	Gauteng	Gaborone	Blantyre	Maputo	Mocuba
Gauteng	1.000000	0.764788	0.285294	0.455502	0.061226
Gaborone	0.764788	1.000000	0.084115	0.553064	0.002819
Blantyre	0.285294	0.084115	1.000000	0.144453	0.347452
Maputo	0.455502	0.553064	0.144453	1.000000	0.655694
Mocuba	0.061226	0.002819	0.347452	0.655694	1.000000

Pairwise Granger Causality Tests

Null Hypothesis:	F-Statistic	Probability
GAUTENG does not Granger Cause GABORONE	3.29900	0.00114**
GABORONE does not Granger Cause GAUTENG	2.48869	0.01152**
MAPUTO does not Granger Cause GABORONE	0.77202	0.64242
GABORONE does not Granger Cause MAPUTO	1.24550	0.27600
MOCUBA does no Grange Cause GABORONE	1.61046	0.12218
GABORONE does not Granger Cause MOCUBA	1.48013	0.16541
BLANTYRE does not Granger Cause GABORONE	0.83368	0.58641
GABORONE does not Granger Cause BLANTYRE	0.29127	0.97609
MAPUTO does not Granger Cause GAUTENG	0.49462	0.87520
GAUTENG does not Granger Cause MAPUTO	2.55029	0.01096**
MOCUBA does not Granger cause GAUTENG	0.93962	0.49456
GAUTENG does not Granger cause MOCUBA	3.04863	0.00287**
BLANTYRE does not Granger Cause GAUTENG	2.45264	0.01309**
GAUTENG does not Granger Cause BLANTYRE	1.60123	0.12159
BLANTYRE does not Granger Cause MAPUTO	3.44616	0.00105**
MAPUTO does not Granger Cause BLANTYRE	2.60165	0.01006**
MOCUBA does not Granger Cause BLANTYRE	3.09785	0.00273**
BLANTYRE does not Granger Cause MOCUBA	2.79726	0.00607**
MOCUBA does not Granger Cause MAPUTO	1.66494	0.10731
MAPUTO does not Granger Cause MOCUBA	1.95617	0.05229*

Johansen Co-integration Tests Results

Series	Eigenvalue	Likelihood Ratio	Hypothesized Number of CE(s) in H_0
Gaborone Gauteng	0.094077	21.08706	None **
	0.029339	4.883661	At most 1 *
Gauteng Blantyre	0.094606	19.67869	None *
	0.027999	4.373356	At most 1 *
Gauteng Maputo	0.233366	41.85852	None **
	0.054691	7.311602	At most 1 **
Gauteng Mocuba	0.169226	28.95427	None **
	0.043427	5.594127	At most 1 *
Gaborone Blantyre	0.102219	19.83984	None *
	0.020782	3.234155	At most 1
Gaborone Maputo	0.243596	37.62239	None **
	0.010171	1.329063	At most 1
Gaborone Mocuba	0.184354	26.87321	None **
	0.009460	1.197642	At most 1
Maputo Blantyre	0.227857	43.72418	None **
	0.100379	12.69386	At most 1 **
Blantyre Mocuba	0.169260	29.65901	None **
	0.067832	8.148101	At most 1 **
Maputo Mocuba	0.175919	35.67387	None **
	0.085740	11.29465	At most 1 **

Ravallion Model Results

Market Pair	F-statistic	Probability	Chi-Square	Probability	Null Hypothesis
Gauteng Gaborone	124.7630	0.000000	1621.920	0.000000	$\beta_{i0} = 1$ and $\alpha_{is} = \beta_{is} = 0$ for all s **
	130.6737	0.000000	261.3474	0.000000	$\beta_{i0}=1$ and $\sum^{n}_{s=1} \alpha_{is} + \sum^{n}_{s=1} \beta_{is} = 0$**
	0.681247	0.410504	0.681247	0.409158	$\sum^{n}_{s=1} \alpha_{is} + \sum^{n}_{s=0} \beta_{is} = 1$
Gauteng Blantyre	31.92906	0.000000	415.0778	0.000000	$\beta_{i0} = 1$ and $\alpha_{is} = \beta_{is} = 0$ for all s **
	6.295839	0.002427	12.59168	0.001844	$\beta_{i0}=1$ and $\sum^{n}_{s=1} \alpha_{is} + \sum^{n}_{s=1} \beta_{is} = 0$*
	1.476972	0.226355	1.476972	0.224249	$\sum^{n}_{s=1} \alpha_{is} + \sum^{n}_{s=0} \beta_{is} = 1$
Gauteng Maputo	29.57726	0.000000	384.5044	0.000000	$\beta_{i0} = 1$ and $\alpha_{is} = \beta_{is} = 0$ for all s **
	27.35773	0.000000	54.71546	0.000000	$\beta_{i0}=1$ and $\sum^{n}_{s=1} \alpha_{is} + \sum^{n}_{s=1} \beta_{is} = 0$**
	0.093306	0.760582	0.093306	0.760015	$\sum^{n}_{s=1} \alpha_{is} + \sum^{n}_{s=0} \beta_{is} = 1$
Gauteng Mocuba	38.98059	0.000000	506.7476	0.000000	$\beta_{i0} = 1$ and $\alpha_{is} = \beta_{is} = 0$ for all s
	11.39633	0.000032	22.79265	0.000011	$\beta_{i0}=1$ and $\sum^{n}_{s=1} \alpha_{is} + \sum^{n}_{s=1} \beta_{is} = 0$
	5.392471	0.022065	5.392471	0.020224	$\sum^{n}_{s=1} \alpha_{is} + \sum^{n}_{s=0} \beta_{is} = 1$
*(**) denotes rejection of the null hypothesis at 5%(1%) significance level					

Results indicate that the Gauteng-Gaborone markets are characterized by the highest levels of price correlation, significant bidirectional Granger causality, and exhibit 'long run integration' as defined by Ravallion. Co-integration holds with high levels of significance. The continuous, bidirectional trade between Botswana and South Africa, and close trade policy ties between the two countries, possibly explains the close linkages in price movements. Gaborone also seems influential in determining Gauteng prices, regardless of the fact that Gauteng is a much larger market, and Botswana in total imports only about 7% of South Africa's total exports. The price discovery process differs in the two markets, with the state-owned parastatal, the Botswana Agricultural Marketing Board (BAMB) leading the course of maize prices in Botswana, whereas the South Africa Futures Exchanges (SAFEX) – a more market-oriented institution – is influential in maize pricing on the South African markets. Results indicate that despite these differences, a close relationship in price movements exists between these two markets, and prices in one market are influential in determining prices in the other.

The Gauteng-Maputo market pair is also characterized by substantial price correlation, significant unidirectional causality in the Gauteng to Maputo direction, highly significant price co-integration, and long-run Ravallion integration. Similar trends are observed between Gauteng and Mocuba. Trade between Gauteng and Maputo is bidirectional, continuous in the Gauteng to Maputo direction and discontinuous in opposite direction, whereas limited trade is predicted between Gauteng and Mocuba. The close price co-movements between Maputo and Mocuba possibly account for the (indirect) significant price causality observed between Mocuba and Gauteng. Because Gauteng is a larger market than either Maputo or Mocuba, and due to the observed trade flows, we expect that price causality move in the observed direction. Gauteng and Blantyre also follow similar trends with the exception that in this case causality seems to run in an unexpected direction, from Blantyre to Gauteng, and co-integration holds with less significance. Prices in Malawi are largely market determined, with the former state parastatal ADMARC now privatized, although and the state run National Food Reserve Agency remains a significant player in the market. Thus we would expect that because trade between Malawi and Gauteng is predominantly from South Africa to Malawi: imports from South Africa accounting for 25% of Malawi's total imports (and only 5% of South Africa's aggregate exports), whereas South Africa's imports from Malawi account for less than 0.1% of total imports, price causality would also follow the same trend. It is possible, however, that causality is demand driven, and the dominant seller is responsive to its markets, which seems to be the case with Gauteng relative to both Gaborone and Blantyre.

Blantyre and Maputo exhibit significant bidirectional causality and co-integration holds with high levels of significance. Price correlations are however relatively lower than observed elsewhere in the sample. We observe, as expected, that more significant correlation and causality is expected in the price relationship between Blantyre and Mocuba. Trade between Malawi and Mozambique is bidirectional but discontinuous, and given the structure of Mozambique's regional ecological conditions and subsequent differences in maize productivity, it stands to reason that very little of this trade represents direct trade between Maputo and Blantyre, so that these markets are mostly linked through indirect trade. Considering the limited integration between the southern and northern regions of Mozambique (Tostão and Brorsen 2005, Tschirley et al 2005, Arndt forthcoming), we may also assume limited price co-movements between Maputo and Mocuba, hence limited indirect trade and price relations between Maputo and Blantyre. The high degrees of causality and co-integration between both market pairs (Maputo-Mocuba and Maputo-Blantyre) seem to suggest that although these markets appear segmented, important, possibly indirect, feed back relationships exist in the price discovery process.

The Gaborone-Maputo and Gaborone-Blantyre market pairs follow a similar trend exhibiting limited price co-movement, as evidenced by the lack of causal relations, and less significant co-integration. Instantaneous price responses are not observed in this sample of markets, although long-run price co-movements are also observed. These results make sense because the two market pairs are essentially segmented (not linked through trade), though sharing a common trade partner, Gauteng. The observed lagged price responses could be an indication of these markets responding to changes in each other's prices through Gauteng's price responses.

4.2 Level II and Level III Test Results

In this section, the Parity Bounds Model (PBM) and the Barrett-Li Model (BLM) are used to evaluate the levels of integration and efficiency in the sample markets. The Parity Bounds Model described in equations (16) through (18) can be compared to the Barrett-Li Model described in equations (19) through (30) as follows:

		RETURNS TO ARBITRAGE		
		Zero Returns ($R_{jit} = 0$)	Positive Returns ($R_{jit} > 0$)	Negative Returns ($R_{jit} < 0$)
BLM	Positive Trade	Regime 1: perfect integration	Regime 3: imperfect integration	Regime 5: imperfect integration
	No Trade	Regime 2: perfect integration	Regime 4: segmented disequilibrium	Regime 6: segmented equilibrium
PBM	-	Regime 1	Regime 3	Regime 2

The log of the maximum likelihood function defined in equation (30) is used to estimate the parameters λ_1, λ_2 and λ_3 as defined above for the Parity Bounds Model, and α, σ_v and σ_u, initially holding T_{jit} constant. We use the optimization program Solver, which utilizes the generalized reduced gradient (GRG) algorithm, implemented in an enhanced version of the GRG2 code (Lasden and Waren 1979), in solving the maximization problem. The resultant parameter estimates are presented in Table 4. These results and the discussion that follows focus on the regime probability estimates computed using the prevailing markets prices. Trade 'unit value' based estimates are also computed (Appendix 2), and are used mainly as a cautionary base for the results presented in Table 6.

Within the PBM, a priori restrictions have to be made on the trade variable, for meaningful market integration/efficiency conclusions to be made for market interactions such as those represented by regimes 2 and 3. This is because based on contemporary definitions of integration and efficiency, regime 2 could describe efficient but segmented markets if no trade occurs, or inefficient but integrated markets if trade occurs. Baulch 1994 imposed the restriction of 'no trade' on regime 2, so that this regime is consistent with efficiency, and of positive trade on regime 3, so that this regime represents inefficiency. In the PBM analysis performed in this paper, no a priori trade restrictions are made. Rather, the PBM analysis is complemented by a non-parametric assessment of the markets in which the annual trade data are incorporated to provide a more informative characterization of the markets. The limitations of the trade variable outlined in section 3.2 prevent the assessment of the complete set of markets in the sample using the Barrett-Li model. Therefore only a subset of the sample markets for which credible trade statistics were available is analyzed using the full fledged Barrett-Li model.

The markets of choice for the BLM are (1) Gaborone and Gauteng, (2) Gauteng and Maputo, and (3) Mocuba and Blantyre. The sub-sample is used to illustrate the more informative type of analyses that could be performed with accurate, frequent data on market-specific cross-border trade flows for the region. Compared to an evaluation of market integration and efficiency at a national level, this analysis is superior in that it focuses directly on the source/destination of trade within each country, enabling us to identify with greater certainty the sources of inefficiency, and to more concretely identify the necessary policy changes. The resulting parameter estimates are presented in Table 7.

Table 6: Summary of Parity Bounds Model Results

Direction of Trade	Regime Probability					
	λ_1	λ_2	λ_3	σ_u	σ_v	α
Maputo to Blantyre	0.01000	0.905144	0.083856	95.588242	72.043095	-21.967233
Blantyre to Maputo	0.053378	0.945622	0.00	135.528470	50.684218	-14.012201
Maputo to Mocuba	0.035336	0.963664	0.000	57.481217	45.842464	-160.47399
Mocuba to Maputo	0.522907	0.326970	0.150123	58.957983	38.017453	14.97875
Gauteng to Blantyre	0.440883	0.000	0.559116	125.0447	28.33425	-7.23522
Blantyre to Gauteng	0.012522	0.98747	0.000	139.85624	0.0000135	-69.23263
Gaborone to Maputo	0.470590	0.000	0.52841	65.493757	34.294812	-10.55721
Maputo to Gaborone	0.025345	0.973655	0.000	71.882237	29.788798	-43.56793
Gaborone to Blantyre	0.498133	0.000	0.500867	148.85151	26.419679	-44.23422
Blantyre to Gaborone	0.005448	0.993552	0.000	147.87480	19.898351	-43.61586

Table 7: Summary of Barrett-Li Model Results

Direction of Trade	Regime Probability								
	λ_1	λ_2	λ_3	λ_4	λ_5	λ_6	σ_u	σ_v	α
Gauteng to Gaborone	0.25010	0.000	0.62924	0.000	0.11936	0.000	42.5394	0.000001	-6.3584
Gaborone to Gauteng	0.000	0.01584	0.03903	0.06452	0.11606	0.76355	38.6356	1.950421	-19.3133
Gauteng to Maputo	0.00969	0.000	0.89321	0.000	0.09709	0.000	74.9977	0.001	1.09869
Maputo to Gauteng	0.10743	0.000	0.000	0.000	0.04696	0.84441	61.2558	31.15583	-42.4078
Blantyre to Mocuba	0.000	0.06325	0.04154	0.000	0.11601	0.77810	109.979	32.96456	-72.5606
Mocuba to Blantyre	0.22978	0.08769	0.61296	0.06747	0.000	0.000	117.702	37.43352	17.66256

Results from the PBM and BLM analyses indicate that significant efficiency exists between the markets pairs considered in this analysis, with most market pairs recording frequent (5% to 52%) zero returns to arbitrage in at least one trade direction. The lowest level of efficiency is observed for the Blantyre-Maputo market pair, in which the probability of being in regime 1 is relatively small and returns to arbitrage are generally negative in either trade direction. We also notice that the probability of being in the positive returns regimes increases non-trivially when trade unit values are used instead of market prices for most market pairs, indicating that countries on average pay more per unit of maize imported than the prevailing prices in their local markets. In the pair-wise assessment that follows integration and efficiency implication are drawn from these results.

Because regime frequencies are defined for each market pair in a direction specific manner (generally $\lambda_k^{ji} \neq \lambda_k^{ij}$), integration and efficiency are also seem to be uniquely defined for specific trade directions. According to Barrett and Li 2001 we can maintain direction specific descriptions of markets with regards to the concept of market integration, since tradability and contestability are also unidirectional concepts. However, because equilibrium is an omni-directional concept, we would generally need to establish for each market pair, a range of frequencies describing the lower and upper bounds for efficiency. Thus in the following discussion, efficiency conclusions are drawn by considering regime frequencies and trade trends for both trade directions.

Gauteng – Gaborone: This market pair is in perfect integration with a frequency of at least 25% observed on the Gauteng to Gaborone trade route. Trade is bidirectional between these markets, continuous on the South Africa to Botswana trade route and discontinuous on the Botswana to South Africa route. Because very limited trade occurs from Gaborone to Gauteng, the frequently observed negative returns are consistent also consistent with efficiency. Cases of imperfect integration also exist, at a fairly high frequency on the Gauteng to Gaborone trade route where trade fails to exhaust arbitrage returns, and at lower frequency where trade occurs in spite of negative returns (observed in both trade directions). The occurrence of regime 4 (positive returns without trade) concurrently with regime 5 in the Gaborone to Gauteng trade route appears to indicate that although trade in this direction is limited, it is often not consistent with the limited occasion in which Gaborone prices exceed Gauteng prices, an indication of inefficiency in such market interactions.

We observe at a national level that the per-unit value of maize sold from Botswana to South Africa generally exceeds the market prices prevailing in Gauteng, so that with these 'export prices', positive returns to arbitrage are now expected for about 25% of the time on the Gaborone to Gauteng trade route (see Appendix 2). Some possible explanations could be given for these seeming disparities in prices: first, that some form of product differentiation exists, that allows Botswana exports to fetch a higher than average market price in South Africa, second that maize exports from Botswana are destined to markets other than Gauteng, where higher market prices prevail, or third that some form of inefficiency exists in the markets to sustain these price differences. We dismiss the first possibility based on the observation that the maize grain under study in this paper is a fairly homogenous product. On the second possibility, an assessment of South Africa's maize producing regions and deficit regions, considering proximity of these regions to Botswana, indicates that Gauteng is in fact on of the major maize producing regions in the country[12], and we might expected prices in other deficit regions or such as Northern Cape to offer higher prices for Botswana's exports. It is also possible that South African consumers pay more for maize sourced from Botswana either due to imperfect information on prices prevailing elsewhere in the market (especially possible for consumers located in remote parts of country, close to the Botswana exporting regions), or due to hidden costs imbedded in currency conversion[13] and transfer costs. Note, however, that Botswana's total exports of maize to South Africa are rather insignificant, making up a mere 0.5% of the total trade volumes between these two markets.

Gauteng – Maputo: This market pair is characterized mostly by imperfect integration with positive returns to arbitrage, whereby the flow of maize of Gauteng and neighboring regions to Maputo fails to exhaust the arbitrage returns, with limited occurrence of regime 1. This positive returns imperfect integration appears to be the dominant form of inefficiency for this market pair, negative returns imperfect integration is also observed though with a much smaller frequency in both trade directions. The former is probably explained by the presence of a restrictive 17% VAT on imported maize meant for re-sale in grain form, that substantially increases the transfer costs from grain traders. The latter indicates that the very limited trade predicted from Maputo to Gauteng occurs despite the negative arbitrage profits observed regularly on this trade route. At national level, South Africa and Mozambique, trade is almost continuous on the South Africa to Mozambique trade route, with discontinuous and mostly trivial trade in the opposite direction (often less than 5% of Mozambique's total exports and an insignificant proportion of South Africa's total imports). Because the trade variable is included as a 'trade or no-trade' dummy variable, these trade proportions tend to be masked in observed regime frequencies.

At the inter-country level of assessment, it appears the positive trade flows from Mozambique to South Africa do in fact constitute some form of inefficiency since, considering only market prices, we note that the market prices prevailing in South African are generally not large enough to provide an incentive for this positive flows of maize from Mozambique to South Africa, even when we assume that the maize was sourced from the lower

[12] South Africa's major maize producing region includes parts of Gauteng, North-West, Free State and Mpumalanga.
[13] Possible given that the Botswana Pula is generally stronger than the South African Rand, so that prices quoted in Pula may appear lower they actually are when converted to their Rand equivalents.

price, surplus regions of Mozambique such as Mocuba, since in that case much higher transfer costs are have to be incurred. Only when per-unit trade values are considered are non-negative returns to trade expected on this trade route with a frequency of up to 20%. Thus it appears that Mozambican imports attract an above average price in South African markets, for at least parts of the seasons when trade is observed, probably for reasons similar to those discussed above for the Botswana case. Occasionally, however, positive trade is observed from Mozambique to South Africa that is supported by neither prevailing market prices nor per-unit trade values of traded maize.

Blantyre – Mocuba: For this market pair, perfect integration is observed with a frequency of up to 22%, where zero returns with trade are observed on the Mocuba to Blantyre trade route, whereas regime 2 efficiency is observed in the opposite direction. More regularly, positive returns imperfect integration is observed in the Mocuba to Blantyre trade direction and segmented equilibrium in the Blantyre to Mocuba trade direction. We observe in this case that prevailing market prices in Mocuba are consistently lower than Blantyre prices, accounting for the frequently negative returns and the limited of trade on the Blantyre to Mocuba trade route. Considering that Mocuba lies in Mozambique's maize surplus region, whereas Blantyre lies in the southern, mostly deficit region of Malawi, the observed price and trade trends are expected. It appears that this limited trade is also largely inefficient, with negative arbitrage returns, as evidenced by the occurrence of regime 5. In the opposite trade direction, trade generally fails to exhaust arbitrage profits and occasionally, positive returns go entirely unexploited (regime 4), possibly due to inadequacy or seasonality of maize supply on the Mozambican side. We note again here that the proportion of Malawi's exports to Mozambique is rather small, so that positive trade in this direction accounts for at most 1.6% of total exports from Malawi (about 0.1% of Mozambique's imports).

Blantyre – Maputo: Perfect integration is observed with a frequency of up to 5% for this market pair, where zero excess profits prevail more in the Blantyre to Maputo trade direction. The Maputo to Blantyre trade route is instead characterized by positive returns to arbitrage of comparable frequency, and for both trade routes, returns to arbitrage are negative with a frequency of over 90%. These bid-directional negative returns are an indication that market prices in these two markets move in close magnitude and trend (supported by the level I tests) so that price differences are rarely large enough to cover transfer costs. Given limited trade between Blantyre and Maputo, these markets though segmented, appear largely efficient (in segmented equilibrium). The only form of inefficiency observed here is the segmented disequilibrium expected in the Maputo to Blantyre trade direction with a frequency of about 8%, where failure to take advantage of observed positive returns is possibly due to hidden transfer costs or structural barriers to grain movement. Given the relatively low frequency of positive returns however, these could simply be a result of exchange rate fluctuations in either Mozambique or Malawi, generally not sustained long enough to provide incentives for trade.

At national level, trade between Malawi and Mozambique is predominantly in the Mozambique to Malawi trade direction, often between Malawi and the maize surplus northern region of Mozambique (Tschirley at al 2005). Considering the lower market prices in the North, represented in this analysis by Mocuba, we observe that the returns to arbitrage on maize movement from this region to Blantyre are in fact frequently positive (68%), indicating incentive for, and possibly explaining, the frequent positive trade observed between the two countries. When per-unit trade values are considered, the incentives are more pronounced, as computed 'import prices' in Malawi generally exceed Blantyre prices. On the Malawi to Mozambique trade route, when per-unit trade values are considered no significant differences in the prices received for maize on the Mozambique markets are observed (Mozambique appears to pay the market prices for its imports from Malawi).

Maputo – Mocuba: To evaluate the level on integration and efficiency between the southern and northern regions of Mozambique, the price, transfer costs and trade relations between Maputo and Mocuba are considered. Note though that in terms of geographic location, Mocuba is more centrally located than most surplus producing areas of the northern region, so that transfer costs are not as restrictive, and trade is in fact observed though with a frequency of only about 2.25% (Tostão and Brorsen 2005) from Mocuba to Maputo. We observe that for this market pair efficiency holds with a high frequency, up to 52% in zero returns (mostly without trade) type of efficiency, and up to 96% in segmented equilibrium. Inefficiency is observed in the Mocuba to Maputo trade route, whereby with a frequency of up to 15%, positive returns to arbitrage appear to go unexploited. An assessment of the seasonality trend in arbitrage returns on the Mocuba to Maputo trade route indicates that these are highest in the months immediately following harvest, when the prices in Mocuba are lowest. Therefore it does not seem that seasonal supply constraints inhibit the flow of maize from the surplus to the deficit region. Interesting to note though is the presence of an alternative recipient for the maize surpluses in the northern region (Malawi) where, due to proximity of market, larger arbitrage returns can be realized. The southern region is thus served by South Africa's surplus region – also more closely located and serviced by an efficient transport system[14]. Thus it appears that maize trade within Mozambique is responsive to arbitrage opportunities in a largely efficient manner, given current location of surplus/deficit regions and subsequent transport costs.

Gauteng – Blantyre: In this market pair, perfect integration is observed with a frequency of up to 44%, with zero returns to arbitrage observed predominantly in the Gauteng to Blantyre trade direction. For the Blantyre to Gauteng trade route, returns to arbitrage are predominantly negative. These trends are expected because Malawi, though occasionally producing maize in excess of its domestic needs, is generally a deficit producer of maize, hence the higher maize prices observed in Blantyre compared to Gauteng prices. Given these arbitrage returns, we expect Gauteng to export to Blantyre, but not the other way round.

Trade at national level is however observed to be bidirectional, though generally flowing from South Africa to Malawi, with less frequent grain movement from Malawi to South Africa. Exports from Malawi at the formal level currently are mostly through the National Reserve Agency – the management board for the country's strategic grain reserves – and in the early 1990's were through the then state-owned parastatal ADMARC. Thus exports tend to be more responsive to the level of stocks at hand, rather than seasonality of production per se, and it appears that export prices respond more to the presence of a maize glut in the domestic markets, than to the presence of arbitrage incentive elsewhere (Zant 2005). In terms of proportion, exports to South Africa make up a very small share of Malawi's total exports (often between 2% and 4%), and an even smaller proportion of South Africa's total imports. Given these observations, we may expect little market price induced maize movement from Malawi's Blantyre market to Gauteng, so that at the inter-market level (compared to the international level), the frequent negative returns to arbitrage observed on this route are consistent with efficiency. Trade in the Gauteng to Blantyre direction leads to an exhaustion of arbitrage profits with a substantially higher frequency, although different forms of inefficiency could possibly exist in both directions, in the forms of either imperfect integration with positive returns if the positive returns observed with a frequency of 55% happen to coincide with the seasons in which trade is observed, or segmented disequilibrium is these positive returns are consistent with periods in which trade is not observed. The exact type of inefficiency can be established with monthly trade data for this market pair.

Considering the per-unit values of maize traded between these two markets, the 'export price' received for Malawi's maize exports to South Africa generally exceeds Gauteng prices, so that at these apparently higher prices, positive returns to arbitrage would be expected for on the Malawi to South Africa trade route about 25% of time (Appendix 2). Note however that occasional positive trade from Malawi to South Africa is also observed, even for those years in when the returns to arbitrage (readjusted to the per-unit value of trade) are negative – a hint for some form of inefficiency on this route for trade at national level. Additionally, considering the lower maize prices in Malawi's maize surplus northern region, we observe that returns to arbitrage from exports to South Africa still generate negative returns, given the higher transfer costs now

[14] The distance from Maputo to say Gauteng is less than half the distance to Mocuba, and given the geographic location of Maputo lies almost entirely on the South African side of the border, where more efficient transport network systems are in place.

incurred. On the South Africa to Malawi trade route, per unit trade value are also observed to consistently exceed local prices.

Gaborone – Maputo: This market pair is characterized by perfect integration expected with a frequency of up to 45%, where zero returns to arbitrage are expected mainly on the Gaborone to Maputo trade route, and segmented equilibrium expected with a frequency of up to 97% observed on the opposite trade route. These results indicate that though no trade in maize grain is ever observed between these two markets during the study period, significant integration holds, evidenced by contestability of markets through zero arbitrage returns. Note however that the positive returns sometimes observed on the Gaborone to Maputo route to go unexploited, indicating also the existence of segmented disequilibrium on this trade route, with an estimated frequency of over 50%. This trend is possibly due to the fact that Botswana is a deficit market and net importer of maize, thus does not possess the supply capacity to export. We would expect though in an efficient market system re-exports of maize from Botswana's markets to take advantage of the positive arbitrage returns expected elsewhere in the region.

Gaborone – Blantyre: Regime frequencies and trade trends for this market pair are very similar to those observed for the Gaborone – Maputo market pair: returns to trade on the Gaborone to Blantyre trade route are expected to be zero for about 47% of the time and positive for the remainder of the time, the Blantyre to Gaborone trade route is characterized by negative returns to trade for most of the study period, and no trade is observed between these markets during the study period. The positive returns to arbitrage expected on the Gaborone to Blantyre trade route again seem to go unexploited, indicating segmented disequilibrium.

In concluding this section, we explore some of the reasons for the market segmentation and different forms of inefficiency observed in the sample markets. Imperfect integration with positive returns is often a result of either insufficient arbitrage or significant unobservable transfer costs. Imperfect integration with negative returns is explained as resulting from temporary disequilibria that arise from information and contracting lags, or the existence of significant unobservable transactions benefits. In this sample of southern Africa's maize markets we have market pairs for which positive trade is observed even when the observable price differences are negative (for example trade from Botswana to South Africa and on occasion, from Malawi to Mozambique). In such cases, it does not appear that hidden costs are the reason for trade. Plausibly, trade is a result of inter-country transport bottlenecks that force excess producers located close enough to the border to sell across the border for less, if that market is more easily accessible. If these producers acquire most of their daily goods and services from across the border, near batter trade of maize grain for consumer goods is not uncommon. In such cases, and also considering the differences in currency denominations and exchange rate fluctuations, observable price differences could easily become 'hidden' to smallholder producers and informal traders of maize. As has already been suggested earlier however, in some cases, returns to arbitrage may appear negative, when in fact the price paid to the trader exceeds prevailing market prices in either the source or the destination markets. In a competitive market, we expect that these higher import prices would encourage an influx of maize that eventually drives the price of imports down to the local levels. In that case, import prices ought to be observed to converge to local prices. However if the market does not operate competitively, for example when the state is a significant player in grain trade, we have cases in which the government is willing to pay more for imports than it eventually sells the imported commodities for on the local market – a form of subsidy often used in shortage periods to support food insecurity households. In a country such as Malawi, where the state is still a dominant player in maize importation, such trends are not uncommon[15].

With regards unexhausted or unexploited positive returns to arbitrage, it is possible that significant unobservable transfer costs exist. As noted earlier in the description of the transfer costs variable used in this analysis, this variable does not account for costs such as insurance, spoilage, border inefficiency costs,

[15] See also Zant 2005

contracting costs, sanitary and phyto-sanitary compliance costs, exchange rate risk, and a host of other trade-related costs. Barriers to trade may also be structural, so that even when commercial traders may be willing to take advantage of higher market prices in a neighboring country, government restrictions on grain movement may prevent that from happening. The markets in Malawi certainly have been subject to such regulatory restrictions in the past, though reform of such policy has been observed in recent years. We also have cases in which supply side constraints prevent countries from taking advantage of these arbitrage opportunities. A good example is the Gaborone to Maputo, or the Gaborone to Blantyre maize markets. The lack of trade despite the seemingly large arbitrage profits may appear puzzling, however considering that Botswana is already a maize deficit country, little capacity exists to produce for the export market. In this case, efficiency in trade with a common third partner (for example South Africa) would be expected to drive down these excess profits[16]. Imperfect information and risk aversion also play a role here, where issues such as differences in currency denominations for prices, imperfect information on transfer costs, imperfect exchange rate markets, and imperfect information on how to enter foreign markets may inhibit trade.

5. CONCLUSION

As the SADC region grapples with the recurrent issue of food insecurity, reference is often made to increased intra-regional trade as an important integral element of a comprehensive food strategy. The assumption is that as countries reduce tariff and non-tariff barriers to trade, they become more integrated and more efficient, facilitating commodity movement at lower transfer costs, hence lower prices to the final consumer. With the reform of maize markets in most of the region in the past decade, from controlled to market-oriented, we evaluate the extent to which these markets have become integrated and efficient, and identify the nature of inefficiency where it exists. This paper employs a number of price-based market integration tests, in collaboration with the more sophisticated Parity Bounds and Barrett-Li models and comprehensive non-parametric descriptions of market pairs, to provide a holistic assessment of pair-wise market interaction, in the process also providing a comparison of the methods as measures of integration and efficiency.

South Africa and Malawi follow similar trends, although in this case perfect integration holds with higher frequency, and imperfect integration with negative return is occasionally observed from trade in the Malawi to South Africa trade route. Malawi and Mozambique's Northern region exhibit perfect integration of a relatively high frequency, although imperfect integration with positive returns appears dominant on the Mozambique to Malawi route. Trade is bidirectional and discontinuous, predominantly in the Mozambique to Malawi direction. The market interactions between Botswana and Mozambique's Southern region or Malawi follow a related trend exhibiting market segmentation as evidenced by the lack of trade. Efficiency holds with a fairly high frequency mostly in the form of segmented equilibrium, although significant segmented disequilibrium on the Botswana to Mozambique/Malawi route is also observed.

On a market pair level, results indicate that the Gauteng-Gaborone markets are characterized by the highest levels of price correlation, significant bidirectional Granger causality, continuous bidirectional trade and exhibit 'long run integration' as defined by Ravallion. Co-integration also holds with high levels of significance. This market pair exhibits fairly high level of perfect integration as defined by Barrett and Li 2001, though concurrently with imperfect integration of substantial frequency, a result of the persistence of excess profits on the Gauteng to Gaborone trade direction, whereas trade seems to occur despite negative returns to arbitrage on the Gaborone to Gauteng trade direction.

For South Africa and Mozambique, trade is bidirectional and discontinuous, with low frequency of perfect integration. Trade between South Africa and Mozambique's Southern region generally fails to exhaust arbitrage profits, and though integrated, the market pair appears largely inefficient. In particular, the Gauteng-Maputo market pair is characterized by substantial price correlation, significant unidirectional causality in the Gauteng

[16] Note that in this case South Africa is extracting supernatural profits from both markets.

to Maputo direction, highly significant price co-integration, and long-run Ravallion integration. This market pair, however, exhibits very low frequency of perfect integration, with the Gauteng to Maputo trade route characterized mainly by excess trade profits, whereas the Maputo to Gauteng trade direction is often in segmented equilibrium as it is to be in imperfect integration with negative profits. Gauteng and Blantyre follow similar trends, except in this case causality appears to run in the Blantyre to Gauteng direction, co-integration holds but with less significance, and perfect integration holds with slightly higher frequency[17].

Malawi and Mozambique maize exhibit somewhat different forms of interaction between Malawi and southern and northern regions of Mozambique. For the Blantyre-Maputo market pair causality is significant bidirectional, co-integration holds with high levels of significance, and perfect integration holds with a frequency of up to 25%. Price correlations are however much lower, very limited trade is observed, and frequent market segmentation is observed. Blantyre and Mocuba are characterized by higher price correlations, bidirectional causality, and significant co-integration. Perfect integration is observed with a fairly high frequency where zero arbitrage returns observed in both trade directions, with more significant positive returns imperfect integration on the observed in the Mocuba to Blantyre trade direction and segmented equilibrium in the Blantyre to Mocuba trade direction.

The relationship between Gaborone and either Maputo or Blantyre follows a clear, related trend, of limited price co-movements evidenced by fairly low price correlations, the lack of causal relations, and less significant co-integration. Market integration and efficiency however hold with a fairly high frequency in either pair, though market segmentation appears dominant – efficient in the Maputo to Gaborone or Blantyre to Gaborone trade directions, and inefficient otherwise.

Overall, the southern Africa maize markets considered in the sample seem to exhibit significant frequency of market integration, indicating tradability commodities and contestability of markets. Efficiency holds less frequently, although non-trivially, we observe that for those markets characterized by near continuous trade returns to arbitrage are exhausted for about 25% of the time. Often however, when trade is observed, efficiency appears to be weakened by insufficient arbitrage, possibly a result of non-cost barriers to trade (infrastructural or regulatory), imperfect information, or supply side constraints. For these markets, positive trade is also occasionally observed when arbitrage returns are negative, possibly due to contracting lags, and exchange rate fluctuations. Where trade is not observed, efficiency appears to hold with a slightly higher frequency (up to 45%), so that the lack of trade is often justified by the lack of positive arbitrage returns. Significant segmented equilibrium also seems to characterize these markets, where again the lack of trade is consistent with expected arbitrage returns. For these markets, efficiency is also occasionally compromised by insufficient arbitrage, whereby trade sometime fails to occur even when the returns to arbitrage incentives appear favorable (segmented disequilibrium). Therefore in order of frequency, we observe a high frequency of imperfect integration (regimes 3) and segmented equilibrium (regime 6), a fairly regular occurrence of perfect integration (regimes 1 and 2), and irregular occurrence of segmented disequilibrium (regimes 4) and the negative returns type of imperfect integration (regime 5). In specific markets, import prices consistently exceed domestic market prices, an inefficient outcome that appears to result from the involvement of the state in grain trade, where market conduct often is driven by non-profit objectives. These results suggest a need for policy intervention in the areas of improved productivity and access to information to takes advantage of unexploited arbitrage opportunities, and in the longer term, dealing with structural barriers to trade that prevent market entry especially where positive returns are currently observed. In some cases though, the lack of trade is an efficient outcome that probably requires no immediate policy interventions.

The main limitation of this study, already mentioned earlier, is the inadequate trade statistics of high frequency, that prevented the application of the Barrett-Li model to all market pairs. The study also uses imperfect transfer

[17] The higher transfer costs between Gauteng and Blantyre, compared to Maputo, possibly erode some of the excess profits observed in Gauteng's exports to Maputo.

costs data, extrapolated from isolated point estimates, obtained from various sources for different time periods. Such inconsistencies increase measurement error, and compromise the accuracy of parameter estimates. More work is required to accurately measure these variables, and monitor trade between specific markets in the region. In addition, the analysis suffers most of the limitations of parity bounds models identified in section 3.1, such as susceptibility of parameter estimates to choice of probability distribution functions, and the static nature of the analyses. Similar studies handle the former through Monte Carlo sensitivity analyses, to evaluate robustness of the chosen distributional forms (Barrett and Li 2001, Barrett et al 2000, Baulch 1997). Similar robustness test for this study would provide additional information on the validity of test results.

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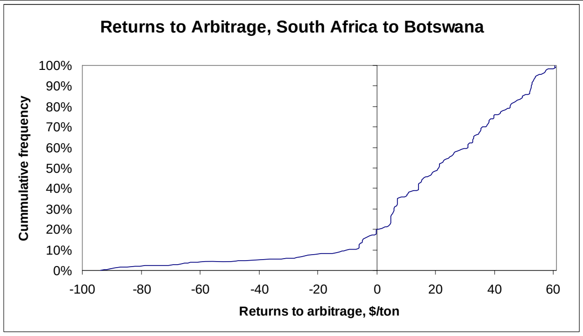
Appendix 1: Returns to Arbitrage, trade unit value estimates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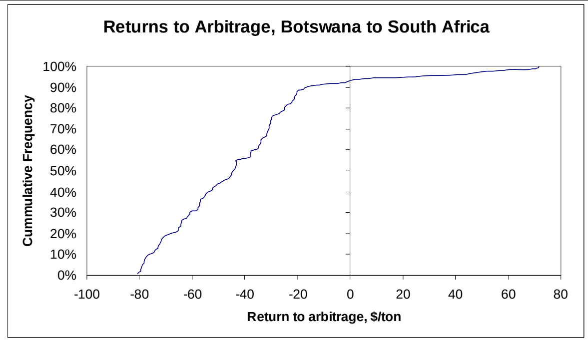
Returns to arbitrage, $/ton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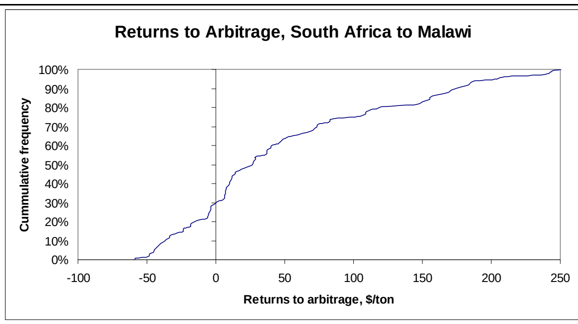
Return to arbitrage, $/ton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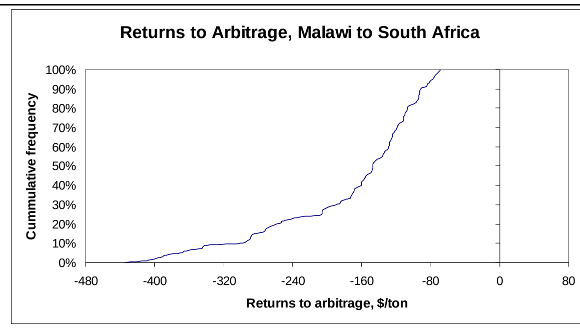
Returns to arbitrage, $/ton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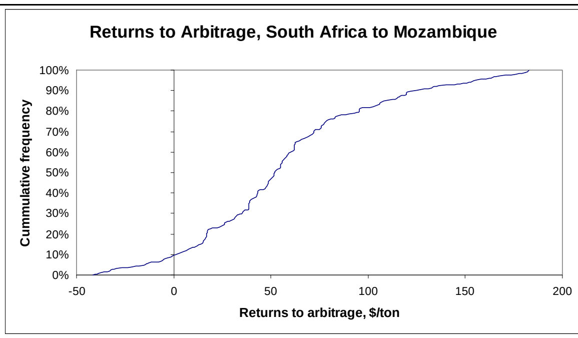
Returns to arbitrage, $/ton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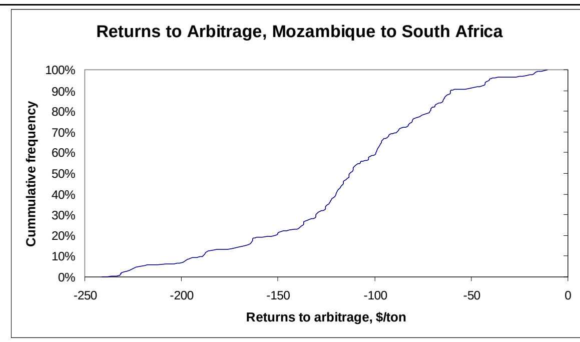
Returns to arbitrage, $/ton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Cummulative frequency
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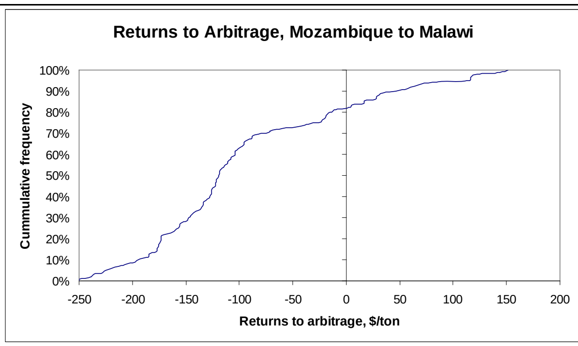
Returns to arbitrage, $/ton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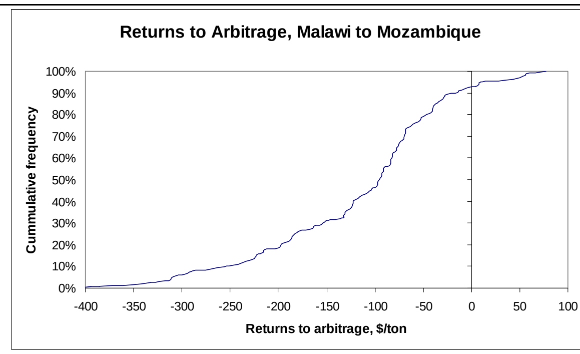
Returns to arbitrage, $/ton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Cummulative frequency
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-400 -350 -300 -250 -200 -150 -100 -50 0 50 100
Returns to arbitrage, $/ton

Appendix 2: Summary of Parity Bounds Model Results, Trade unit value adjusted

Direction of Trade	Regime Probability					
	λ_1	λ_2	λ_3	σ_u	σ_v	α
Gauteng to Gaborone	0.001	0.04257	0.95642	55.37334	33.3178	12.35310
Gaborone to Gauteng	0.00968	0.72816	0.26214	49.66583	0.001	-12.91688
Gauteng to Maputo	0.009695	0.097091	0.89321	74.99773	0.001	1.09869
Maputo to Gauteng	0.03892	0.63149	0.32958	79.47493	1.52442	-62.00201
Gauteng to Blantyre	0.400216	0.001	0.598784	123.6662	27.89085	-7.38528
Blantyre to Gauteng	0.009768	0.81586	0.174371	155.4237	0.000017	-69.23264
Maputo to Blantyre	0.009332	0.640991	0.349676	96.05077	0.000001	-1.56956
Blantyre to Maputo	0.255405	0.681504	0.06309	146.10972	52.27847	-36.66282

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