Maize Trade In Southern Africa: Whence Comparative Advantage?

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Abstract

Differences in storage costs, in particular differences in real interest rates, are a significant determinant of comparative advantage and hence the pattern of production and trade within a set of six major Southern African countries (SA6). Applying a spatial-temporal price equilibrium model of regional maize trade, we confirm the hypothesis that South African comparative advantage is rooted in more developed financial market and storage infrastructure rather than costs of maize production. With a decline in real interest rates, results indicate that Mozambique and Tanzania would export maize to the other SA6. Intra-SA6 maize trade intensifies, with a simultaneous decline in trade with the rest of the world. A stochastic version of the model, that accounts for year-to-year production variability among SA6, produces results similar to the deterministic version.

Key words: international maize trade, southern Africa, storage costs, real interest rates, spatial-temporal price equilibrium.

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1 Introduction

Traditionally, trade models have focused on relative production efficiencies, trade barriers, such as tariffs, and transport costs as major drivers behind the pattern of trade. However, Benirschka and Binkley (1995) show, in the context of the United States, that another factor, storage cost – the opportunity cost of capital proxied by the real rate of interest paid by storing agents plus direct storage costs plus any risk premium – has significant implications for the pattern of commodity trade. As storage costs, most visibly the opportunity cost of capital component, are much higher in the Southern Africa region than in the United States, the implications of storage costs, including differentials in storage costs across countries, are likely to be more profound in Southern Africa than in the United States. This study analyzes the implications of storage costs and storage cost differentials across countries in the Southern Africa region on market prices, trade patterns, and volume of production and consumption.

To accomplish this, a spatial and temporal equilibrium model is constructed in the tradition of Takayama and Judge (1971). The analysis emphasizes changes in trade patterns, including trade with the rest of the world, and changes in welfare following shocks to storage costs in various regions. A deterministic version of the model establishes the fundamental role of storage in determining comparative advantage. More efficient storage scenarios are also combined with lower transportation cost and intra-SA6 tariff free trade scenarios in order to account for simultaneous effects. In addition, a stochastic version of the model examines the relative roles of regional and international markets while accounting for correlations in production volumes across the various productive regions.

This article is structured as follows. The second section identifies the key features of the maize market in Malawi, Mozambique, South Africa, Tanzania, Zambia, and Zimbabwe (henceforth known as SA6 countries). The third section provides a brief literature review. The fourth section defines the spatial-temporal price equilibrium model. Section five presents data and discusses specification issues. Section six develops model simulations and presents results for both the deterministic and the stochastic versions of the model. A final section concludes.

2 Maize Market in SA6 Countries

Maize is an important commodity among SA6 countries representing up to half of total calorie intake in human consumption, and about three quarters of total cereal output. Importance differences in technology employed exist across the SA6 countries. In Malawi, Mozambique, Tanzania, Zambia and Zimbabwe (MMTZZ) maize is mostly grown by smallholder farmers. Smallholders grow from 65% in Zambia to 90% in Malawi, as a share of the total national maize output in each country. In these countries, smallholder farmers use predominantly low productive and labor intensive technologies, local seed varieties, and a limited amount of fertilizers (RATES 2003a-d). Hence, productivity, measured in yields per hectare, is also low, ranging from 0.9 tons/ha in Mozambique to 1.5 tons/ha in Zambia (Pingali 2001).

On the other hand, in South Africa, 89% of total maize output is grown by commercial farmers. These farmers use capital intensive technology, improved seed varieties, and have access to fertilizers and pesticides, contributing to a higher maize productivity of 2.3 tons/ha. South Africa has consistently been the major maize producer among SA6, with a share between 50-60% of the aggregate output.

The aggregate SA6 domestic maize balance for the 2001-02 marketing year was a positive 1.2 million tons (SADC 2002). This result is obtained by subtracting Gross Domestic Requirements (GDR) from the Domestic Availability (DA) – being DA equal to Opening Stocks plus Gross Harvest. GDR includes maize used for human and animal consumption, input for the processing industry, seed and waste. The positive balance is mainly due to the 125% ratio of DA/GDR for South Africa. Mozambique (101%) and Tanzania (99%) are around the self-sufficiency status (Jayne *et al* 1995). Malawi (89%), Zambia (70%) and Zimbabwe (95%) are deficit maize producers, for the period under consideration.

The production/consumption data clearly establish South Africa as both the major producer and the major surplus producer in the region and hence the source country for the vast majority of regional maize trade. Assuming a typical static trade model and competitive conditions, this dominance in maize trade would be rooted in comparative advantage in production. However, the price data tell a different story. For example, in the 2001-02 marketing year, immediate post-harvest maize prices in Malawi, Mozambique, Tanzania, and Zimbabwe were substantially *below* post-harvest prices in South Africa (see Figure 1). Taking post-harvest maize prices as a proxy for costs of production, South African farmers are high cost rather than low cost maize producers.

South African maize achieves a significant price advantage only in the pre-harvest lean season. In MMTZZ, prices increased from two to five fold between the harvest and the lean period. In South Africa, on the other hand, maize prices exhibited an intra-seasonal rise of less than 50% (Figure 1). Viewing intra-seasonal maize price increases as indicative of storage costs, the behavior of prices suggests that South Africa has a substantial comparative advantage in storage over the remainder of SA6. Available trade data indicates that South Africa exports maize primarily in the lean period of the marketing season when market prices in MMTZZ are relatively high.

Year-to-year production variability among different SA6 countries is another important factor determining trade patterns. Output correlations among SA6 countries also play a role. Holding other factors constant, a strong positive output correlation indicates lower possibility of trade between the regions involved, as good crop years would be common among them and vice-versa. Similarly, negative output correlations suggests higher chances for trade development Generally, the presence of significant correlations in production imply that regional trade opportunities are likely to be more restricted (positive correlations) or less restricted (negative correlations) than simple average would predict.

Correlation coefficients in production are derived for the period 1987-2002. In deriving the matrix, it was assumed that de-trended variations in output from one year to the other are mainly due to climate induced changes in yields than in area planted. South Africa, Zambia and Zimbabwe reveal strong positive output correlation (Table 1). If year-to-year changes in maize yields are due mainly to the weather pattern, these countries would have lower possibilities for trade. These results coincide with those found by Jayne *et al* (1995). The current study also includes Malawi, Mozambique and Tanzania. Country pairs Malawi-Zambia (with correlation coefficient of 0.51), Malawi-Mozambique (0.40) and Malawi-Zimbabwe (0.38) may also have reduced chances for consistent trading maize.

3 Literature Review

Spatial equilibrium problems have claimed the attention of economists for a long time (Cournot 1838; Koopmans 1949; Enke 1951). However, it was with the development of linear and non-linear programming techniques that many authors were able to construct models of optimal allocation of resources in space and time (Samuelson 1952; Takayama and Judge 1971). Application of spatial equilibrium models often dealt with issues for international trade in goods and services. An important limitation (among several) to these models involved treatment of ad-valorem tariffs. In the presence of differential ad-valorem tariff rates across countries, non-linear programming (NLP) was not a satisfactory approach. These tariffs render coefficient matrix of the demand and/or supply functions asymmetric and hence violating integrability conditions. To achieve an exact solution, the NLP approach had to be solved through a sequence of iterations, which was inefficient and lacked transparency (Harker 1986; Nagurney *et al* 1996).

Takayama and Uri (1983) showed that the linear complementarity programming formulations were more appropriate than NLP when integrability was lost. Rutherford (1995) formulated a general spatial equilibrium problem as a system of nonlinear equations or variational inequalities. These mixed complementarity problems (MCP) incorporate both equality and inequality relationships. At the same time, Dirkse and Ferris (1995) developed the PATH solver that allows the implementation of a stabilized Newton method for the numerical solution of mixed complementarity problems thus enhancing capacity to conduct spatial/temporal equilibrium analysis.

Arndt *et al* (2001) pointed out that interest rate differentials in spatial/temporal equilibrium models are analogous to ad-valorem tariffs in international trade models. They applied this insight and employed the new MCP solver technology in a spatial/temporal analysis of maize markets in Mozambique. They showed that interest rate differentials between formal and informal sector market participants – due, for example, to the high transactions costs of delivering credit to small borrowers in the rural sector – substantially influenced maize marketing patterns and provided a plausible explanation to the seasonal commodity flow reversals observed in rural zones of many developing countries (Jones 1984; and Timmer 1974).

This study applies an MCP formulation of a spatial-temporal price equilibrium framework with differentiated import tariff rates and interest rates by country to a model of maize trade for the Southern Africa region. The following section presents the model.

4 The Spatial-Temporal Price Equilibrium Model

A Spatial-Temporal Price Equilibrium (STPE) model is used to account for storage, transportation and trade costs on the maize market and intra-SA6 commodity flows. The model simulates the impact on production, consumption, trade patterns and on welfare measures of changes in economic conditions and alternative policies affecting the maize market in Malawi, Mozambique, South Africa, Tanzania, Zambia and Zimbabwe. The current study extends the framework of Arndt *et al* (2001) in which a Mixed Complementarity Problem approach is applied to a case of maize marketing within Mozambique in the presence of differentiated interest rates. The MCP is an efficient and more transparent approach to solve an optimization problem in the presence of ad valorem tariff rates and differentiated interest rates, as is considered here (Takayama and Uri 1983; Rutherford 1995; Langyintuo *et al* 2005).

In this STPE model, with a partial equilibrium approach, it is assumed that producers maximize profits, consumers maximize utility and trade is competitive. It is assumed that agents minimize costs when choosing quantities of maize transported among SA6, and storing maize in each region. In international trade, agents choose exporting and importing quantities that maximize revenue and minimize costs, respectively. Maize is treated as a single and homogenous good.

The simplifying assumption of market competitive behavior in the chosen model does not exclude the possibility of non-competitive behavior in the real world (Varian 1992). However, it is expected that the STPE model generates useful insight in the SA6 maize market. Except for Mozambique (three regions), South Africa (two regions) and Zambia (two regions), each one of the other SA6 countries is taken as a region. Each region under study is considered a separate market from all other regions. The presence of differentiated transaction costs is manifested through differences in storage and transportation costs, and differentiated import tariff rates.

In the model it is assumed that producers and consumers are risk neutral. These agents value their future transactions at the expected value. In addition, they have perfect foresight of maize prices within the entire marketing year. This simplifying assumption allows the model to solve simultaneously all equations for the 12 months.

The non-linear formulation of the optimization problem consists of maximizing the present value of the net quasi-welfare function (1) by finding the optimal quantities for demand ($D_{g,t}$), supply ($S_{g,t}$), shipment among SA6 regions ($X_{g,gp,t}$), storage ($Z_{g,t}$), and imports from and exports to the rest of the world ($M_{g,t}, E_{g,t}$), as follows (Arndt *et al* 2001; Harker 1986):

$$\begin{aligned}\underset{S_{g,t},D_{g,t},X_{g,gp,t},Z_{g,t},M_{g,t},E_{g,t}}{Max.} \sum_{t=1}^{T}\left(\frac{1}{1+r}\right)^{t}&\left(\sum_{g\in G}\int_{0}^{D_{g,t}}\Phi_{g,t}(D)dD-\sum_{g\in G}\int_{0}^{S_{g,t}}\Psi_{g,t}(S)dS\right.\\ &-\sum_{g\in G}\sum_{gp\in G}\int_{0}^{X_{g,gp,t}}TC_{g,gp,t}(X)dX-\sum_{g\in G}\int_{0}^{Z_{g,t}}SC_{g,t}(Z)dZ \\ &\left.-\sum_{g\in G}\int_{0}^{M_{g,t}}PM_{g,t}(M)dM+\sum_{g\in G}\int_{0}^{E_{g,t}}PE_{g,t}(E)dE\right)\end{aligned} \tag{1}$$

s.t.

$$\begin{aligned}&Z_{g,t+1}\le Z_{g,t}-D_{g,t}+S_{g,t}-\sum_{gp\in G}X_{g,gp,t}+\sum_{g\in G}X_{gp,g,t}+M_{g,t}-E_{g,t},\\ &\quad \forall g\ne gp\in G, t\in T,\end{aligned} \tag{2}$$

$$D_{g,t},S_{g,t},X_{g,gp,t},Z_{g,t},M_{g,t},E_{g,t}\ge 0 \qquad \forall g\ne gp\in G, t\in T, \tag{3}$$

$$S_{g,t}=0, \qquad \forall g\in G, and\ t\in T^{NH} \tag{4}$$

$$Z_{g,t}=0, \qquad \forall g\in G, and\ t\in T^{H} \tag{5}$$

$$M_{g,t},E_{g,t}=0, \qquad \forall g\in G^{NP}, and\ t\in T. \tag{6}$$

Model functions, variables and parameters are defined for sets of regions G; regions without ocean ports G^{NP}; time periods T; and non-harvest and harvest time periods T^{NH} and T^{H}, respectively. The objective function is defined by the inverse demand function $\Phi_{g,t}(D)$, the inverse supply function $\Psi_{g,t}(S)$, the parameter for transportation costs between countries g and gp, $TC_{g,gp,t}(X)$, the parameter of unit storage costs $SC_{g,t}(Z)$, the parameter for import price $PM_{g,t}(M)$ and the parameter for export price $PE_{g,t}(E)$. The present value of the objective function over 12 months (T) is discounted by the inverse of the real interest rate $\left(\frac{1}{1+r}\right)^{t}$.

The NLP formulation is transformed into the MCP approach by deriving the first order conditions from the Lagrangian form and adjusting them to handle ad-valorem tariffs ($\tau_{g,gp}$), differences in storage costs, and real interest rates across space (r_g). Considering the first order conditions with respect to strict positive values of intra-SA6 transported maize and storage, it follows:

$$\frac{\partial L^*}{\partial X_{g,gp,t}} = -c_{g,gp} + (\lambda_{gp,t} - \lambda_{g,t})(1+r)^t = 0, \qquad (7)$$

$$\frac{\partial L^*}{\partial Z_{g,t}} = -h_g + (\lambda_{g,t} - \lambda_{g,t-1})(1+r)^t = 0, \qquad (8)$$

where $c_{g,gp}$ corresponds to the intra-SA6 trade unit transportation cost, h_g represents the unit storage cost, and λ symbolizes the storage constraint Lagrange multiplier. Equation (7) provides the spatial dimension of the model. This equation entails that the unit transport cost ($c_{g,gp}$) is equal to the difference between prices in two regions. Equation (8) indicates that the unit storage cost (h_g) is equal to the difference in prices between two consecutive months. This equation bestows the time element to the model, through the real interest rate. When differentiated by region, interest rates operate like *ad valorem* tariff rates distinguished also by region. They violate the integrability condition of the equilibrium equations system, making the coefficient matrix for the system of equations asymmetric for each region (Takayama, and Uri 1983). It reinforces the need for choosing the MCP approach as a more transparent alternative to the NLP approach.

5 Data and Model Specification

The SA6 countries included in this analysis are all located in southern Africa mainland. They have been trading with each other in the recent past without interruptions caused by internal wars, and are the most relevant regarding total population, and the total volume of maize production and consumption. This group of countries are classified and divided into regions as follows: Malawi, Mozambique-Center, Mozambique-North, Mozambique-South, South Africa-East, South Africa-West, Tanzania, Zambia-East, Zambia-West, and Zimbabwe.

Linear inverse demand functions (IDF) for maize for each region are derived through a benchmarking procedure. The corresponding parameters are also derived for the linear inverse supply function (ISF). Table 2 provides data used to derive both IDF and ISF.

The unit transportation cost for Mozambique is set to US$0.048 per metric ton per kilometer. This value is adjusted for 3% inflation during five years from the original value in Arndt *et al* (2001). Transport costs are differentiated as follows: Mozambique-Center (US$0.048), Mozambique-North (US$0.050), and Mozambique-South (US$0.046). The unit transportation cost for both regions of South Africa (US$0.038) corresponds to the distance between Gauteng and Cape Town (Poonyth *et al* 2002). The transportation cost for Zimbabwe as reported by Masters and Nuppenau (1993) is adjusted to reflect a lower cost than among MMTZZ countries (US$0.042). Unit transportation cost for Malawi, Zambia and Tanzania are set with the same value between the Mozambican and the Zimbabwean levels (US$0.045). Unit transportation costs include freight costs, insurance, and discharging costs, wherever it applies (Poonyth *et al* 2002).

Monthly real interest rate is set at 2.5% for Mozambique which is the average for urban areas and rural areas. Corresponding rate for South Africa is set at 1.5%, for Malawi and Tanzania are set at 2.75%, and for Zambia and Zimbabwe at 3%. Monthly unit storage cost is assumed to be US$3 per metric ton in Mozambique, which is $0.5 above the value mentioned in MICTUR *et al* (1999). Storage cost in South Africa is 2/3 of the cost in Mozambique. Corresponding values for Zimbabwe, Zambia, Malawi and Tanzania are US$2.5, US$2.7, US$2.8, and US$2.9, respectively. Except for South Africa with an assumed storage loss rate of 0.5%, all other countries have a storage loss rate of 0.85%. This value is skewed towards the 1% storage loss in rural areas in Mozambique as compared with 0.5% in urban areas. The transportation loss rate is set to 1.1%, and 0.6% for MMTZZ and for South Africa, respectively.

In 2001-2002, Malawi, and South Africa applied a zero tariff rate on maize imports from other SA6 countries (RATES 2003a; SADC 2000-01). Tanzania applied an uniform tariff rate of 30%. Mozambique and Zambia applied tariff rates of 2.5% and 5% to imports from South Africa. Zimbabwe imposed a tariff rate of 30% to imports from South Africa and 17.5% to imports from all other SA6. Even if effective tariff rates are below legal tariff rates, it imposes a burden on importers that is not always measured accurately.

Demand for maize is a monthly event. For simplicity, it is assumed that each region harvests maize once a year, in the first month of the period between *April 2001 and March 2002*. This period is referred to as the 'marketing season'.

It is assumed no beginning stocks. In the first period, provision of maize is made by farmers. Thereafter, each region will source their maize from domestic storage, from other SA6 regions, or from the rest of the world. Each region with ocean ports is allowed to export to the rest of the world in the first period, and to import after the first period. The world price for exports and imports are set at $79/ton and $141/ton, respectively (World Bank 2003; MARD, and MSU 2001-02a, 2001-02b; MIC *et al* 2001; SAGIS 2001; Coulter 1996; Miller 1996). These price thresholds determine which regions with ocean ports are exporting to or importing from the rest of the world.

Each region is allowed to store maize, without capacity constraints. Transportation of maize occurs between SA6 regions, using the point-representation approach (Mwanaumo *et al* 1997).

Stochastic Output

In reality, maize output varies from year-to-year mainly due to changes in weather, although other non-economic factors may have an impact. Incorporating the stochastic nature of output changes throughout the years, the comparison of various scenarios would have to consider the criterion of the degree of risk.

The STPE model is adjusted so that output becomes exogenous, reproducing historical output variations for the period 1987-2002. The same simulations run for the deterministic version of the model are also used in the stochastic version. The analysis of transaction costs improvement is relevant for maize, which is a food and cash crop whose production is subject to weather vagaries. Using the actual output time series for maize ($S_{g,y}$), it is estimated the expected output ($\hat{S}_{g,y}$), through an Ordinary Least Squares regression on time, y (FAO 2002-03). Running the model in GAMS, simulated output values ($\bar{S}_{g,y}$) are obtained through:

$$\bar{S}_{g,y} = \frac{S_{g,y}}{\hat{S}_{g,y}} * E(S_g)_{base}, \qquad (9)$$

where $E(S_g)_{base}$ is the estimated output in the Base scenario, for each SA6 country. Results from model simulations provide a time series on net social welfare (NSW), corresponding to 1987-2002 for each scenario. These data are the basis to estimate cumulative density functions (CDF).

6 Empirical Results

Simulation Cases

The role of storage costs, transportation costs and import tariffs on the pattern of production, consumption and trade in SA6 regions is studied through a set of four simulations (Table 3). Table 4 and Table 5 show parameter values used in each simulation. The Base scenario is run with benchmarked parameters (Table 6). This scenario is set as the standard from which all other simulations are defined, by changing specified parameters.

Simulation 1 verifies how South Africa's comparative advantage in storage shapes trade patterns within SA6 regions. Only parameters for South Africa are changed, revealing a development scenario with lower storage costs. In order to achieve this state, the Government could offer incentives to build new silos at lower costs, to adopt equipment with modern technology, and/or the macro policy environment could be conducive to lower real interest rates. Alternatively, simulation 2 assesses trade and welfare effects of a more efficient storage in MMTZZ. These countries are assumed to catch-up with South Africa's storage efficiency. Simulation 3 represents a more efficient storage scenario in all SA6 regions, keeping relative differences in costs among them. Although there is an improvement in storage efficiency among MMTZZ countries, South Africa still maintains an advantage in this activity with lower real interest rates.

Simulation 4 combines the more efficient storage scenario with a more efficient transportation and trade free from import tariffs among SA6 countries. This last simulation provides a view on simultaneous effects from combining the reduction in the three types of transaction costs in the maize market.

Simulation Outcomes

The Base scenario illustrates two distinct cases of pattern of trade. South Africa-East, a region with comparative advantage in storage costs relative to other SA6 regions, stores maize throughout the entire marketing season. It exports 27% of its maize to Mozambique-South and sells the remaining to South Africa-West throughout the marketing year. This model result is consistent with reality regarding Mozambique-South imports from other countries. Moreover, it arrived to a similar outcome as in Arndt *et al* (2001), whose model results show that Maputo starts importing maize in September. In the current study, the Base scenario indicates that Mozambique-South imports from South Africa between August and October.

Mozambique-Center, Mozambique-North and Tanzania export maize to the rest of the world, immediately after harvest importing back in February-March of the following year. These are relatively low storage efficient regions. Again, model results with respect to Mozambique-Center are consistent with reality as reported by Uaiene (2004) based on a field survey carried out in Manica. Farmers tend to sell maize immediately after harvest. Part of this maize is exported by large scale traders. In normal years, maize lasts about 10 months for rural families, after which smallholders have to buy back maize from the market. The current study shows that Mozambique-Center starts importing maize in February, which is the eleventh month after harvest. The international market provides the largest proportion (82%) of the total imported maize with the remainder sourced within SA6.

Simulation 1 results in larger net intra-SA6 trade (+94%), reducing both ROW imports and exports by 15.2% and 20.5%, respectively, relative to the base. Maize farmers in Mozambique-South and in Zambia-West must sell at lower prices due to South Africa's enhanced comparative advantage in storage costs, cutting their supply. Consumers in these two regions and in South Africa benefit from lower prices leading to an improvement of 1.6% in the net social welfare indicator (Table 7).

The outcome in simulation 1 is driven by a more efficient storage in South Africa, which reduces market prices later in the marketing season in both SA-East and SA-West. A reduction in both the real interest rate (0.75%) and the storage loss rate (0.25%) reduces the rate of increase in market prices throughout the marketing season. Prices at harvest in the SA-East are anchored at export parity. This is largely a surplus producer region, which exports to the rest of the world, stores for domestic consumption, and for selling to other SA6 regions later in the marketing year. The anchoring of immediate post-harvest (May) prices at export parity implies no change in maize output. However, the volume of maize stocks in May increases (6.2%). With greater stocks, regional trade is also enhanced as most regional trade occurs late in the marketing season. For the case of South Africa-East, exports to the rest of the world are reduced in order to sell more maize to other SA6 regions throughout the marketing season.

Continuing with the same scenario, market prices in Zambia-West and in Mozambique-South lower later in the marketing season (pre-harvest period), following the trend in South Africa. Prices in these regions also decline at harvest reducing maize output. Reductions in real interest rates in South Africa further enhance South Africa's trade advantage implying increases in imports and reductions in maize production in these two deficit regions that already rely on imports from South Africa. Consumers in importing regions are the winners.

Simulation 2 brings MMTZZ storage costs down to South Africa's levels. Overall, maize farmers in MMTZZ largely benefit in a scenario with improved storage technology, reduced storage costs and lower opportunity cost of capital. Consumers benefit from marginal welfare gains, resulting in an improvement of 2.9% in net social welfare for the overall MMTZZ regions (Table 7). Overall, regional trade is stimulated dramatically. Intra-SA6 trade increases by 49%. Imports from and exports to the ROW decline by 87% and 27%, respectively.

In May, despite the reduction in storage costs, market prices, and hence production, remain constant at the export parity price level of $79 per ton in Mozambique-Center and in Mozambique-North. Both regions are surplus maize producers among MMTZZ. Conversely, harvest prices rise in Tanzania, Malawi, Zambia and Zimbabwe, increasing maize output. The reduction in storage costs reduces the growth rate of prices throughout the marketing season and increases prices at harvest providing benefits to both producers and consumers.

Simulation 3 improves general SA6 storage efficiency, keeping constant cost differentials between MMTZZ and South Africa. The opportunity cost of capital is still relatively lower in the latter country. Under this scenario, farmers and consumers benefit with an increase in both the producer surplus (7.6%) and consumer surplus (2.4%). Net social welfare increases by 3.9% (Table 7). Regional trade is stimulated even more than in Simulation 2 with an increase in intra-SA6 maize flows by 94%, and a decline in trade with the ROW. The degree of SA6 self-sufficiency in maize increases, as both output (2.4%) and demand (1.7%) rise.

The growth rate of prices is reduced throughout the season in Mozambique-Center, Mozambique-North and South Africa-East, but, as before, prices at harvest are kept at the export parity price level. South Africa-East increases intra-SA6 exports, namely to Mozambique-South (178%) and sales to South Africa-West (11.5%), by reducing exports to the rest of the world (22.4%). The lower annual average price increases domestic demand by 3.3%. Mozambique-Center and Mozambique-North also increase domestic consumption of maize by 3.2% and 2.7%, respectively, but they reduce exports to the ROW (65.2% and 55.5%, respectively), responding to price movements.

Mozambique-South, Zambia and Zimbabwe are deficit maize producers, whose producers, and consumers benefit from welfare gains. Zambia-West and Zimbabwe obtain similar results as in Simulation 2. In Mozambique-South, consumers increase demand due to lower annual average prices. But in Zambia-East demand declines. Malawi, South Africa-West and Tanzania have the expected change in prices, rising at harvest, but declining towards the end of the marketing season. Farmers increase maize output by 4.3%, 1.0% and 6.2%, respectively. The volume of maize in storage increases. In Tanzania, the decline in the growth rate of prices does not compensate for the substantial increase in prices at harvest, reducing domestic demand for maize in 0.2%. Conversely, Malawi (+0.3%) and South Africa-West (+3.1%) increase their domestic demand for maize. Except for South Africa-West, trade declines with the rest of the world. Malawi reduces drastically (-77%) her imports from Mozambique-Center. Tanzania reduces re-exports to Zambia-East, eliminates exports to the ROW, and reduces imports from the latter origin. However, intra-SA6 trade increases by 205 thousand tons.

Simulation 4 combines scenarios with improved transaction costs: lower opportunity cost of capital, more efficient transportation within MMTZZ countries and intra-SA6 trade free from tariffs. Considering the aggregate SA6 regions, simulation 4 obtains better results than all other previous simulations in terms of net social welfare (+4.0%), with gains in producer surplus (+6.5%) and consumer surplus (+2.9%). Consistent with the welfare measures for joint SA6 countries, output increases by 312 thousand tons and demand rises by 281 thousand tons of maize (Table 8). Trade within SA6 regions, net of re-exports, increases by 163% (not shown), and imports from and exports to the ROW decline by 94% and 47%, respectively.

Stochastic Version

In the stochastic version, the model is run 16 times with each iteration representing a different draw from the distribution of production outcomes. This discrete distribution of 16 outcomes represents the production correlation matrix presented in Table 1. Stochastic models produced large volumes of results. These results are summarized using cumulative density functions of net social welfare values. Stochastic dominance analysis can be used to rank simulations. Using this approach, simulations 2, 3 and 4 first degree stochastic dominate simulations 0 and 1. Therefore, any of the simulations in the first group (2, 3 and 4) is preferred to any other in the second group (0 and 1). In Figure 2, simulations "storsa6" and "combination" represent the first group and the "Base" scenario represents the second group. Simulations 3 and 4 are the most relevant in terms of representing the lowest degree of risk among those in the second group (Figure 2). None of these two simulations first degree stochastic dominates over the other.

The stochastic dominance analysis emphasizes the importance of improving storage efficiency, i.e., reducing the opportunity cost of capital for the economic performance in the maize market (Table 9). In both simulations 3 (storsa6) and 4 (combined) consumers are better off by facing lower market prices and increasing their demand for maize.

7 Summary and Conclusion

The model presented captures two distinct trade patterns presented in the literature. First, consistent with the observations of Timmer (1974) and the modeling of Arndt et al. (2002), the model captures seasonal commodity flow reversals for the cases of Mozambique-Center, Mozambique-North and Tanzania. These regions export immediately after harvest, importing back later in the "hungry" season. This pattern of trade is typically associated with inefficient storage, particularly in rural areas. Second, consistent with Benirschka and Binkley, regions with lower opportunity cost to storage tend to store for longer durations and then provide grain to the market late in the marketing season. This is the case of South Africa, particularly South Africa East.

Storage costs, in particular the opportunity cost of capital, drive maize market price rises between harvest and the lean season within the marketing season. In considering the hypothesis that differences in storage costs between South Africa and other SA6 are a source of international comparative advantage, results support the hypothesis. Simulations 1, 2 and 3 simulate reductions in storage costs – including the opportunity cost of capital – in respectively South Africa, the MMTZZ countries, and all SA6. In Simulation 1, South Africa increases exports to the region by 94% with particularly strong increases to Mozambique-South and Zambia-West. In Simulations 2 and 3, intra-SA6 trade rises by 49% and 94%, respectively. Simulation 2 reveals that improving storage efficiency in MMTZZ countries has a significant effect on producer welfare, increasing it by 9.4%. Viewing the economic development process as based on the improvement of agricultural productive performance, simulation 2 confirms the benefits of reducing storage costs among MMTZZ. Simulation 3 represents a more regional integrated scenario, where producers increase their welfare by 7.6%, but consumers also benefit from a 2.5% raise in their welfare measure. A strengthening of specialization between surplus and deficit producer regions, leads to a more efficient allocation of resources and provides a greater contribution to food security in SA6. Simulation 3 indicates that maize producer regions in Tanzania and Mozambique-Center and North can contribute to supply deficit SA6 regions under a less regulated trade regime.

The combined scenario, which simulates a generalized reduction in storage costs, including the opportunity cost of capital, plus improvement in transportation efficiency for MMTZZ countries and trade liberalization delivers the highest increment to welfare. Net social welfare increases by 4.0%, with consumers benefiting by the largest absolute change in welfare (2.9%), and producers' welfare improving by 6.5%. The combined scenario also provides a more equal distribution of benefits. For example, producer welfare losses under trade liberalization are more than compensated for by producer welfare gains associated with storage efficiency improvement, in particular lower real interest rates.

Results from the stochastic version of the model support the intuition obtained from the static model. The stochastic model highlights the benefits of lower storage costs under a broad variety of production outcomes.

8 References

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Annex: Figures and Tables

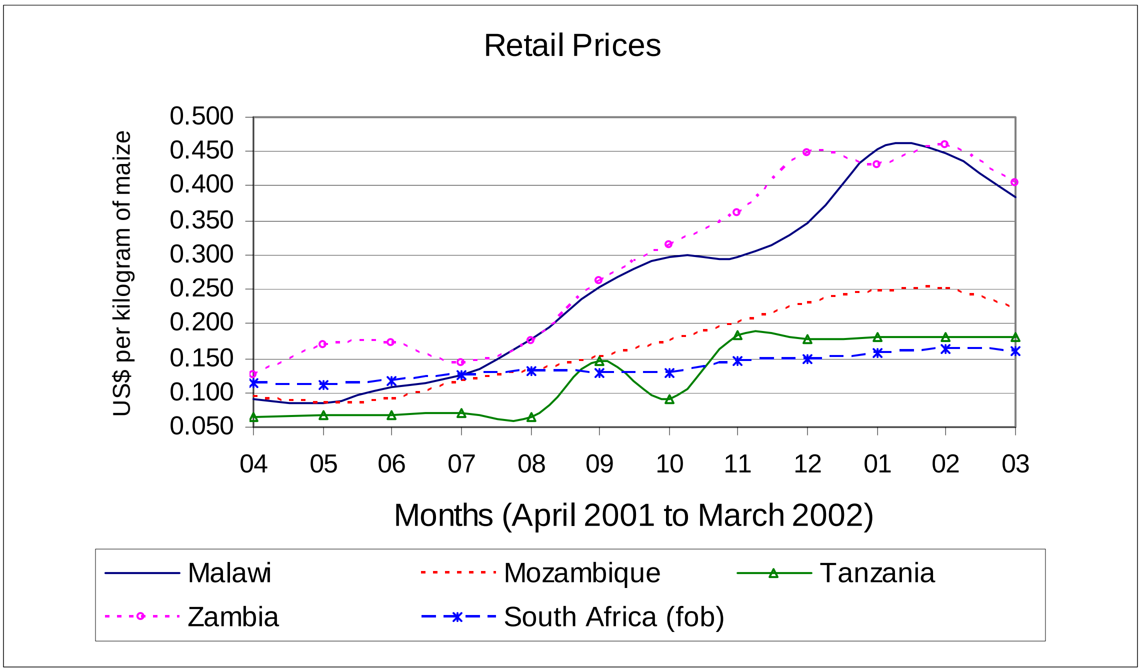

Figure 1. Large intra-seasonal price changes within most of SA6 countries.

Table 1. Correlation Coefficients of Maize Output among SA6, 1987-2002

	Mozambique	South Africa	Tanzania	Zambia	Zimbabwe
Malawi	0.40	0.27	0.33	0.51	0.38
Mozambique		0.17	0.13	0.26	0.26
South Africa			0.01	0.62	0.73
Tanzania				0.18	-0.18
Zambia					0.57

Source: Calculated by the author based on FAO 2002-03.

Table 2. Input Parameters for the Inverse Demand and Supply Functions

Regions	Inverse demand function			Inverse supply function		
	Annual quantity demanded 10^3 ton	Demand price $/ton	Price elasticity of demand ε_d	Annual quantity supplied 10^3 ton	Producer price $/ton	Price elasticity of supply ε_s
Malawi	1,763	179	-0.3	1,713	108	0.40
Mozcenter	436	101	-0.3	597	79	0.45
Moznorth	348	114	-0.3	416	80	0.60
Mozsouth	309	147	-0.3	129	94	0.30
SA-east	5,102	98	-0.4	6,256	76	0.65
SA-west	1,549	100	-0.4	1,227	80	0.65
Tanzania	2,718	116	-0.4	2,579	78	0.50
Zameast	280	196	-0.5	253	110	0.42
Zamwest	630	153	-0.5	549	100	0.42
Zimbabwe	1,594	158	-0.3	1,476	102	0.50

Source: Elaborated by the author based on Arndt *et al* (2001); Coulter (1996); FAO (2002); FAO, and WFP (2003c, 2003d); Jayne *et al* (1995); MARD, and MSU (2001-02a); Masters, and Nuppenau (1993); Mwanaumo (1994); ProAgri (2002); RATES (2003a, 2003d); SADC (2002); Whiteside (2003).

Table 3. Identification of Simulations

Simulation	Short name	Explanation
0	Base	Benchmark data replication
1	Storage	More efficient storage in South Africa
2	Storagesa5	More efficient storage in MMTZZ regions
3	Storsa6	More efficient storage in all SA6 regions
4	Combined	More efficient storage and transportation, and intra-SA6 trade free from import tariffs

Table 4. Parameter Values Used in Simulations (Storage Components)

Simulations	0	1	2	3	4
	Direct storage cost (US$/ton)				
Malawi	2.8		2.0	2.3	2.3
Mozcenter	3.0		2.0	2.5	2.5
Moznorth	3.0		2.0	2.5	2.5
Mozsouth	3.0		2.0	2.5	2.5
SA-east	2.0	1.5		1.5	1.5
SA-west	2.0	1.5		1.5	1.5
Tanzania	2.9		2.0	2.4	2.4
Zameast	2.7		2.0	2.2	2.2
Zamwest	2.7		2.0	2.2	2.2
Zimbabwe	2.5		2.0	2.0	2.0
	Storage loss rate (monthly %)				
Malawi	0.85		0.5	0.35	0.35
Mozcenter	0.85		0.5	0.35	0.35
Moznorth	0.85		0.5	0.35	0.35
Mozsouth	0.85		0.5	0.35	0.35
SA-east	0.50	0.25		0.25	0.25
SA-west	0.50	0.25		0.25	0.25
Tanzania	0.85		0.5	0.35	0.35
Zameast	0.85		0.5	0.35	0.35
Zamwest	0.85		0.5	0.35	0.35
Zimbabwe	0.85		0.5	0.35	0.35
	Real interest rate (monthly %)				
Malawi	2.75		1.50	1.75	1.75
Mozcenter	2.50		1.50	1.50	1.50
Moznorth	2.50		1.50	1.50	1.50
Mozsouth	2.50		1.50	1.50	1.50
SA-east	1.50	0.75		0.75	0.75
SA-west	1.50	0.75		0.75	0.75
Tanzania	2.75		1.50	1.75	1.75
Zameast	3.00		1.50	2.00	2.00
Zamwest	3.00		1.50	2.00	2.00
Zimbabwe	3.00		1.50	2.00	2.00

Table 5. Parameter Values Used in Simulations (Transportation Components)

Simulations	0	1	2	3	4
	Unit transport cost (US$/ton-km)				
Malawi	0.045				0.038
Mozcenter	0.048				0.038
Moznorth	0.050				0.038
Mozsouth	0.046				0.038
SA-east	0.038				0.038
SA-west	0.038				0.038
Tanzania	0.045				0.038
Zameast	0.045				0.038
Zamwest	0.045				0.038
Zimbabwe	0.042				0.038
	Transport loss rate (%)				
Malawi	1.1				0.6
Mozcenter	1.1				0.6
Moznorth	1.1				0.6
Mozsouth	1.1				0.6
SA-east	0.6				0.6
SA-west	0.6				0.6
Tanzania	1.1				0.6
Zameast	1.1				0.6
Zamwest	1.1				0.6
Zimbabwe	1.1				0.6

Table 6. Benchmarked Parameters for the IDF and ISF

Regions	Inverse Demand Function		Inverse Supply Function	
	Autonomous Parameter	Quantity coefficient[‡]	Autonomous Parameter	Quantity coefficient
Malawi	560.0	-3.191	-142.5	0.139
Mozambique-Center	697.7	-21.822	-190.5	0.907
Mozambique-North	619.7	-15.488	-64.7	0.323
Mozambique-South	849.3	-29.973	-171.0	0.973
South Africa-East	472.5	-1.620	-59.2	0.028
South Africa-West	472.5	-1.830	-59.2	0.114
Tanzania	542.5	-1.633	-90.0	0.063
Zambia-East	495.0	-10.272	-165.7	1.134
Zambia-West	495.0	-4.570	-165.7	0.476
Zimbabwe	771.3	-4.644	-130.0	0.176

[‡] Quantity coefficients have a negative sign in the demand function.

Table 7. Impact of Simulations on SA6 Regions: Percentage Change with Respect to Base Scenario

Welfare measures	Storage	Storagesa5	Storsa6	Combined
Producer surplus	-0.2	9.4	7.6	6.5
Consumer surplus	2.3	0.4	2.4	2.9
Net social welfare	1.6	2.9	3.9	4.0

Table 8. Impact of Simulations on SA6 Regions

Indicators\ Simulations	Annual price	Harvest price	Production	Demand	Intra-SA6 trade	Net exports	Storage in May
base	132	97	15,652	14,709	585	476	12,809
storage	129	96	15,650	14,940	738	324	13,115
storagesa5	129	105	16,106	14,742	328	966	13,691
storsa6	127	103	16,021	14,963	442	810	13,796
combined	127	103	15,965	14,989	590	728	13,846

Notes: Prices are expressed in US$/ton, and volume is expressed in thousand tons for the entire year. Column "Intra-SA6 trade" includes re-exports.

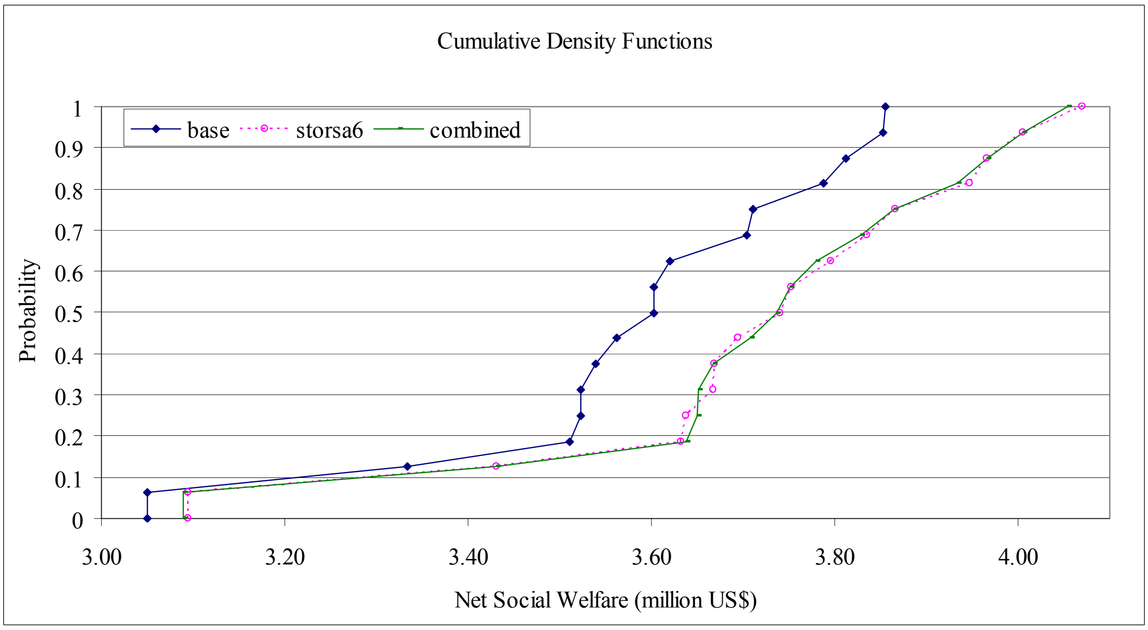

Figure 2. ‘Combined’ and ‘Storsa6’ Scenarios First Degree Stochastic Dominate ‘Base’ Scenario.

Table 9. Annual Average Values for the Period 1987-2002, SA6 Regions

	Annual price	Harvest price	Output	Demand	Intra-SA6 trade	Net exports	Storage in May
base	125.3	93.2	15,693	14,780	892	456	12,403
storage	123.8	93.3	15,691	14,933	984	376	12,668
storagesa5	120.2	98.2	16,147	14,885	814	885	13,094
storsa6	118.5	96.5	16,061	15,048	914	776	13,205
combined	117.7	95.8	16,006	15,069	1,018	703	13,234

Notes: Prices in US$/ton, and volume in thousand tons.