Journal of Agricultural Economics, Vol. 59, No. 2, 2008, 257–270
doi: 10.1111/j.1477-9552.2007.00146.x

Impacts of Market Reform on Spatial Volatility of Maize Prices in Tanzania

Fredy T. M. Kilima, Chanjin Chung, Phil Kenkel and Emanuel R. Mbiha[1]

(Original submitted February 2007, revision received September 2007, accepted October 2007.)

Abstract

Maize is one of the major staples and cash crops for many Tanzanians. Excessive volatility of maize prices destabilises farm income in maize-growing regions and is likely to jeopardise nutrition and investment in many poor rural communities. This study investigates whether market reform policies in Tanzania have increased the volatility of maize prices, and identifies regional characteristics that can be attributed to the spatial price volatility. To achieve the objectives, an autoregressive conditional heteroskedasticity in mean (ARCH-M) model is developed and estimated in this study. Results show that the reforms have increased farm-gate prices and overall price volatility. Maize prices are lower in surplus and less developed regions than those in deficit and developed regions. Results also show that the developed and maize-deficit regions, and regions bordering other countries have experienced less volatile prices than less developed, maize-surplus and non-bordering regions. Our findings indicate that investments in communication and transportation infrastructures from government and donor countries are likely to increase inter-regional and international trade, thereby reducing the spatial price volatility in Tanzanian maize prices in the long run.

Keywords: *maize; price volatility; market reform.*

JEL classifications: *C33, D40, O12, O55.*

1. Introduction

In the 1980s, the Tanzanian economy experienced economic hardships and fiscal deficits that resulted from poor performance of the state-controlled market system

[1] Fredy T. M. Kilima and Emanuel R. Mbiha are lecturer and senior lecturer at Sokoine University of Agriculture in Tanzania, respectively. Chanjin Chung and Phil Kenkel are associate professor and professor, respectively, at the Department of Agricultural Economics, Oklahoma State University, 322 Agricultural Hall, Stillwater, OK 74078-6026, USA. E-mail: chanjin.chung@okstate.edu for correspondence. This research was supported by the Oklahoma State University Agricultural Experiment Station. The authors thank the editor, David Harvey, and two anonymous reviewers for many constructive comments.

and subsidised production and consumption. The state-controlled markets limited the role of private traders by restricting their trade volumes and procurement rights at the farm level. Government-owned institutions such as cooperatives and national milling companies were given complete access to the maize procurement market, whereas private traders were allowed to buy only a limited amount of maize each year. Along with imposing the restrictions on maize procurement, minimum prices were also instituted at different stages of the marketing chain (Suzuki and Bernard, 1987; World Bank, 1994). These interventions were intended to ensure self-sufficiency of food at the controlled price level by the government. However, such interventions led to low agricultural prices and production, which later required major market reforms and external assistance.

In 1987, Tanzania adopted reform programmes prescribed by the International Monetary Fund and the World Bank to restore macroeconomic balance and efficiency to the economy. The reform programmes raised the limit on private grain movement from 30 to 500 kg, and private grain traders were allowed to buy maize from cooperative unions. However, private traders were still not allowed to trade Tanzanian maize with foreign countries. A comprehensive reform was achieved in 1991 when all restrictions on maize procurement were lifted (Coulter and Golob, 1992).[2] The thrust behind this reform was to enhance efficiency in price formation to stimulate output growth and technological innovation (Barrett, 1997).

However, views in the literature are mixed on the impact of market reforms on agricultural prices in developing countries. Newbery and Stiglitz (1985) claim that greater price volatility may be found under perfect information than in a world of no information due to arbitrageurs. In other words, reform leading to more competitive commodity markets may cause greater price volatility after reform. The standard firm theory suggests that production increases with price while decreasing with its variance. Therefore, contrary to the purpose of market reform, reform could actually dampen domestic food production and lower prices. However, Tyers and Anderson (1992) find that countries under state-controlled commodity policies often have high price volatilities and tend to have more stability after reform.

Some studies actually point out that market reform could have ambiguous effects on commodity price volatilities (for example, Speece, 1989; Barrett, 1997; Winters, 2002). The studies state that while reform could directly foster competition and spatial market integration, it could also indirectly restrain competition and market integration. After the termination of pan-territorial pricing, the private sector could be too weak to provide sufficient information to form an equilibrium market price, and the government may have to reduce its investment in rural infrastructure due to decreased government revenue, thereby limiting market competition and integration. Without sufficient market competition and integration, price signals will not be transmitted efficiently, prices will be more volatile due to imperfect competition, agricultural producers will fail to specialise according to long-term comparative advantage, and trade gains will not be efficiently realised and distributed (Baulch, 1997; Abdulai, 2000).

[2] Liisa and Biström (2001) also indicate that the structural adjustment, which commenced in the middle of the 1980s was a gradual process to liberalise grain markets in Tanzania and was completed in the early 1990s. On the other hand, Skarstein (2005) indicates that official procurement prices existed up to 1990 when price deregulation occurred.

Simulation models for small open economies suggest that trade liberalisation can provide domestic price stability more efficiently than locally designed policies such as maintaining buffer stock (Bigman and Reutlinger, 1979). However, the impact of international price on domestic price stability has generally been difficult to resolve analytically. The impact might be minimal when trade margins are eroded by high transportation, port and handling charges, or when other trade taxes/subsidies are imposed. Winters *et al.* (2004) indicate that transfer costs are higher in LDCs than in developed countries, and these costs often attenuate border shocks as they pass through to households for importable goods and exacerbate the shocks for exportable goods. Moreover, the shocks can even get lost completely if domestic competition is not keen and the government is uncertain about market conditions after liberalisation and is willing to maintain some level of market control.

Goodhue *et al.* (1998) indicate that when market liberalisation is accompanied by uncertainty over market conditions, a more vigorous liberalisation may increase the short-run price, production volatility and the time it takes for this volatility to decay. According to Poulton *et al.* (2006), this volatility can affect poor consumers and net-deficit producers (about 55% of rural population in Africa) and net-deficit sellers (about 15%) and surplus producers (about 30%). For the poor consumers who devote a larger share of their income (often more than 50%) to purchase food items, their purchasing power may decrease significantly if prices rise sharply. Also high price volatility may force net-deficit producers to continue with staple food production, thus discouraging investment in high-value crops. High price volatility can also affect net-deficit sellers who are often forced to sell crops soon after harvesting (when prices are low) to meet cash demands even if the harvested and stored foods fall short of household's food demand. For surplus producers, who are also important sources of food for domestic and foreign markets, the volatility can force them to seek income diversification thereby sacrificing potential gains of specialisation in favour of spreading risks over multiple enterprises (Skarstein, 2005; Poulton *et al.*, 2006).

In summary, farmers' response to price changes is, to a greater extent, an outcome of factors influencing the transmission of price signals. Such factors include structure of distribution sector, cost and constraints of marketing, quality of infrastructure and resource endowment. Thus, market reforms may result in different implications on product prices and volatility by country, region and commodity (Speece, 1989; Barrett, 1997; Winters, 2002; Isinika *et al.*, 2005).

In Tanzania, a growing concern is whether reforms have exacerbated the degree of maize-price volatility. Maize is one of the major staples and cash crops for many Tanzanians. Excessive volatility of maize prices may be detrimental particularly to growers in remote areas where producers tend to sell some of their food reserves to meet cash demands even when the price is very low. This tendency has often jeopardised nutrition and investment in rural communities of developing countries (Feldman, 1989).[3]

[3] Lack of transportation systems and storage capacities has been a problem in rural Tanzania. This constraint discourages most traders from buying crop products from remote areas. Therefore, these remote areas are generally less competitive and tend to be buyers' markets.

Many maize marketing studies show that spatial volatility has become apparent in Tanzania after market reforms. Santorum and Tibaijuka (1992) and Kähkönen and Leathers (1999) found that substantial temporal and spatial differences are found in the volatility of maize prices after market reforms. Oya (2004) claims that reforms increased price spreads and volatilities in all countries of sub-Saharan Africa and particularly hurt small producers located in remote regions, forcing them to sell their crops at give-away prices in the form of 'distressed sales'. Overall, these studies conclude that the reforms have adversely affected these regions due to the increased price volatility.[4] Nevertheless, the conclusions are mostly based on qualitative analysis with limited price data. More comprehensive quantitative analysis should be conducted to better understand the impact of market reforms on the spatial volatility of commodity prices.

In this study, we examine whether the market reforms in Tanzania have increased the volatility of maize prices and identify region-specific factors that can be attributed to the spatial price volatility. To identify these factors, we test whether the price volatility differs across regions because of differences in economic development, maize production and border trading. An autoregressive conditional heteroskedasticity in mean (ARCH-M) model is estimated to achieve the objectives.

Our results show that market reform policies have increased the volatility of maize prices in Tanzania, and regional differences in trade networks, economic development and maize production have significantly contributed to the increased price volatility. The results suggest that infrastructure development to foster market integration and to increase trade volume between regions could reduce the observed price volatility in the long run.

2. Model

Drawing on Engle *et al*. (1987) and Barrett (1997), mean and variance equations of maize prices are specified as functions of various economic, regional and seasonal variables with the ARCH term in the variance equation.[5] The choice of this specification is motivated by the following two reasons. First, a theoretical

[4] High price volatility after market reforms could be attributed to other factors such as continued state intervention (for example, regulations on imports and exports to achieve either private rent seeking or political desires) or market failures (for example, traders' limited access to credit markets and poor market information on crop production and price changes). However, vigorous liberalisation might not be the appropriate means to promote market competition in a predominantly poor and socialistic country. Evidence suggests that the liberalisation process contains several shortcomings (Skarstein, 2005; Poulton *et al*., 2006) that might have contributed to destabilising the agricultural market in Tanzania. Goodhue *et al*. (1998), for example, indicate that privatisation and liberalisation are complementary reforms in transition economies, but when pursued too vigorously, liberalisation may fail to take into account the cost of rapid privatisation in an uncertain environment and can contribute to destabilising markets after liberalisation.

[5] Barrett (1997) examines the temporal price volatility of commodity markets in Madagascar, whereas our study focuses on identifying regional characteristics that can be attributed to the spatial price volatility of Tanzanian maize.

belief exists that many storable commodity prices have an ARCH process because current price volatility transmits itself into future periods by creating volatility in inventory carryover (Beck, 2001). When an ARCH effect is present in price series, market participants can forecast the variance, which affects their inventory-holding decision especially when they are risk averse. Therefore, if a commodity is storable and the production lag is one period, then there can be an ARCH process of order one in price series. Second, unlike standard time-series models, an ARCH in mean (ARCH-M) model allows conditional volatility to directly influence the conditional mean. The model also accounts for the expectation that agents command a larger risk premium (RP) in more turbulent periods.[6]

The conceptual model is specified as:

$$\begin{aligned} Y_{it} &= \alpha_0 + \sum_h \alpha_h X_{hit} + \delta h_{it}^{1/2} + \sum_j \kappa_j D_{ji} + \varepsilon_{it}, \\ \varepsilon_{it}|\psi_{t-1} &\sim \text{i.i.d. } N(0, h_{it}), \\ h_{it} &= \beta_0 + \sum_k \beta_k \varepsilon_{it-k}^2 + \sum_l \gamma_l Z_{it} + \sum_m \eta_m D_{mi}. \end{aligned} \tag{1}$$

Y is a dependent variable generated by an autoregressive process, and X and Z are vectors of exogenous variables. D is a vector of region-specific attributes that account for differences in price volatility across regions. The error term ε is assumed to be independently, identically and normally distributed, conditional on the information set ψ_{t-1} with mean zero and variance h. $\varepsilon_{t-1},\ldots,\varepsilon_{t-k}$ are lagged disturbances where k is the order of the autoregressive process appropriate for the ARCH-M model. α, β, γ, δ, κ and η are parameters of mean and variance equations. The empirical model of equation (1) can be specified as:

[6] Volatility can also be modelled as a conditional variance in the General Autoregressive Conditional Heteroskedasticity (GARCH) framework. A number of studies have employed this method to analyse price volatility for various commodities (Yang and Brorsen, 1992; Jayne and Myers, 1994; Yang *et al.*, 2001). Nevertheless, well-established empirical evidence suggests that monthly data usually do not have GARCH effects, and whenever these effects are detected, they are usually due to a structural break of unconditional variance (Ballie and Bollerslev, 1990). However, it should be noted that the absence of GARCH effects does not necessarily imply the absence of ARCH effects. An alternative specification is the stochastic volatility (SV) model, which has been used extensively to model volatility in time series data (for example, Friedman and Harris, 1998; Pitt and Shephard, 1999). However, a major problem with the SV model is that its density function has no closed form, and therefore neither does the likelihood function, even for the simplest form. Contemporary approaches suggest that the model can be estimated by approximating likelihood functions. Other specifications such as threshold-ARCH (T-ARCH), which tests whether the observed price variance depends on past prices in a non-linear fashion, have also been used to model volatility. The T-ARCH model assumes that a change in regime is triggered by a price change in excess of a defined threshold value and is estimated through permitting changes in structural parameters of the ARCH process conditional on previous information (Shivley, 2001). However, its use might be relevant when leverage effects are detected in the dataset.

$$\begin{aligned}\ln P_{it} &= \alpha_0 + \alpha_1 \ln P_{it-1} + \alpha_2\, TR_t + \alpha_3 \ln RE_t + \sum_h \pi_h S_{ht} + \sum_j \lambda_j \times RG_{ji} + \varphi\, RF_t \\ &\quad + \kappa_1\, BORDER_i + \kappa_2\, DEV_i + \kappa_3\, SURP_i + \delta h_{it}^{1/2} + \varepsilon_{it} \\ h_{it} &= \beta_0 + \beta_1 \varepsilon_{it-1}^2 + \gamma_1 \ln P_{it-1} + \gamma_2\, TR_t + \gamma_3 \ln RE_t + \sum_h \xi_h S_{ht} + \phi RF_t \\ &\quad + \eta_1\, BORDER_i + \eta_2\, DEV_i + \eta_3\, SURP_i\end{aligned} \tag{2}$$

where P_{it} and P_{it-1} are real maize prices (deflated by Consumer Price Index) in region i in months t and t−1, respectively.[7] TR, RE, S and RG represent monthly trends, real exchange rates (calculated as the ratio of the Tanzanian shilling to the US dollar and deflated by Consumer Price Index), seasonal dummy variables and regional dummy variables, respectively. ε is a conventional error specified in equation (1), whereas 'ln' stands for the natural logarithm. RF is a dummy variable representing market reform: one for the liberalised period and zero for the preliberalised period. $BORDER$ is a dummy variable for informal cross-border maize trade: one for bordering regions and zero otherwise. DEV is a dummy variable representing the extent of regional economic development: one for regions that are either classified as cities or municipals and zero otherwise. $SURP$ is a dummy variable with one for maize-surplus regions and zero for maize-deficit regions.

The model is estimated in a system framework (with mean and variance equations) using the autoregressive procedure using SAS (SAS Institute Inc., Cary, NC 27513, USA). Thus, coefficients in model (2) are interpreted as deviations in region and time-specific prices from a regional or national mean price over the entire data period. Prior to the estimation, the maize price, the dependent variable, was tested for stationarity. The Augmented Dickey–Fuller (ADF) test for each of seven regions provided test statistics well below the ADF critical values, which leads us to reject the null hypothesis of non-stationarity at the 5% significance level. We also test for panel unit root following Im *et al.* (2003). The ADF test for panel unit root is specified as:

$$\Delta \ln P_{it} = a_i + b_i \ln P_{it-1} + c_i\; trend_{it} + \sum_j d_{ij} \Delta \ln P_{it-j} + v_{it}. \tag{3}$$

The Akaike Information and Shwarz Bayesian criteria are used to select lags appropriate for each series. Series-specific t-statistics for the null hypothesis $b_i = 0$ are calculated, and its sample mean is compared with critical values from the statistical table developed by Im *et al.* (2003). The panel unit root test also rejects the null hypothesis of non-stationarity at the 5% level.[8] We also test for interaction effects between the reform dummy variable and other explanatory

[7] The national level Consumer Price Index (CPI) is used to convert nominal prices to real prices. Regional CPIs should be more appropriate to account for the regional differences in economy. However, such data are not available in Tanzania.

[8] The sample mean of t-specific statistics is −1.58 and critical values from the Im, Pesaran and Shin (2003) panel unit root test are −2.38, −2.44 and −2.54 at 10%, 5% and 1% levels, respectively. Therefore, we fail to reject that $b_{\mathrm{i}} = 0$ from equation (3), which implies the panel is stationary.

variables specified in equation (2) following Allison (1977) specifications. The test is specified as:

$$\ln P_{it} = \theta_0 + \theta_1 \ln P_{it-1} + \cdots + \rho\ RF_t + \sum_{k=1}^{p} \tau_k\ Z_{ki} + \mu_{it}, \tag{4}$$

where Z_{ki} is the kth interaction term between RF and ith independent variable. A joint test for the null hypothesis $\tau_1 = \cdots = \tau_p = 0$ is performed and the test fails to reject the null hypothesis of no interaction effects at the 5% level.

The order of the ARCH model is determined through an assessment of the statistical significance generated from the Lagrange multiplier test. Results suggest that an autoregressive order of one is appropriate for the data. Misspecification of the variance equation could lead to inconsistent estimates of parameters in the mean equation. Thus, attempts are made to model for alternative functional forms such as exponential and square root. However, we find that results are not sensitive to the functional forms. The leverage effects are analysed by testing whether the lagged values of standardised residuals influenced the standardised variance.[9] Results indicate that the standardised variance is uncorrelated with the level of standardised residual, suggesting that there are no leverage effects.

In equation (2), the coefficient φ tests whether the mean prices before and after the reform are different, whereas the coefficient ϕ tests whether the price volatility has changed after the reform. The coefficients η_1–η_3 test whether price volatility is attributable to regional differences in trade, economic development and maize production, respectively. The coefficients κ_1–κ_3 test whether differences in wholesale prices are attributable to spatial differences in trade, economic development and maize production, respectively. Regional dummy variables are omitted in the variance equation because regional effects are captured by dummy variables such as *BORDER*, *DEV* and *SURP*.

3. Data

Price series used in this study are monthly wholesale prices from seven regions, Arusha, Dodoma, Iringa, Morogoro, Mbeya, Ruvuma and Sindida for years 1983–1998. The data were collected from the Ministry of Agriculture and Cooperatives Development in Tanzania. Maize prices for each region are measured in Tanzanian shillings per kilogram (Tshs/kg) and are deflated by the Tanzanian food CPI.

Location and road networks of each region are shown in Appendix 1. Arusha is a city. Dodoma, Iringa, Morogoro and Mbeya are municipals.[10] Regions bordering with foreign countries include Arusha, Iringa, Mbeya and Ruvuma.[11] The biggest consumer market in Tanzania is Dar es Salaam city, followed by the other cities

---

[9] The leverage effect is the tendency for downward price changes to be followed by higher volatility than upward price movements of the same magnitude.

[10] A city is relatively more populated and developed than a municipal or town. A town is the least populated and developed living area in Tanzania.

[11] Despite the fact that Iringa and Ruvuma regions share borders with foreign countries, there are no direct infrastructural links to facilitate cross-border trade.

and municipals. Among the regions included in the analysis, Iringa, Dodoma, Morogoro and Mbeya are well connected to Dar es Salaam. Although Arusha and Mbeya are far from the major consumer market, Dar es Salaam, both regions have access to cross-border trade opportunities with Kenya and Zambia, respectively. Ruvuma is linked to Dar es Salaam *via* Iringa.

The estimation proceeds through pooling regional prices into a panel data structure that permits an estimation of the aggregate effects of market reforms on price volatility and tests whether the volatility is attributable to the specified regional factors in the variance equation.

4. Results and implications

4.1. Mean and variance of price series

Estimated results are summarised in Table 1. Results from the mean equation indicate that maize prices have increased after reform, and the coefficient of the reform variable is statistically significant at the 10% level. Results from the regional dummy variables suggest that the prices in Mbeya and Ruvuma are lower than those in other regions (Arusha, Dodoma, Iringa, Morogoro and Singida) with the statistical significance at the 5% level. The results also show that prices are lower in less developed and maize-surplus regions with statistical significance at the 5% and 10% levels, respectively. Coefficients of seasonal dummy variables show that maize prices are the lowest in the harvest season from July to October and the highest between February and March.[12]

Estimates from the variance equation show that the price volatility has also increased after market reform, and the increase is statistically significant at the 5% level. The short-term trend of price volatility is represented by γ_2 and the short-term difference in price volatility before and after reform is represented by ϕ in the variance equation. The corresponding long-term effects can be estimated by

$$\frac{\gamma_2}{1-(\gamma_1/p_{it-1})}$$

and

$$\frac{\phi}{1-(\gamma_1/p_{it-1})},$$

respectively. Parameter estimates indicate that both short- and long-term price volatilities have been increasing, and that reform policies have contributed to the increase in price volatility. Overall, these results are consistent with findings

[12] Crop production cycles in Tanzania vary across regions. For example, some regions such as Morogoro have two production cycles with two rainy seasons. The short rainy season (*vuli*) is between September and October, whereas the long rainy season (*masika*) is between early March and late June. The harvest period for *vuli* crops is from November to January, whereas the harvest period for *masika* crops is in July and August. The production of *vuli* crops is normally very small compared with that of the *masika* crops. However, regions such as Iringa and Ruvuma have only one production cycle with one rainy season between late November and early May. The harvest period in these regions is normally between July and October.

from many previous studies in the literature (such as Newbery and Stiglitz, 1985; Santorum and Tibaijuka, 1992; Barrett, 1997; Kähkönen and Leathers, 1999; Oya, 2004).

4.2. Risk premia (RP)

The risk term δ can be interpreted as a portion of the observed price attributable to a RP. The short-term RP is a necessary gain demanded by an existing agribusiness for assuming price risk and is calculated as:

$$\mathrm{RP} = \delta \frac{h_t^{1/2}}{P_t}. \tag{5}$$

The long-term RP can also be calculated by dividing equation (5) by $(1 - \alpha_1)$.

Values of short-term and long-term risk premia are estimated as −0.08 and −4.10, respectively. Barrett (1997) also found negative risk premia for staple foods (such as rice and manioc) and states that a negative RP in staple food pricing could be interpreted as the consumers' dedication to maintaining diet and food preparation habits around staple foods. Domiwitz and Hakkio (1985) argue that risk-averse investors normally demand greater compensation than the average uncertainty. Therefore, a negative RP may signify that price risk widens the marketing cost wedge between wholesale and retail maize prices. When price risk creates higher costs for traders, it

Table 1

ARCH-M estimate (dependent variables: mean = $\ln P_{it}$; variance = h_{it})

Variable	Mean equation	Variance equation
Constant	0.50 (5.70)	
$\ln P_{t-1}$	0.98 (0.01)**	0.00 (0.00)
TR	0.00 (0.00)	0.00 (0.00)
ln *RE*	−0.00 (0.02)	0.00 (0.00)
RF	0.09 (0.03)**	0.03 (0.00)**
$h^{1/2}$	−0.21 (0.06)**	
β_1, ARCH(1) term		0.76 (0.06)**
Regional dummies		
Arusha	0.40 (5.70)	
Iringa	−0.00 (0.02)	
Mbeya	−0.35 (0.06)**	
Ruvuma	−0.06 (0.03)**	
Seasonal dummies		
February–March	0.11 (0.02)**	0.00 (0.00)
April–June	−0.02 (0.01)	0.00 (0.00)
July–October	−0.06 (0.01)**	0.01 (0.00)**
BORDER	0.39 (5.70)	−0.01 (0.00)**
DEV	0.07 (0.02)**	−0.03 (0.00)**
SURP	−0.04 (0.02)*	0.00 (0.00)**
N	1330	
r^2	0.9154	

Notes: Values in parentheses are asymptotic standard errors. ** and * denote significance at 5% and 10% levels, respectively.

might cause upward pressure on retail prices and lower wholesale and producer prices.

In Tanzania, high marketing costs might be attributed to many factors including the following. The maize business relies on cash transactions in the spot market. The cash transactions reduce the volume of maize trade because of cash constraints and potential risk of theft. Traders purchasing maize from remote areas are also subject to risks associated with less certain supply, insecure procurement and long distance transportation. Smallholder farmers tend to sell small quantities of maize. Therefore, traders must be willing to tie up working capital for at least one week while searching for desired quantities of maize. In addition, the traders must be able and willing to sell the procured maize in distant markets because local demand might turn out to be lower than expected (Santorum and Tibaijuka, 1992; Kähkönen and Leathers, 1999).

4.3. *Spatial volatility of maize price*

Spatial price volatility across regions is analysed through regrouping the panel data based on differences in cross-border trade linkages (*BORDER*), economic development (*DEV*) and maize production (*SURP*).

Results indicate that coefficients of *DEV*, *BORDER* and *SURP* are statistically significant at the 5% level. The coefficient of *DEV* is positive, which indicates developed regions, such as cities and municipals, tend to show lower price volatility than towns. Previous studies also indicate that price volatility tends to be lower in developed markets (such as Santorum and Tibaijuka, 1992). The positive parameter estimate of *BORDER* indicates that prices in regions with access to the informal cross-border trade are less volatile than other regions. The informal maize trade in Tanzania has been substantial in regions bordering other countries. In the 1995/1996 farming year, Tanzania exported a total of 18,686 tons of maize and imported 284 tons through informal cross-border trading (Ackello-Ogutu, 1998). For the entire period of 1983–1998, the export ban was still effective on Tanzanian maize for food security purposes even after agricultural markets were liberalised in 1991. The finding suggests that the trade effect could have had more impact on maize price and its volatility in some regions if there was no export ban. Similarly, the coefficient of *SURP* suggests that prices in maize-surplus regions are more volatile than prices in maize-deficit regions.[13]

The findings of this study have important policy implications, which policy-makers can explore to mitigate spatial volatility of the maize prices in Tanzania. Based on our empirical results, it seems logical to invest in infrastructure to promote trade linkages between Iringa and Dodoma, Dodoma and Singida and Singida and

[13] The coefficients of *BORDER*, *DEV* and *SURP* from the variance equation in Table 1 should be interpreted as the difference in price volatility that can be attributed to the specific regional characteristic while controlling for effects of other regional characteristics. Notice that all three of the regional characteristics are assigned to each of seven regions. Therefore, countervailing effects should be found among regional characteristics of each region. For example, Morogoro is categorised as a developed and maize-deficit region without access to cross-border trade. The increasing effects of price volatility from regional characteristics, such as developed economy, no-border-trade opportunity, could have been offset, or even overtaken, by the decreasing effects from the maize-deficit characteristic.

Arusha. The linkages would contribute to increasing trade volume among the regions. The resulting trade effects might be transmitted further to neighbouring regions, hence stabilising maize prices in those regions.

5. Summary and Concluding Remarks

The objective of this study was to investigate whether the market reforms have increased the volatility of maize price in Tanzania and to identify regional characteristics that can be attributed to the spatial price volatility. To achieve the objectives, an ARCH-M model has been developed and estimated in this study.

Mean and variance equations of maize price are specified as functions of various economic, regional and seasonal variables with an ARCH(1) term in the variance equation. Our study finds that the market reform policy increased both mean and volatility of maize prices in Tanzania. Estimated risk premia indicate that equilibrium maize prices are not adequate to compensate suppliers for bearing the risk. Our study also finds that Tanzanian maize prices were the lowest during the harvest season from July to October and the highest between February and March. Prices were also lower in maize-surplus and less developed regions than in maize-deficit and developed regions. Regional characteristics, such as the extent of economic development, cross-border trade and maize production, are important factors in determining spatial price volatility. More developed and maize-deficit regions, and regions bordering other countries, show less volatile prices than less developed, maize-surplus and non-bordering regions.

The findings suggest an important policy implication in mitigating spatial volatility of maize prices in Tanzania. The government could expand its investment in infrastructure development to link the regions, thereby offsetting price swings from too much surplus or scarcity.

The relevance of the maize export ban in Tanzania has been hotly debated. Some researchers have suggested that removing restrictions on the external trade of maize would help Tanzanian producers gain from the trade with other countries that face shortages and would boost the domestic production of maize. Others have argued that lifting the export ban would mainly help producers along the border of the country, but would hurt consumers in urban and maize-deficit regions through the increased price. Policy-makers tend to believe that the cost to urban consumers exceeds the benefit to rural producers. However, the World Bank (1994) finds that an adverse relationship exists between good and bad production years in Tanzania and those in the southern African countries. Therefore, integrating regional markets *via* cross-border maize trade could reduce transaction costs (such as harassment and demand for bribes) of the continuing informal trade and produce net foreign exchange gain for participating regions.

References

Abdulai, A. 'Spatial price transmission and symmetry in the Ghanaian maize market', *Journal of Development Economics*, Vol. 63, (2000) pp. 327–349.

Ackello-Ogutu, C. Unrecorded cross-border trade between Tanzania and her neighbors: Implications for food policy, *SD Publication Series, Technical Paper No. 89* (Washington, DC: Office of Sustainable Development, Bureau for Africa, 1998).

Allison, P. D. 'Testing for interaction in multiple regression', *The American Journal of Sociology*, Vol. 83, (1977) pp. 144–153.

Ballie, R. T. and Bollerslev, T. 'A multivariate generalized ARCH approach to modeling risk premia in forward foreign exchange markets', *Journal of International Money and Finance*, Vol. 9, (1990) pp. 309–324.

Barrett, C. B. 'Liberalization and food price distributions: ARCH-M evidence from Madagascar', *Food Policy*, Vol. 22, (1997) pp. 155–173.

Baulch, B. 'Transfer costs, spatial arbitrage, and testing for food market integration', *American Journal of Agricultural Economics*, Vol. 79, (1997) pp. 477–487.

Beck, S. 'Autoregressive conditional heteroskedasticity in commodity spot prices', *Journal of Applied Econometrics*, Vol. 16, (2001) pp. 115–132.

Bigman, D. and Reutlinger, S. 'Food price stabilization: National buffer strocks and trade policies', *American Journal of Agricultural Economics*, Vol. 61, (1979) pp. 657–667.

Coulter, J. and Golob, P. 'Cereal marketing liberalization in Tanzania', *Food Policy*, Vol. 17, (1992) pp. 420–430.

Domiwitz, I. and Hakkio, C. S. 'Conditional variance and the risk premium in foreign exchange market', *Journal of International Economics*, Vol. 19, (1985) pp. 47–66.

Engle, R. F., Lilien, D. M. and Robins, R. P. 'Estimating time varying risk premia in the term structure: The ARCH-M model', *Econometrica*, Vol. 55, (1987) pp. 391–407.

Feldman, M. *Women for Change: The Impact of Structural Adjustment on Women in Zambia, Tanzania, and Mozambique* (London: War on Want, 1989).

Friedman, M. and Harris, L. 'A maximum likelihood approach for non-Gaussian stochastic volatility models', *Journal of Business and Economic Statistics*, Vol. 16, (1998) pp. 284–291.

Goodhue, R. E., Rausser, C. G. and Simon, L. K. 'Privatization, market liberalization and learning in transitional economies', *American Journal of Agricultural Economics*, Vol. 80, (1998) pp. 724–737.

Im, K. S., Pesaran, H. M. and Shin, Y. 'Testing unit root in heterogeneous panels', *Journal of Econometrics*, Vol. 115, (2003) pp. 53–74.

Isinika, A. C., Ashimogo, G. C. and Mlangwa, E. D. 'From Ujamaa to structural adjustment – agricultural intensification in Tanzania', in *African Food Crisis Lessons from Asian Green Revolutions* (UK: CABI Publishing, 2005, pp. 197–217) Djuffeldt, G., Holmén, H., Jirström, M. and Larsson, R. (eds.)

Jayne, T. S. and Myers, R. J. 'The effect of risk on price levels and margins in international wheat market', *Review of Agricultural Economics*, Vol. 16, (1994) pp. 63–73.

Kähkönen, S. and Leathers, H. *Transaction Cost Analysis of Maize and Cotton Marketing in Zambia and Tanzania* (Washington, DC: Agriculture, Natural Resources and Rural Enterprise, Office of Sustainable Development, Bureau for Africa, US Agency for International Development, 1999).

Liisa, M. and Biström, T. *Food Aid and Disincentive Effects in Tanzania, Department of Economics and Management Publications no. 31*, Agricultural Policy, (2001), University of Helsinki.

Newbery, D. M. G. and Stiglitz, J. E. *The Theory of Commodity Price Stabilization: A Study in the Economics of Risk* (New York: Oxford University Press, 1985).

Oya, C. 'Agricultural mal-adjustment in sub-Saharan Africa in the context of macroeconomic reforms', Conference paper on *Agrarian Constraints and Poverty Reduction: Macroeconomic Lessons for Africa*, 17–19 December, Addis Ababa, Ethiopia (2004).

Pitt, M. K. and Shephard, N. 'Filtering via simulation: Auxiliary particle filter', *Journal of the American Statistical Association*, Vol. 94, (1999) pp. 590–599.

Poulton, C., Kydd, J., Wiggins, S. and Dorward, A. 'State intervention for food price stabilization in Africa: Can it work?' *Food Policy*, Vol. 31, (2006) pp. 342–356.

Santorum, A. and Tibaijuka, A. 'Trading responses to food market liberalization in Tanzania', *Food Policy*, Vol. 17, (1992) pp. 431–442.

Shivley, G. E. 'Price thresholds, price volatility, and the private costs of investment in a developing country grain market', *Economic Modeling*, Vol. 18, (2001) pp. 399–414.

Skarstein, R. 'Economic liberalization and smallholder productivity in Tanzania. From promised success to real failure, 1985–1998', *Journal of Agrarian Change*, Vol. 5, (2005) pp. 334–362.

Speece, M. 'Market performance of agricultural commodities in semi-arid south Kordofan, Sudan', *Geoforum*, Vol. 20 (1989), 409–424.

Suzuki, Y. and Bernard, A. *Effects of Panterritorial Pricing Policy for Maize in Tanzania* (Washington, DC: International Food Policy Research Institute, 1987).

Tyers, R. and Anderson, K. *Disarray in World Food Markets: A Quantitative Assessment* (Cambridge: Cambridge, University Press, 1992).

Winters, A. L. 'Trade, trade policy and poverty: What are the links?' *The World Economy*, Vol. 25, (2002) pp. 1339–1367.

Winters, L. A., McCulloch, N. and Mckay, A. 'Trade liberalization and poverty', *Journal of Economic Literature*, Vol. 42, (2004) pp. 72–115.

World Bank *Tanzania: Agriculture*, World Bank country study (Washington, DC: World Bank, 1994).

Yang, S. R. and Brorsen, B. W. 'Nonlinear dynamics of daily cash prices', *American Journal of Agricultural Economics*, Vol. 74, (1992) pp. 706–715.

Yang, J., Haigh, M. S. and Leatham, D. J. 'Agricultural liberalization policy and commodity price volatility: A GARCH application', *Applied Economics Letters*, Vol. 8, (2001) pp. 593–598.

Appendix 1.

Locations and road networks of studied regions in Tanzania.