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Economic growth notes

ZIMBABWE:
SPATIAL INTEGRATION IN ZIMBABWEAN PRODUCT MARKETS

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1 OVERVIEW

The purpose of this policy note is to provide evidence on the level of integration between Zimbabwe's domestic markets for grains and staple foods. In order for prices to deliver the appropriate incentives, markets must be efficient and hence, integrated. Integrated markets have a long-term relationship whereby price changes in one market are transmitted to another, providing the necessary signals that guide production and trading decisions. From a theoretical perspective, integrated markets are consistent with the law of one price, which postulates an arbitrage driven equilibrium whereby the difference in price between two markets for the same good remains only with the transaction costs between them. In practice, integration is a signal of well-functioning markets that are characterized by competition, information and absence of policy impediments to supply and demand response.

Efficient and integrated agricultural markets are an important vehicle for growth and poverty reduction. A key stimulant to agricultural growth and poverty reduction is small farmers' incentives, whether through higher sale prices at the farm-gate, reduced costs of production and transport, or the spread between them. In order for prices to deliver the appropriate incentives to smallholders, markets must be integrated and assure the participation of the poor. These factors provide the motivation for this policy note, which covers six grain markets[1] across the ten provinces of Zimbabwe. These markets represent some of the most significant products in the economy as well as some of the most important commodity markets for the poor, both as producers and consumers. Indeed, Zimbabwe's grain markets are estimated to contribute between 17 and 32 percent of rural household incomes[2].

The note determines whether Zimbabwe's provincial markets are integrated and explores the determinants of market integration. It begins by determining whether Zimbabwe's provincial markets are integrated, and provides estimates of the speed of adjustment between markets pairs. The analysis is then extended to investigate the extent to which distances and demand for the products determine market integration. The paper concludes with a discussion of other structural or policy related factors that affect integration and efficiency of domestic markets. The literature on market integration and price transmission is vast[3], and has contributed to the understanding of market dynamics and transmission channels especially in times of global price volatility. Price transmission analysis has been used to investigate the relationship between world prices and local prices for given commodities, to analyze the prices of two competing commodities (such as maize and cassava), or the prices of two commodities in the same value chain (e.g. maize grain and maize meal). In this study, we focus on spatial integration between regional prices for the same commodities.

[1] Maize grain, maize meal, sorghum, cowpeas, sugar beans and groundnuts.
[2] ZIMVAC Rural Livelihoods Assessment (2011).
[3] Sekhar (2012); Jacks et al. (2011); Minot (2011).

The main finding of the study is that Zimbabwe's largest domestic grain market, the market for maize, is segmented between surplus and deficit areas. Although maize markets tend to be integrated *within* these zones, the linkages between surplus and deficit areas are weak. The other commodities (cowpeas, groundnuts and sugar beans) have more robust level of integration with the exception of sorghum, which has the lowest levels of market integration. However, these grains are narrowly produced and traded.

A domestic marketing structure that is strong on aggregation and weak on arbitrage, and high transactions costs for small traders, are highlighted as the main drivers of the observed segmentation. In particular, a requirement for traders to obtain an annual permit at a cost of USD 1,000, doubled to USD 2,000 in case of late registration is an onerous cost that may dampen their role in moving maize across zones. High transport costs between the regions and the low production levels are also discussed as drivers. The policy note concludes by offering some policy recommendations to strengthen market integration. First, liberalizing market entry for small traders by removing the current set of administrative fees would reduce their transaction costs and strengthen their role in facilitating spatial arbitrage. Second, prioritizing rural roads and transport costs to and within deficit areas would reduce transaction costs and deepen integration. Lastly, deepening the focus of key agricultural programs on stimulating production in deficit areas would ease local food shortages and help mitigate the effects of weak market integration.

2 BACKGROUND

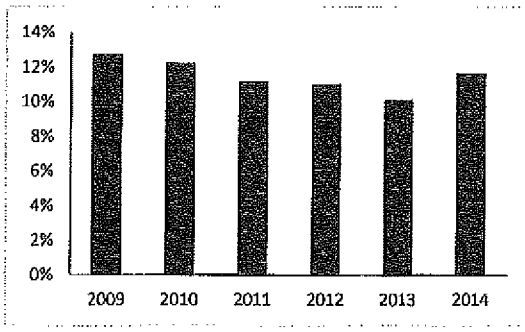
Grain production, maize in particular, is a dominant feature of Zimbabwe's agricultural landscape. Agriculture plays an important role in Zimbabwe's economy and represents a major source of income for the poorest and most vulnerable households. Its contribution to GDP averaged 11.5 percent since 2009 (figure 1) and it is the source of over 40 percent of export earnings. Grains dominate the agricultural landscape. They are grown by over 90 percent of farming households across the country and are both the main source of calories and income for the rural population. Maize alone covers over 60 percent of the total cropped area and represents over 50 percent of the average calorie intake of the population[4]. These trends underline the importance of efficient grain markets for welfare, by ensuring access and affordability for consumers and the right price signals for producers.

Zimbabwe's grain production levels have declined markedly over the past years, and imports have come to play a growing role in domestic supply. In spite of Zimbabwe having had a long history as a surplus producer in the southern Africa region, both yield and production levels have declined in recent years as the sector evolved from a large-scale commercial farming structure to one dominated by low yield smallholder production (figure 2). This trend, combined with periodic

[4] ZIMSTAT, 2012. Poverty Income Consumption and Expenditure Survey

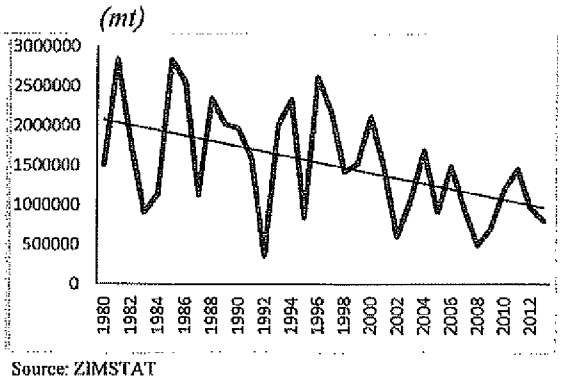
drought episodes, has opened a deficit in the national grain balance sheet. Zimbabwe's persistent grain deficits are plugged by imports, mostly from South Africa and Zambia. During the past decade, imports as share of maize requirement have averaged approximately 20 percent.

Figure 1: Contribution of Agriculture to GDP



Source: ZIMSTAT

Figure 2: Trends in Maize Production (mt)



Source: ZIMSTAT

3 DATA AND METHODOLOGY

The analysis is based on monthly and weekly grain price series collected at main provincial markets. Table 1 presents a summary of the dataset and its sources. Maize prices series cover all ten provinces of Zimbabwe, whereas the selection of provinces for other commodities is guided by the areas for which sufficient data was available. These tend to be the areas where the commodity is produced and most frequently traded[5].

Table 1: Commodity Price Data Sources

Commodity	Frequency	Years	Source	No. of provinces selected
Maize grain	Monthly	2010-2014	World Food Program[6]	All provinces
Maize meal	Monthly	2010-2014	FEWSNET	All provinces
Cowpeas	Weekly	2012-2014	Ministry of Agriculture	8 provinces
Sugar beans	Weekly	2012-2014	Ministry of Agriculture	9 provinces
Groundnuts	Weekly	2012-2014	Ministry of Agriculture	7 provinces
Sorghum	Weekly	2012-2014	Ministry of Agriculture	5 provinces

In terms of methodology[7], the analysis of market integration relies on a vector error correction model (VECM) to assess spatial cointegration between markets. Two variables are

[5] Any missing observations were computed using a filling algorithm.
[6] http://foodprices.vam.wfp.org/Analysis-Monthly-Price-DataADV.aspx
[7] Annex I presents a detailed description of the methodology applied in this study.

said to be cointegrated if they tend to move together in the long-run. Although deviations from the equilibrium may be observed in the short-run, these are corrected in the long-run if the price transmission mechanism is functioning and hence, the markets are said to be cointegrated. Unlike many other studies which analyze the price transmission between domestic and world markets of a given commodity (in this case the standard hypothesis is that world prices affect local prices), this analysis investigates spatial price transmission between *all* possible combinations of domestic markets at the provincial level.

The VECM approach is appropriate if two conditions are met. First, each price series is non-stationary and integrated to degree 1, written as I(1). That is, the variable (commodity price) is a random walk but the first differences (commodity return) is stationary or I(0). Second, the variables are cointegrated, meaning that there is a linear combination of the variables that is stationary. If the time series of prices of a given market is not unit root, by definition, no cointegration can be tested. Such market will be excluded from the VECM estimation. Hence, for each pair of markets the analysis consists of three steps:

i. Unit root tests: to check whether the price process is stationary. These tests are the Augmented Dickey-Fuller (standard, with drift and with trend), and the Phillips-Perron test (standard or with drift).
ii. Cointegration tests: the Engle-Granger and Johansen tests are used to determine whether the two series are cointegrated. This indicates whether there is a long-run relation between these two time series.
iii. VECM: the model is estimated only for cointegrated market pairs to estimate the speed of price adjustments between them.

4 MARKET INTEGRATION PATTERNS

The cointegration analysis detects the existence of a long-term relationship between markets and estimates its strength. Table 2 presents a summary of the results[8]. Three main indicators are presented. The first is the existence of a cointegration relationship between a market pair for a given commodity[9]. This identifies the existence of a long-term relationship. The second is the long-term elasticity, which indicates the strength of price transmission in the long-term. The third is the speed of price adjustment between markets.

[8] The full results of the analysis are presented in annex II.
[9] Cointegration is accepted provided that either the Engel Granger test or the Johansen tests identifies a long-term relationship.

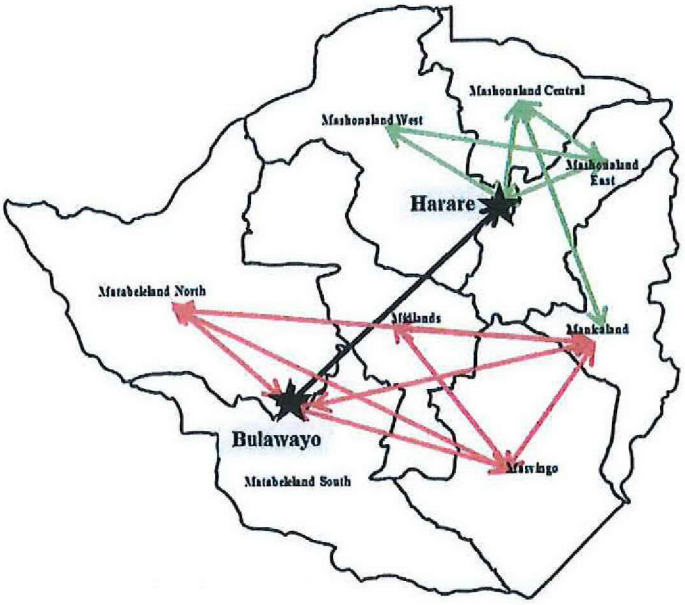
Maize markets

The cointegration results indicate that maize grain markets are characterized by segmentation between the northern surplus and the southern deficit production regions[10]. In general, maize grain prices in deficit production areas are not integrated with surplus areas. Although integration is found within the two zones, grain prices in low production areas such as Matabeleland North and South do not have a long-term relationship with prices in the main producing areas of Zimbabwe. These regions are concentrated in the northern and eastern parts of the country. In effect, the results show two separate enclaves, with grain moving within the surplus and deficit producing areas but not between them (figure 3). Overall, 41 percent of the market pairs for maize grain are integrated. The average long-term price transmission elasticity for the integrated markets is very close to full price transmission. The speed of adjustment between these market pairs is also high compared to the other commodities in the sample (table 2).

The only link between the surplus and deficit regions is through the Harare - Bulawayo trading corridor. Although surplus and deficit markets are segmented, the prices series for Harare and Bulawayo are integrated. This result reflects the aggregator role of Harare, where much of the maize produced in the northern surplus areas is collected for milling or for shipment to Zimbabwe's second trading and processing hubs in Bulawayo. They also reflect the structure of Zimbabwe's road network, whereby the main provincial hubs in the southern deficit regions are connected to northern surplus production areas through Harare.

[10] Surplus/ deficit regions are defined as those with cereal production in excess/ deficit of internal requirements on average over the last three crop seasons. See annex IV for average production gaps by region.

Figure 3: Segmented Integration Pattern for Maize Grain



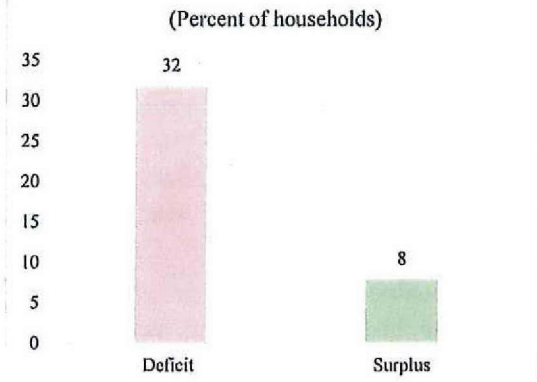
The segmentation extends to regional integration, whereby surplus maize grain markets are integrated with South Africa whereas the deficit regions are not. The cointegration between Zimbabwe and South Africa's maize grain markets is not surprising given that South Africa is the main source of imports for closing Zimbabwe's production deficit. The liberalization of Zimbabwe's maize market in 1990 has facilitated trade and integration with this major regional market. What is less expected is the absence of a long-term relationship between maize prices in Zimbabwe and Zambia. This may reflect the characteristics of the Zambia maize markets which might not be efficient and integrated with regional and world markets.[11]

In contrast, the markets for maize meal are relatively well integrated. Maize meal is one of the most efficient markets in the sample with full long-term elasticity and the highest speed of adjustment amongst the selected commodities. This is not surprising. Maize meal is the most widely consumed staple food. Its production and distribution infrastructure is well developed with processing hubs in both surplus and deficit areas and the co-existence of large and micro milling industries. However, these results should be treated carefully when making comparisons, given that domestic maize meal movements are determined by the distribution decisions of a handful of large processors.

[11] Myers and Jayne (2012), Minot (2010, 2011).

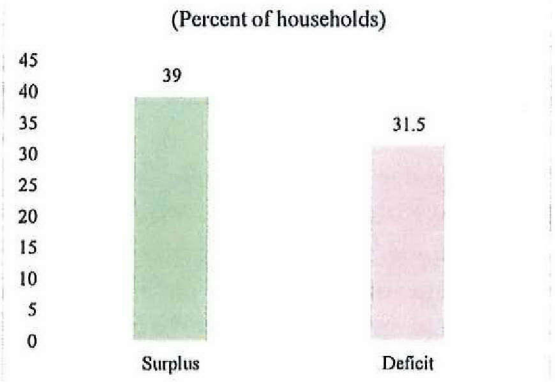
Given the major role played by maize in Zimbabwe's food basket, the segmentation of this market has direct implications in terms of food security and demand stimulus for agricultural production. Although surplus and deficit regions are connected through the Harare-Bulawayo corridor, the maize traded through this channel is mostly destined for the milling industries that serve these large urban hubs as opposed to the small markets that serve vulnerable and food insecure rural households[12]. Rural households in deficit areas rely largely on unprocessed maize grain for their needs during parts of the year, and are more likely to purchase maize form their neighbors than from local retailers or markets. They are also more likely to report difficulties in sourcing maize for their basic consumption needs than in other regions (figure 4 and 5). Therefore, the integrated markets for maize meal do not necessarily counteract the inefficiencies stemming from segmented grain markets and their impact on growth and food security.

Figure 4: Prevalence of food insecurity



Source: ZIMVAC Rural livelihoods assessment, 2014.

Figure 5: Percent of households stating maize is readily available



Source: ZIMVAC Rural livelihoods assessment, 2014.

Other commodities

The other staple food markets are relatively well integrated in the areas where they are traded, with the exception of sorghum. Unlike maize, small grain markets are more narrowly transacted making the regional coverage of small grains in our sample less broad. The market coverage for these commodities in the sample tends to be concentrated in the drier regions of the country, with the exception of sugar beans which are more widely traded. In those areas, small grains show robust levels of cointegration[13]. On average, 78, 60 and 52 percent of the market pairs for groundnuts, cowpeas and sugar beans are cointegrated. The exception is in the sorghum market, where only 17 percent of market pairs are cointegrated. Although fairly well integrated in the

[12] Kapuya et al (2010).

[13] See annex III for mappings of cointegration relationships for the other commodities.

observed areas, small grains have slightly lower long-term elasticities and slower speeds of price adjustment than maize, with sorghum registering the slowest rates of adjustment.

Sugar beans are the only commodity in the sample, other than maize, which is regularly traded across surplus and deficit areas. Unlike the markets for maize grain, sugar bean markets are integrated between surplus and deficit zones. This suggests that the observed segmentation maybe a phenomenon that affects maize more acutely than it applies to other tradable food crops.

Table 2: Summary of cointegrated and VECM results (average)[14]

	% of integrated pairs	Long-term price transmission elasticity[15]	Speed of price adjustment[16]	Time needed to close 50 percent of the price gap between markets[17]
Maize grain	41%	1.01	0.53	1.0 month
Maize meal	60%	0.99	0.76	1.8 months
Cowpeas	60%	0.92	0.33	2.4 weeks
Sugar beans	52%	0.98	0.32	9.1 weeks
Groundnuts	78%	0.90	0.44	2.7 weeks
Sorghum	17%	1.08	0.24	5.7 weeks

[14] See annex IV for the results for each estimated market pair.
[15] Average for integrated pairs only.
[16] This is the average combined speed of adjustment in absolute terms for the integrated pairs only.
[17] These estimates are based on the half-life measure, which estimates the amount of time (months for maize and weeks for other commodities) needed to correct 50 percent of the deviation in prices between market pairs.

5 DETERMINANTS OF MARKET INTEGRATION

To explore the determinants of market integration, the analysis turns to estimating the role of distance, production and population as driving factors. Having determined the levels of spatial integration between the main provincial markets for the selected commodities, the analysis was extended to consider the extent to which distance between markets and the respective levels of demand explain the observed patterns of integration[18] and the speeds of adjustment between market pairs. The estimations focused on maize grain given that maize is the commodity in the sample with the widest regional coverage, and to investigate the observed segmentation in this market. Three explanatory variables were considered (i) distance between markets on major roads; (ii) difference in production between market pairs as a share of their joint total output[19]; and (iii) difference in the provincial population between market pairs as a share of their joint total population. The first variable represents transport as the main transaction cost in the domestic marketing of maize. It is expected that shorter distances between market pairs would increase the level of integration between them. The second and third variables are proxies of respective levels of demand for maize between two areas. The estimated model (OLS linear regression) is as follows and the results of the estimations are reported in annex IV:

$$\text{Cointegration}_{ij} = \beta_1 \text{ distance}_{ij} + \beta_2 \text{ production diff}_{ij} + \beta_3 \text{ population diff}_{ij} + e$$

The results indicate that distances have significant and negative effect on the levels of market integration for maize grain. In contrast, differences in production levels between market pairs and the respective population shares were not found to have a significant effect. These results partly confirm the observed pattern of market integration, whereby the integrated markets are clustered within two distant zones, one in the northern fertile regions and the other in the southern arid areas of Zimbabwe[20]. The distances between these two areas are large. In terms of the speed of adjustment, the explanatory variables were not found to not have an effect. Overall, these results suggest that although distances have the expected effect on market integration, distance, production and populations have relatively low levels of explanatory power for market integration[21]. Factors other than these are likely to be important determinants of both the level of integration and the speed of adjustment between Zimbabwe domestic markets. Some of these factors are discussed below.

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[18] As measured by the test statistic of the cointegration test between market pairs (Johansen's trace statistic).

[19] The proxy for the production differentials is computed as follows:

$$Production = \frac{|(\%P_A - \%P_B)|}{\%P_A + \%P_B}$$

where $\%P_A$ and $\%P_B$ denote the annual percentage of a given commodity production over the total production for the two provinces.

[20] Annex VII presents a map and description of the agro-ecological zones of Zimbabwe.

[21] The adjusted R-square is 0.1

Other factors that influence the levels of integration

The formal marketing chain has evolved in favor of aggregation and distribution rather than arbitrage. Zimbabwe's formal grain marketing and processing industries absorb a large share of total production. The industry is composed of large buyers that import maize and that purchase it on a wholesale basis in domestic markets, and large processors that mill grain to distribute it through national networks. The industry also includes some firms that are vertically integrated across both segments. The main function of these firms in the domestic marketing chain is to consolidate grain in volumes large enough to feed the large scale milling industries. In other words, they aggregate grain in the most cost effective way and process it for delivery to urban and semi/urban consumption hubs. Arbitrage, which involves the movement of grain between surplus and deficit areas, is the domain of a smaller, less organized group of agents: small agro dealers and traders.

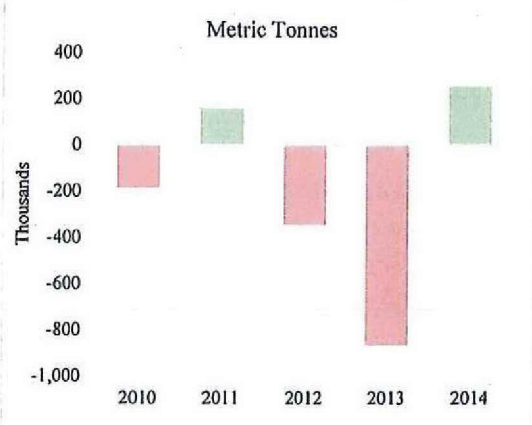
Arbitrage through informal channels is limited by the high transaction costs faced by small traders. The spatial arbitrage between surplus and deficit areas relies largely on the operations of small itinerant traders and agro dealers. Unlike the large formal industries, these agents are fragmented, dispersed and under-capitalized. They typically trade in small volumes at high transaction costs relating to search, financing and transport, amongst others. Their margins are low and they face high entry costs associated with the administrative procedures and fees for small traders. An important example is a requirement to obtain an annual permit at a cost of USD 1,000 for buyers, brokers or traders, which is doubled to USD 2,000 in case of late registration[22]. This fee alone represents a large cost and an obstacle to market entry for small traders. The late registration penalty also limits flexibility to enter the market for traders who are likely to operate on an opportunistic basis as they become aware of seasonal opportunities for arbitrage or free-up operating capital during the course of the year. Other transaction costs are also likely to be important, particularly those related to transport. Taken together, high entry and transaction costs and low margins will limit the number agents engaged in spatial arbitrage. These factors also dampen the level of competition governing the first transaction in the domestic marketing chain at the farm-gate, to the disadvantage of small farmers that have limited information and access to markets.

The national production deficit and thin markets for small grains limit the volume of trade and dampen the potential for integration between markets. Zimbabwe has transitioned from being a surplus to a deficit producer of food over the past two decades. It posted a national deficit for grain in three of the past five years (figure 6). Hence, the shortage of production may be one of the factors limiting the volume of trade and integration between surplus and deficit regions, particularly since a large share of surplus production in the northern regions is absorbed by the large urban population of Harare. Moreover, most food commodities (except maize) such as small

[22] These charges are instituted through the Agricultural Marketing Authority's by-laws (2013). See annex VI for an extract of the by-laws with a summary of the charges.

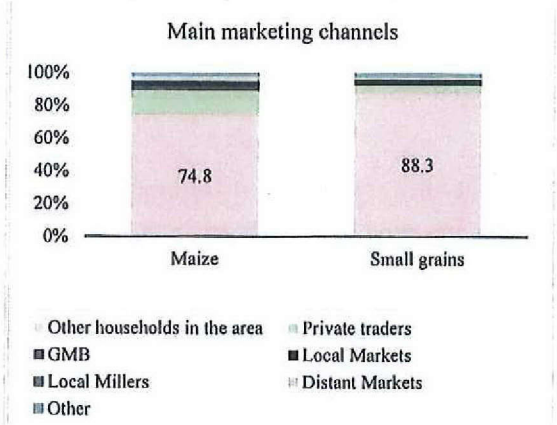
grains, pulses and oil seeds operate in thin markets that are characterized by low production volumes and limited marketing activity. These crops represent between 10% and 14 % percent of household production[23], and households that grow these crops are more likely to produce them for own consumption. Only a very small share is traded (figure 7). Small grains and pulses are also less represented in the commercial farming portfolio and in trade flows. It follows that thin markets are less integrated and are more exposed to local demand and supply fluctuations.

Figure 6: Zimbabwe's grain balance



Source: ZIMVAC.

Figure 7: Thin markets for small grains



Source: ZIMVAC Rural livelihoods assessment, 2014.

6 CONCLUDING REMARKS

Using spatial price transmission analysis, this paper empirically measures the levels and patterns of integration for some of Zimbabwe's most important domestic product markets. Weak domestic market integration is indicative of slow spatial arbitrage. In the absence of robust market linkages, prices are vulnerable to local availability and may fluctuate widely if domestic markets do not respond by increasing supply during times of scarcity or by exporting surplus during times of plenty. Weak integration would also contribute to widening the spread in prices between surplus and deficit areas as prices in low production areas continue to reflect tight supply conditions.

The analysis has shown that Zimbabwe's domestic markets for maize are segmented between surplus and deficit areas. Although regional markets tend to be integrated *within* these zones, the linkages between them, as indicated by systematic price co-movement, are absent. It is a finding that is indicative of a failure in arbitrage and weak trade flows between these two zones. This matters not only for production incentives and agricultural growth, but also for vulnerability and

[23] ZIMVAC Rural livelihoods assessment, 2013.

food security in some of Zimbabwe's poorest regions. The markets for the other small commodities reviewed show more robust integration patterns across surplus and deficit regions.

The policy note highlights four main drivers of the observed segmentation in domestic maize markets. (i) a domestic marketing structure that is strong on aggregation and retail distribution but weak on arbitrage; (ii) high transaction and market entry costs facing small traders who are main agents for arbitrage; (iii) costly domestic transport given the large distances between surplus and deficit zones; and (iv) low national production levels and thin markets for domestic commodities other than maize. The note concludes by discussing potential interventions and priorities that could ease the obstacles to spatial market integration.

First, liberalizing market entry for small traders, agro dealers and brokers would reduce their transaction costs and strengthen their role in facilitating spatial arbitrage. The current set of administrative fees required of these agents increases their transaction costs and dampens their role as the primary agents for spatial arbitrage. Waiving all licensing and permit fees, or reducing them to a nominal amount, would increase the number of active traders and their flexibility to enter the market in response to arbitrage opportunities. Other interventions that increase their access to finance and information, and that deepen their linkages to the formal marketing chain would also strengthen this segment of the domestic market.

Second, prioritizing rural roads and transport costs to and within deficit areas would further reduce transaction costs and deepen integration. Prioritizing infrastructure investments in these areas would tangibly reduce transaction costs for domestic marketing, resulting in better trade linkages and wider spatial arbitrage. Interventions that reduce the incidental costs of road transport such as reducing toll fees and the costs associated with controls points would also contribute to this result.

Third, deepening the focus of key agricultural programs on stimulating production in deficit areas would ease local food shortages and help mitigate the effects of market segmentation. Raising agricultural production and productivity has been a priority issue for Zimbabwe, and the recommendations to attain this goal are addressed in numerous policies, studies and texts[24]. Amongst these, the findings of this paper point to the importance of increasing productivity in deficit areas, especially for the production of small grains given the comparative advantage of deficit areas in the production and marketing of these commodities.

Lastly, the analysis revealed differences in the extent of spatial integration between maize (and sorghum) and the other small commodities. Various factors could explain these results. Firstly, unlike maize and sorghum, the marketing chains for small grains do not have large formal processing industries. Hence, their marketing networks rely more heavily on informal channels and small traders that look to arbitrage for profit. Second, the marketing profit margins of each

[24] See World Bank (2012) and World Bank (2014) for recent analysis and references to on this body of work.

crop are an important factor in determining the incentive to trade in small grains. Higher margins would raise the returns from trading, and support integration across regional borders. An analysis of these margins by crop may yield further insights to these underlying dynamics of market transactions. Lastly, the marketing of maize grain is a delicate issue in Zimbabwe, and is subject to heavy attention by the authorities. Hence, its spatial market integration may be dampened to the extent that it is subject to more burdensome administrative controls. Further analysis of these questions that, combines quantitative value chain analysis with and qualitative assessments of market regulations at the local level would yield further insights to the constraints to stronger spatial integration in Zimbabwean markets.

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ANNEXES

I: Methodology

II: Cointegration analysis results

III: Cointegration maps

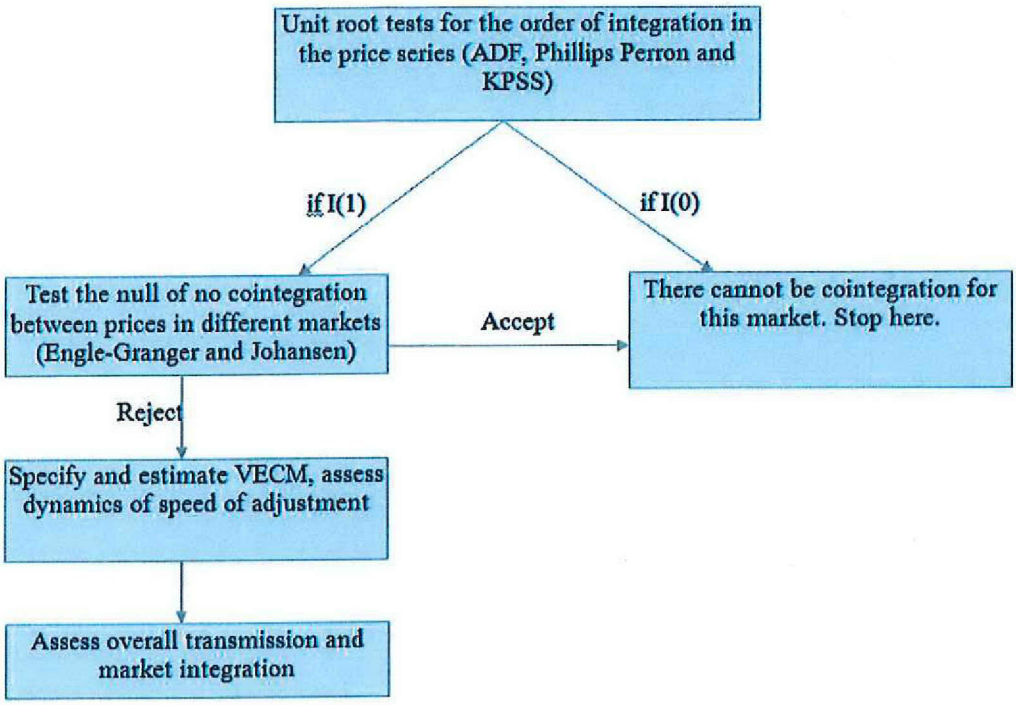
IV: Regression results

V: Surplus/ deficit regions (2008/09 to 2013/14 average)

VI: Agricultural Marketing Authority trader/ buyer registration fees

VII: Natural regions of Zimbabwe

I: Methodology



Unit root tests

A time series y_t is said to have a unit root if it follows the autoregressive process

$$y_t = y_{t-1} + e_t$$

where e_t is a white noise. The process y_t is said to be 'non-stationary' as mean is not constant over time and variance is diverging to infinity with $t \to \infty$.

Augmented Dickey-Fuller test

This test, dubbed ADF test, is the extension of the Dickey-Fuller test allowing for more lags to be considered. Consider an AR(3) process

$$y_t = \theta_1 y_{t-1} + \theta_2 y_{t-2} + \theta_3 y_{t-3} + e_t \ .$$

Rewriting the model as

$$\Delta y_t = \alpha + \beta t + \pi y_{t-1} + c_1 \Delta y_{t-1} + c_2 \Delta y_{t-2} + e_t$$

under the null hypothesis of unit root we have that

$$H_0 : \pi = 0 \text{ against } H_1 : \pi < 0$$

The t-test on H_0 is called Augmented Dickey-Fuller test. Allowing α and β to be different from zero is the version of the test which include drift and trend, respectively.

The optimal number of lags to be included can be selected relying on some goodness-of-fit criterion, e.g. AIC or BIC.

Phillips Perron test

Whereas the ADF test involves estimating (assuming no drift/trend/lag)

$$\Delta y_t = \pi y_{t-1} + e_t$$

the Phillips Perron test (PP) estimates

$$y_t = \rho y_{t-1} + e_t .$$

In the ADF test e_t is I(0) and can be heteroskedastic. The PP tests correct for any serial correlation and heteroskedasticity in the errors e_t non-parametrically by modifying the Dickey Fuller test statistics. One advantage of the PP tests over the ADF tests is that the PP tests are robust to general forms of heteroskedasticity in the error term e_t.

Kwiatkowski, Phillips, Schmidt, and Shin test

This test, known as KPSS test, differs from the previous two as the null hypothesis is now that the process is stationary, i.e. I(0).

Assuming no trend is present, the starting point of the test is the process

$$y_t = \xi_t + e_t$$

where e_t is stationary and ξ_t is a random walk, i.e.

$$\xi_t = \xi_{t-1} + v_t,\ v_t \text{ is } IID(0, \sigma_v^2).$$

If $\sigma_v^2 = 0$ then $\xi_t = \xi_0$ hence y_t is a stationary process.

The simple regression

$$y_t = \hat{u} + \hat{e}_t$$

can be used to get an estimate of the stochastic component. Under the null hypothesis, e_t is stationary.

The test reads

$$H_0 : \sigma_v^{\ 2} = 0 \text{ against } H_1 : \sigma_v^{\ 2} > 0 .$$

The test statistic is given by

$$KPSS = \frac{1}{T^2} \frac{\sum_{t=1}^{T} S_t^2}{\hat{\sigma}_\infty^2}$$

where $S_t = \sum_{s=1}^{t} \hat{e}_s$ is a partial sum and $\sigma_\infty^{\ 2}$ is a HAC estimator of the variance of $\hat{e}_t$.

Cointegration tests

As we are analyzing two prices at the time, the cointegration relation reads:

$$P_1 = \alpha + \beta P_2 + \epsilon \text{ or } P_1 - \alpha - \beta P_2 = \epsilon \text{ where } \epsilon \text{ is a stationary process.}$$

Engle and Granger (1987)

Consider the following equation;

$$p_{1t} = \beta p_{2t} + u_t .$$

If u_t is non-stationary, then $p_{1t} - \beta p_{2t}$ is not a cointegrating relationship. Engle and Granger suggested estimating the above relation via OLS and then testing for the presence of a unit root on the estimated residuals $\hat{u}_t$ in order to test the null of no cointegration.

Johansen (1988, 1991)

Consider at VAR of two variable p_{1t} and p_{2t} and two lags, i.e. a VAR(2)

$$\begin{pmatrix} p_{1t} \\ p_{2t} \end{pmatrix} = \begin{pmatrix} u_1 \\ u_2 \end{pmatrix} + A_1 \begin{pmatrix} p_{1t-1} \\ p_{2t-1} \end{pmatrix} + A_2 \begin{pmatrix} p_{1t-2} \\ p_{2t-2} \end{pmatrix} + \begin{pmatrix} V_{1t} \\ V_{2t} \end{pmatrix}.$$

This VAR(2) has Vector Error Correction (VECM) representation

$$\begin{pmatrix} \Delta p_{1t} \\ \Delta p_{2t} \end{pmatrix} = \begin{pmatrix} u_1 \\ u_2 \end{pmatrix} + (A_1 - A_2 - I) \begin{pmatrix} p_{1t-1} \\ p_{2t-1} \end{pmatrix} + \begin{pmatrix} V_{1t} \\ V_{2t} \end{pmatrix}.$$

The rank of the matrix $(A_1 - A_2 - I)$ is equal to the number of cointegrating vectors. If it is 2, both variables are stationary. If it is 0 the non cointegration relation is present. If it is equal to 1 then the variables are cointegrated.

With two price variables, cointegration can be assessed by testing the significance of the characteristic roots or eigenvalues of $(A_1 - A_2 - I)$. If the variable are cointegrated then $0 < \lambda_1 < 1$ and $\lambda_2 = 0$. Johansen (1988, 1991) derived the distribution of the two statistics for the null of no cointegration referred as the Trace and Maximum Eigenvalues test.

Vector Error Correction Model

The VECM model takes the general form:

$$\Delta p_t = \alpha + \Pi p_{t-1} + \sum_{k}^{q} \Gamma_k \Delta p_{t-k} + v_t$$

where

p_t is $nx1$ the vector of n price variables

Δ is the difference operators so that $\Delta p_t = p_t - p_{t-1}$

v_t is an $nx1$ vector of error terms

α is $nx1$ vector of estimated parameters describing the trend component

Π is an nxn matrix of estimated parameters that describe the long-term relationship and the error correction adjustment

Γ_k is a set of nxn matrices of estimated parameters that describe the short-run relationship between prices, one for each of the q lags included in the model.

Since we only consider pairs of variables, each representing the prices in a pair of commodity market in Zimbabwe, the VECM specification can be simplified and re-written as:

$$\Delta p_t^A = \alpha + \theta(p_{t-1}^A - \beta p_{t-1}^B) + \delta \Delta p_{t-1}^B + \rho \Delta p_{t-1}^A + \nu_t$$

where

p_t^A and p_t^B are the (log) prices of a given commodity in Market A and Market B, respectively

$\alpha, \theta, \beta, \delta$ and ρ are parameters to be estimated.

If prices are I(1), the first difference Δp_t will be stationary or I(0).

The following interpretation is given to the model parameters

1. With prices expresses in logarithm, the cointegration factor β represents the long-run elasticity of the prices in Market A with respect to Market B. Hence β is the long-run elasticity of price transmission. For example, if $\beta = 0.5$, 50 percent of the proportional change in prices of Market B will be transmitted to prices of Market A in the long-run.

2. The error correction coefficient θ reflects the speed of adjustment. The term
$$p_{t-1}^A - \beta p_{t-1}^B$$
represents the deviation or 'error' between prices in the previous period and the long-run relationship between the two prices. If the 'error' is positive (price in Market A is too high given the long-term relationship) then a negative value of θ helps correcting the 'error' by making it more likely that the Δp_t^A is negative. The larger θ in absolute value, the more quickly the price in Market A will return to the value consistent with its long-term relationship to Market B.

3. The coefficient δ of change in prices of Market B is the short-run elasticity of prices in Market A relative to prices in Market B. It represent the percentage adjustment of Market A prices one period after a 1 percent shock to Market B prices.

4. The coefficient of the lagged change in prices of Market A (ρ) is the autoregressive term, reflecting the effect of each change in the price of Market A on the next period changes of prices in the same market.

After the VECM model is estimated – only for pairs in which the cointegration hypothesis cannot be rejected – statistical significance of each coefficient is assessed in order to be able to correctly comment on the long-run equilibrium values, elasticities and speeds of adjustment. In a last step, for statistically significant speeds of adjustment, *half-lives* are computed. The half-life statistic measures how long it takes to correct 50 percent of the deviation (or 'error') of the two prices from the long-run equilibrium. It is calculated as:

$$Half\ Life = \frac{-log(2)}{log(1-|(\theta)|)}$$

Annex II: Cointegration analysis results

Maize Grain

Location		Long-term Relationship			Adjustment	
Market 1	Market 2	Engle Granger	Johansen	Long-term Elasticity	Combined Adjustment	Average Half life
Cointegrated markets						
MatNorth	Midlands	Yes	No	1.01	0.25	2.40
MatNorth	Midlands	Yes	Yes	1.05	0.29	1.22
MatNorth	Masvingo	Yes	No	1.03	0.17	-
MatNorth	Bulawayo	Yes	Yes	0.94	0.35	1.08
MatNorth	Manicaland	Yes	Yes	0.99	0.41	1.07
Midlands	Midlands	Yes	Yes	1.05	0.44	0.74
Midlands	Masvingo	Yes	Yes	1.02	0.48	-
Midlands	Bulawayo	Yes	No	0.93	0.38	0.97
Midlands	Manicaland	Yes	No	0.97	0.52	0.84
Midlands	Masvingo	Yes	Yes	0.97	0.94	0.31
Midlands	Bulawayo	Yes	Yes	0.88	0.45	1.09
Midlands	Manicaland	Yes	No	0.92	0.61	0.71
Masvingo	Bulawayo	Yes	Yes	0.90	0.29	1.05
Masvingo	Manicaland	Yes	No	0.94	0.26	1.86
Bulawayo	Manicaland	Yes	Yes	1.03	0.49	0.70
MashCentral	MashEast	No	Yes	1.09	0.77	0.25
MashCentral	Harare	No	Yes	1.11	0.66	1.73
MashCentral	Manicaland	No	Yes	1.12	0.88	1.28
MashWest	MashEast	No	Yes	1.10	0.86	0.35
MashWest	Harare	No	Yes	1.12	0.71	0.53
MashEast	Midlands	No	Yes	1.11	0.62	0.54
MashEast	Harare	No	Yes	1.01	0.91	1.20
Harare	Bulawayo	No	Yes	0.97	0.32	1.00
Not Cointegrated						
MashCentral	MatNorth	No	No	1.12		
MashCentral	MashWest	No	No	0.98		
MashCentral	MatSouth	No	No	-0.10		
MashCentral	Midlands	No	No	1.15		
MashCentral	Midlands	No	No	1.21		
MashCentral	Masvingo	No	No	1.18		
MashCentral	Bulawayo	No	No	1.08		
MatNorth	MashWest	No	No	0.86		
MatNorth	MashEast	No	No	0.96		
MatNorth	MatSouth	No	No	-0.16		
MatNorth	Harare	No	No	0.97		

MashWest	MatSouth	No	No	-0.10		
MashWest	Midlands	No	No	1.17		
MashWest	Midlands	No	No	1.22		
MashWest	Masvingo	No	No	1.19		
MashWest	Bulawayo	No	No	1.09		
MashWest	Manicaland	No	No	1.14		
MashEast	MatSouth	No	No	-0.11		
MashEast	Midlands	No	No	1.05		
MashEast	Masvingo	No	No	1.08		
MashEast	Bulawayo	No	No	0.99		
MashEast	Manicaland	No	No	1.03		
MatSouth	Midlands	No	No	-0.20		
MatSouth	Midlands	No	No	-0.16		
MatSouth	Harare	No	No	-0.21		
MatSouth	Masvingo	No	No	-0.17		
MatSouth	Bulawayo	No	No	-0.25		
MatSouth	Manicaland	No	No	-0.21		
Midlands	Harare	No	No	0.95		
Midlands	Harare	No	No	0.90		
Harare	Masvingo	No	No	1.06		
Harare	Manicaland	No	No	1.01		

Maize Meal

Location		Long-run Relationship			Adjustment	
Market1	**Market2**	**Engle Granger**	**Johansen**	**Long-term Elasticity**	**Combined Adjustment**	**Average Halflife**
Cointegrated						
Bulawayo	Harare	No	Yes	0.76	1.67	0.39
Bulawayo	Manicaland	No	Yes	0.89	0.71	1.78
Bulawayo	MashEast	No	Yes	0.88	0.62	1.39
Bulawayo	MashWest	No	Yes	0.79	0.77	1.43
Bulawayo	MatSouth	No	Yes	0.78	0.92	1.26
Harare	Manicaland	Yes	Yes	0.82	0.54	0.97
Harare	MashWest	No	Yes	1.01	0.54	1.12
Harare	Midlands	Yes	Yes	0.94	0.19	5.70
Manicaland	MashWest	No	Yes	0.88	0.45	1.46
Manicaland	Masvingo	No	Yes	1.15	0.66	1.98
Manicaland	MatNorth	No	Yes	1.15	0.49	1.85
Manicaland	MatSouth	No	Yes	1.02	0.87	1.63
MashCentral	MashEast	No	Yes	1.01	1.07	
MashCentral	MashWest	No	Yes	1.06	0.59	1.38

MashCentral	Masvingo	No	Yes	1.28	0.55	0.98
MashCentral	MatNorth	No	Yes	1.22	0.12	6.04
MashCentral	Midlands	No	Yes	1.15	1.29	
MashEast	MatNorth	No	Yes	0.98	0.48	1.85
MashEast	MatSouth	No	Yes	0.88	0.90	1.40
MashEast	Midlands	No	Yes	0.87	1.33	0.83
MashWest	MatNorth	No	Yes	0.92	0.85	0.76
MashWest	MatSouth	No	Yes	1.10	0.83	1.36
MashWest	Midlands	No	Yes	1.04	0.25	3.18
Masvingo	MatNorth	No	Yes	0.99	0.37	2.31
MatNorth	MatSouth	No	Yes	0.87	1.80	
Manicaland	MashCentral	Yes	No	1.09	0.72	0.61
Manicaland	Midlands	Yes	No	1.24	1.00	1.23
Not Cointegrated						
Bulawayo	MashCentral	No	No	0.86		
Bulawayo	Masvingo	No	No	0.91		
Bulawayo	MatNorth	No	No	1.08		
Bulawayo	Midlands	No	No	1.05		
Harare	MashCentral	No	No	0.97		
Harare	MashEast	No	No	0.95		
Harare	Masvingo	No	No	1.02		
Harare	MatNorth	No	No	1.22		
Harare	MatSouth	No	No	1.16		
Manicaland	MashEast	No	No	1.01		
MashCentral	MatSouth	No	No	1.16		
MashEast	MashWest	No	No	1.10		
MashEast	Masvingo	No	No	1.19		
MashWest	Masvingo	No	No	1.13		
Masvingo	MatSouth	No	No	1.07		
Masvingo	Midlands	No	No	0.86		
MatNorth	Midlands	No	No	0.83		
MatSouth	Midlands	No	No	0.91		

Cowpeas

Location		Long-run Relationship			Adjustment	
Market 1	Market 2	Engle Granger	Johansen	Long-term Elasticity	Combined Adjustment	Average Half Life
Cointegrated markets						
Midlands	Manicaland	No	Yes	0.87	0.56	1.38
Midlands	MatNorth	No	Yes	0.75	0.51	2.46
MashCentral	Masvingo	No	Yes	1	0.35	3.66
MashCentral	MatNorth	No	Yes	0.86	0.32	1.49
MatNorth	Masvingo	No	Yes	1.17	0.15	2.83
Midlands	Masvingo	No	Yes	0.88	0.06	2.65
Not cointegrated						
MashCentral	Midlands	No	No	1.13		
MashCentral	Manicaland	No	No	1		
MatNorth	Manicaland	No	No	1.16		
Masvingo	Manicaland	No	No	0.96		

Sugar beans

Location		Long-Run Relationship			Adjustment	
Market 1	Market 2	Engle Granger	Johansen	Long-term Elasticity	Combined Adjustment	Average Half life
Cointegrated markets						
Harare	MashWest	No	Yes	1.03	0.68	0.87
MashCentral	Masvingo	No	Yes	0.98	0.52	2.6
MashEast	Masvingo	No	Yes	0.98	0.51	5.09
Harare	Midlands	No	Yes	1.01	0.39	1.62
MashEast	MatNorth	No	Yes	0.94	0.34	4.13
MashCentral	MatNorth	No	Yes	0.94	0.31	2.2
MashCentral	MashWest	No	Yes	1	0.24	5.74
Harare	MatNorth	No	Yes	0.97	0.23	3.06
MashEast	Midlands	No	Yes	0.98	0.22	6.02
Harare	MashEast	No	Yes	1.03	0.11	16.72
Midlands	MatNorth	No	Yes	0.95	0.01	52.02

Not cointegrated						
Harare	MashCentral	No	No	1.02		
Harare	Masvingo	No	No	1		
MashEast	MashCentral	No	No	1		
MashEast	MashWest	No	No	1		
MashWest	Midlands	No	No	0.98		
MashWest	MatNorth	No	No	0.93		
MashWest	Masvingo	No	No	0.97		
Midlands	Masvingo	No	No	0.98		
MatNorth	Masvingo	No	No	1.03		
MashCentral	Midlands	No	No	0.98		

Groundnuts

Location		Long-Run Relationship			Adjustment	
Market 1	Market 2	Engle Granger	Johansen	Long-term Elasticity	Combined Adjustment	Average Half Life
Cointegrated markets						
Harare	MatNorth	No	Yes	0.71	0.67	1.72
Harare	Manicaland	No	Yes	0.82	0.63	1.32
Harare	Harare	No	Yes	0.96	0.51	1.08
MatNorth	Manicaland	No	Yes	1.13	0.44	3.3
Harare	MatNorth	No	Yes	0.74	0.37	3.79
Midlands	Manicaland	No	Yes	1	0.34	2.24
Harare	Midlands	No	Yes	0.82	0.14	5.02
Not cointegrated						
Harare	Midlands	No	No	0.8		
Harare	Manicaland	No	No	0.85		
Midlands	MatNorth	No	No	0.89		

Sorghum

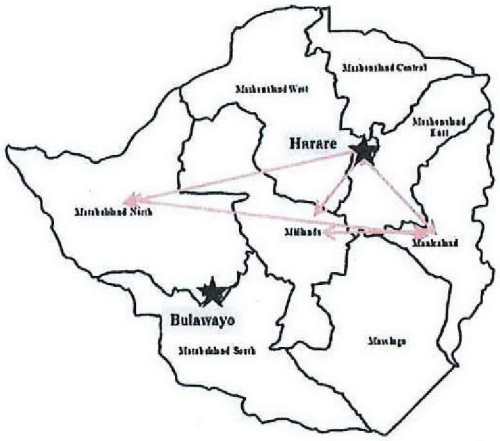
Location		Long-run Relationship			Adjustment	
Market 1	Market 2	Engel Granger	Johansen	Long-term Elasticity	Combined Adjustment	Average Half life
Cointegrated markets						
Masvingo	Manicaland	No	Yes	1.08	0.24	5.68
Not cointegrated						
MashWest	Midlands	No	No	0.9		
MashWest	Masvingo	No	No	0.91		
MashWest	Manicaland	No	No	1.01		
Midlands	Masvingo	No	No	1.02		
Midlands	Manicaland	No	No	1.1		

Zimbabwe maize prices integration with regional and world prices

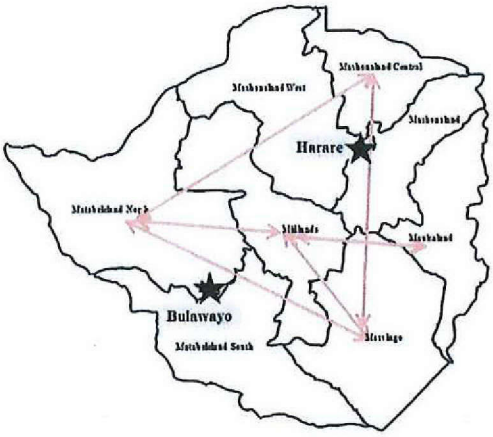
Location		Long-Run Relationship			Adjustment	
Market 1	Market 2	Engle-Granger	Johansen	Long-term Elasticity	Combined Adjustment	Average Half-Life
Cointegrated markets						
South.africa	Zim.grain	No	Yes	-0.47	0.12	12.2
South.africa	Zim.grain.surplus	Yes	No	-0.64	0.23	4.1
World.grain	Zim.grain	No	Yes	1.3	0.02	72.6
Not cointegrated						
World.grain	Zim.grain.surplus	No	No	1.67		
Zimbabwe.grain	Zim.grain.deficit	No	No	1.76		
Zimbabwe.grain	Zim.grain.surplus	No	No	1.3		
Zimbabwe.grain.deficit	Zim.grain.surplus	No	No	0.54		
Zambia	South.africa	No	No	0.09		
Zambia	Zim.grain	No	No	-0.19		
Zambia	Zim.grain.deficit	No	No	-0.33		
Zambia	Zim.grain.surplus	No	No	-0.24		
South.africa	Zim.grain.deficit	No	No	-0.5		

III: Cointegration maps

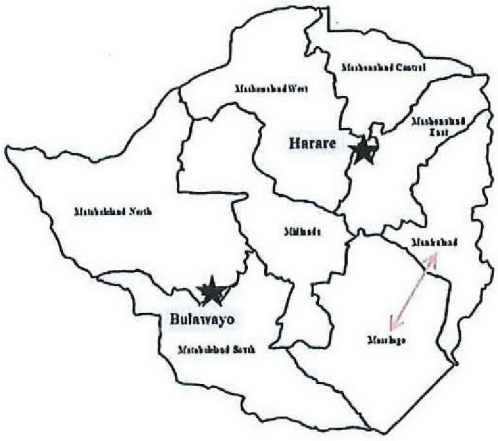
Groundnuts



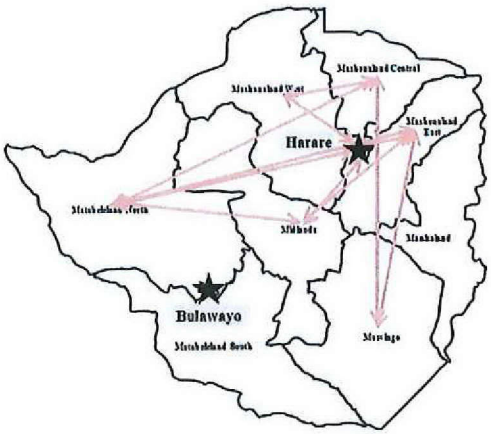
Cowpeas



Sorghum



Sugar Beans



IV: Regression results

	Maize Grain			Maize meal	
	Cointegration	Speed of adjustment		Cointegration	Speed of adjustment
Distance	0.01183*	-0.00049	**Distance**	0.4306	-0.00798
	(-2.362)	(-1.429)		(0.5587)	(-0.167)
Population	-2.025	-0.04438	**Population**	-3.2429	-0.42239
	(-0.335)	(-0.088)		(-0.7556)	(-0.1.577)
Production	-1.96813	-0.14258	**Production**	-2.5827	-0.25359
	(-0.755)	(-0.719)		(-0.6267	(-1.069)
Constant	23.2501***	0.81198***	**Constant**	20.9293***	0.9582***
	(9.933)	(5.560)		(6.1070)	(4.391)
R Square	0.1518	0.2261	**R Square**		0.1304
Adjusted R Square	0.1009	0.06021	**Adjusted R Square**		0.03381
F-stat	2.982	1.363	**F-sts**		1.35

V: Surplus/ deficit regions (2008/09 to 2013/14 average)

Province	Maize Production (MT)	Requirement	Balance	Surplus/ Deficit
Mashonaland West	260,661.20	164,962.00	95,699.20	Surplus
Mashonaland Central	219,499.00	128,674.00	90,825.00	Surplus
Midlands	204,144.40	182,060.00	22,084.40	Surplus
Mashonaland East	155,736.20	151,522.00	4,214.20	Surplus
Matabeleland North	63,981.40	82,646.00	(18,664.60)	Deficit
Matabeleland South	51,960.40	76,111.00	(24,150.60)	Deficit
Manicaland	152,439.40	197,321.00	(44,881.60)	Deficit
Masvingo	88,717.20	167,475.00	(78,757.80)	Deficit

VI: Trader/ buyer registration fees

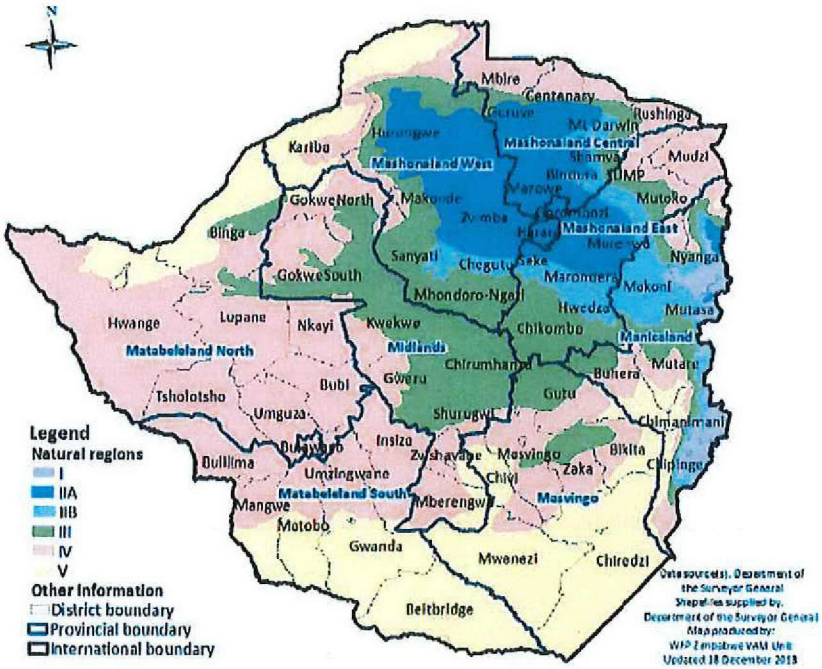
Agricultural Marketing Authority (Grain, Oilseed and Products) By-laws, 2013

SECOND SCHEDULE (*Section 6*)

FEES

Form No.	*Form description*	Fee US$
AMAG 1	Application for registration as Grain Industry Stakeholder Association	500,00
	On late registration	500,00
AMAG 2	Application for registration as a contractor or processor	1000,00
	On late registration	2000,00
AMAG 3	Application for registration as a buyer, broker or trader	1000,00
	On late registration	2000,00
AMAG 4	Application for registration as a grower	1,00
	On late registration	2,00
AMAG 5	Application for service hammer miller	2,00
	On late registration	5,00

VII: Natural regions of Zimbabwe[25]



Region I: Receives more than 1 000 mm per annum of generally well distributed rains and temperatures are relatively low. The region is suitable for dairy farming, forestry, tea, coffee, fruit, beef and maize production.

Region IIA: Rainfall confined to summer and is moderately high, ranging from 700-1050 mm per annum. Suitable for intensive farming, such as maize, tobacco, cotton and livestock.

Region IIB: Rainfall confined to summer and is moderately high, ranging from 700-1050 mm per annum. However, the region experiences short rainy seasons with severe dry spells during the rainy season. Suitable for intensive farming based on maize, tobacco, cotton and livestock.

Region III: Rainfall is moderate, ranging from 500 – 800 mm per annum. In addition, the region experiences are relatively high temperatures and infrequent heavy rainfalls. Subject to seasonal droughts and severe mid-season dry spells. This region is a semi-intensive farming region suitable for livestock production, fodder crops and cash crops under good farming management.

Region IV: The region experiences fairly low rainfall in the ranges of 450 – 650 mm per annum. Seasonal droughts severe dry spells during the rainy season are frequent in this region. Suitable for semi - extensive farming systems based on livestock, resistant fodder crops, forestry, wildlife and tourism.

Region V: Receive low and highly erratic rainfall below 450 mm per annum. The topography and soils of the region are poor. The region is suitable for extensive cattle ranching, forestry, wildlife and tourism. Zambezi Valley was infested with tsetse fly, which is largely eradicated.

[25] Source: WFP. Zimbabwe: Results of exploratory food and nutrition security analysis. October 2014.