Maize Trade in Southern Africa: Comparative Advantage on Storage Costs

António Sousa Cruz

Discussion papers

No. 32E
August 2006

National Directorate of Studies and Policy Analysis

Ministry of Planning and Development

Republic of Mozambique

The intent of the discussion paper series is to stimulate discussion and exchange ideas on issues pertinent to the economic and social development of Mozambique. A multiplicity of views exists on how to best foment economic and social development. The discussion paper series aims to reflect this diversity.

As a result, the ideas presented in the discussion papers are those of the authors. The content of the papers do not necessarily reflect the views of the Ministry of Planning and Development or any other institution within the Government of Mozambique.

The Logo was kindly provided by the Mozambican artist Nlodzy.

Contact:

António Sousa Cruz
Direcção Nacional de Estudos e Análise de Políticas (DNEAP)
Ministério de Planificação e Desenvolvimento

Av. Ahmed Sekou Touré nº 21, 4º andar

Maputo, Moçambique

Tel: (+258) 2 1 499442

Fax: (+258) 2 1 492625

Web: www.mpd.gov.mz

Email: antonioscruz@gmail.com

Resumo

Diferenças em custos de armazenagem, em particular diferenças nas taxas de juro reais são uma determinante importante de vantagens comparativas e portanto dos padrões de produção e comércio internacional em seis dos maiores países da África Austral (AA6). Usando um modelo espácio-temporal de equilíbrio de preços do comércio intra-continental do milho, confirmamos a hipótese da vantagem comparativa da África do Sul estar baseada em mercados financeiros e infraestruturas de armazenagem mais desenvolvidos ao invés de em custos de produção do milho. Com uma redução nas taxas de juro reais, os resultados das simulações indicam que Moçambique e Tanzania exportariam milho para outros AA6. A comercialização do milho intra-AA6 intensifica-se, com uma queda simultânea no comércio com o resto do mundo. Considerando a variabilidade anual de produção entre os AA6, os resultados do modelo são semelhantes aos da versão determinística.

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. Accounting for year-to-year production variability among SA6, model results are similar to those in the deterministic version.

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

Index

Introduction

Maize is an important commodity among SA6 countries representing an estimated 46% in total calorie intake in human consumption, and 74% of the total cereal output, in 2001. Maize market prices in Malawi, Mozambique, Tanzania and Zambia increased from two to five fold between harvest and the lean period, in the 2001-02 marketing year (Figure 1). Viewing maize price series as indicative of storage costs, the intra-seasonal rise of less than 50% in South Africa suggests that this country has a comparative advantage in storage over the other SA6. South Africa exports maize to these countries in the lean period of the marketing season when market prices are relatively higher for the later. Year-to-year production variability among different SA6 is another important factor determining trade pattern.

This study determines and analyzes the effects of a more efficient storage, in particular lower real interest rates, on market prices, trade pattern, volume of production and consumption, and on welfare measures on the SA6 maize market, using a spatial-temporal price equilibrium model. The analysis emphasizes the role of storage costs as a determinant of the pattern of trade. This paper also studies the potential for intra-SA6 supply of maize while competing with the supply from the international market, given the year-to-year production variability. This pattern is captured by the output correlation matrix for years 1987-2002. Finally, a more efficient storage scenario is combined with lower transportation costs and intra-SA6 tariff free trade scenarios, to account for simultaneous effects.

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 for cases of one and more commodities, and imperfect competition with a single product monopoly (Samuelson 1952; Takayama and Judge 1971). This type of models were extended to deal with cases of two monopolies and a Cournot-Nash oligopoly, and discriminatory ad valorem tariffs, using the variational inequalities approach (Harker 1986; Nagurney *et al* 1996).

When dealing with ad valorem tariffs, non-linear programming (NLP) was not a satisfactory approach. It could not solve cases when the coefficient matrix of the demand and/or supply functions was asymmetric - i.e., the integrability condition was violated. The NLP approach had to be solved through a sequence of iterations, which was inefficient and lacked transparency. Takayama and Uri (1983) showed that the linear complementarity programming formulation was more appropriate than quadratic programming when integrability was lost. Rutherford (1995) applied the mixed complementarity problem (MCP) approach to economic problems using the General Algebraic Modeling System (GAMS) (Brooke *et al* 1992). He defined MCP as an economic equilibrium model formulated as systems of nonlinear equations, complementarity problems or variational inequalities. Mixed complementarity problems may incorporate both equality and inequality relationships. Dirkse and Ferris (1995) developed the PATH solver that allows the implementation of a stabilized Newton method for the solution of mixed complementarity problems. Ferris and Pang (1997) presented a few examples of non-linear complementary problems in equilibrium modeling.

Traditionally, trade models focus 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 that another factor, storage costs – the opportunity cost of capital proxied by the real rate of interest paid by storing agents plus direct storage costs plus any risk premium – have significant implications for the pattern of commodity trade. Arndt *et al* (2001) build upon this idea for the case of Mozambique. They show 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 influence maize marketing patterns and provide 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 the MCP version of a spatial-temporal price equilibrium framework with differentiated import tariff rates and interest rates by country to a model of international maize trade, given the relevant contribution of this activity for the provision of food security in bad crop years among SA6 countries. In better weather conditions, price differences still justify maize trade among some SA6, which are currently involved in a process of gradual trade liberalization within the Southern African Development Community, in line with the international movement of creating blocks of free trade areas.

The second section identifies the key features of the maize market in SA6 countries. Third section defines the spatial-temporal price equilibrium model, providing a literature review, presenting the model, and its assumptions. Fourth section presents data, and specification issues. Fifth section defines and develops model simulations and results, presenting scenarios for the deterministic and the stochastic versions of the model. Last section concludes.

Maize Market in SA6 Countries

In Malawi, Mozambique, Tanzania, Zambia and Zimbabwe (MMTZZ) maize is mostly grown by smallholder farmers. They 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).

In South Africa, 89% of total maize output is grown by commercial farmers, which is the exception among SA6 countries. These farmers use capital intensive technology, improved seed varieties, and have access to fertilizers and pesticides, contributing for a higher maize productivity of 2.3 tons/ha.

Even though productivity in the SA6 countries is currently below the world average of 4.3 tons/ha, maize has been an important crop whose output has been growing steadily in the past five decades. In the period 1988-99 farmers produced a total annual average output of about 16.3 million tons compared with approximately 6.1 million tons in 1951-60 (FAO 2002-03; and Pingali 2001). This variation in output of 165% is well above the output variation of 43% for the entire world in the same period. South Africa has been consistently 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 is a positive 1.2 million tons (SADC 2002). This result is reached 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.

Although the most prominent sources of intra-SA6 maize trade statistics do not show consistent figures among themselves, the author estimated a total trade volume of 169 thousand tons for the 2001-02 marketing year (FAO 2004; RATES 2003a-d; SADC 2002; and Whiteside 2003). This trade volume is one fifth of the total maize imported into SA6, but it is still important given maize price differentials between countries and its role in contributing for food security.

Maize trade is affected by output correlations among SA6 countries. It is assumed here that variations in output from one year to the other are mainly due to changes in yields than in area planted. Keeping all 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. A negative output correlation suggests higher chances of trade development between a region with bad crop season and another with a bounty season. Low positive correlation coefficients denote some chances of trading between two regions.

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 to trade among them. This result coincides with the one in Jayne *et al* (1995). The difference is that the current study includes additional countries Malawi, Mozambique and Tanzania. Country pairs Malawi-Zambia (with correlation coefficient of 0.51), Malawi-Mozambique (0.40) and Malawi-Zimbabwe (0.38) may have lower chances of trading maize among them. However, since South Africa is a surplus maize producer, it is a regional source of maize supply to deficit producer countries like Malawi, Zambia and Zimbabwe, or to regions like Mozambique-South. Tanzania, Mozambique-Center and Mozambique-North are potential surplus producers, hence intra-SA6 maize suppliers.

It is not well understood the economic effects of differences in storage costs among SA6 countries, as well as of exogenous shocks and policy measures aimed at improving transactions costs in the regional maize market. These factors are analyzed in the current study applying an optimization framework.

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):

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

s.t.

$$Z_{g,t+1} \leq Z_{g,t} - D_{g,t} + S_{g,t} - \sum_{gp\in G} X_{g,gp,t} + \sum_{g\in G} X_{gp,g,t} + M_{g,t} - E_{g,t}, \quad \forall g \neq gp \in G, t \in T, \quad (2)$$

$$D_{g,t}, S_{g,t}, X_{g,gp,t}, Z_{g,t}, M_{g,t}, E_{g,t} \geq 0 \qquad \forall g \neq gp \in G, t \in T, \quad (3)$$

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

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

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

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.

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 ($\overline{S}_{g,y}$) are obtained through:

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

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).

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 traded 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 food 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, being the remaining sourced within SA6.

Simulation 1 results in larger net intra-SA6 trade (+94%), reducing both Rest of the World (ROW) imports and exports by 15.2% and 20.5%, respectively. Maize farmers in Mozambique-South and in Zambia-West must sell at lower prices due to South Africa's comparative advantage in storage costs, cutting in supply. Consumers in the former two regions and in South Africa are those who 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. Total reduction in storage costs are not enough to affect prices at harvest, hence, it does not change maize output. However, the volume of maize stocks in May increases (6.2%). When facing a reduction in direct storage costs, storage losses and the opportunity cost of capital producers will have higher returns in the overall marketing season, by storing more maize at harvest and selling it during the marketing season at relatively higher prices compared to the Base scenario. 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.

Market prices in Zambia-West and in Mozambique-South decline later in the marketing season (pre-harvest period), following the trend in South Africa. These prices also decline at harvest reducing maize output. Given the Base scenario, this is the expected result when reducing real interest rates in South Africa, which is also consistent with the current trade pattern among SA6 regions. South Africa's trade advantage reduces part of maize production in deficit producer regions, which will increase imports from South Africa, driving down market prices. 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). Intra-SA6 trade increases by 49%. Imports from and exports to the ROW decline by 87% and 27%, respectively.

At harvest, the reduction of storage costs, keep constant market prices at the export parity price level, $79 per ton, in Mozambique-Center and in Mozambique-North. Both regions are surplus maize producers among MMTZZ, in the 2001-02 crop season, keeping supply constant. 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, but increases prices at harvest in order to compensate storekeepers from selling maize at lower prices at the end of the season.

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 reaches the best result (+3.9%) compared with previous simulations (Table 7). Trade pattern changes 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 (Table 8 only shows levels).

The growth rate of prices is reduced throughout the season in Mozambique-Center, Mozambique-North and South Africa-East, but prices at harvest are kept at the export parity price level (not shown). These regions are maize surplus producers, whose output levels do not change, compared to the Base scenario. 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 under the current scenario. 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 as annual average prices rise. 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 by 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 t. 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, improve by 163% (not shown), but imports from and exports to the ROW decline by 94% and 47%, respectively.

Stochastic Version

Cumulative density functions of net social welfare annual values are estimated to compare all simulations, informing on risk differences among them. 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. In simulation 3 more maize is available to consumers due to an increase in domestic output within each region, while in simulation 4, consumers benefit from an increase in intra-SA6 trade and a reduction in trade with the rest of the world.

Conclusion

Two distinct trade patterns are highlighted from the study. Timmer’s theory of the seasonal commodity flow reversals is well suited to the case 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, which is the case of the three mentioned regions.

In the Benirschka and Binkley pattern of trade, grain is stored in the producer region and is released into the market later in the marketing season when prices are high enough to benefit producers, i.e., when the grain prices grow at the rate of interest. This theory successfully explains the case of South Africa-East – a storage efficient region, which is selling maize to Mozambique-South and to any other SA6 region, in the pre-harvest period.

Storage costs, in particular the opportunity cost of capital, play an important role in 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 from simulation 1 confirms it. Due to more efficient storage in South Africa-East, its intra-seasonal maize price growth is further reduced. As a surplus maize producer, this region increases intra-SA6 trade by 94% through additional exports to Mozambique-South and Zambia-West, which are both deficit maize producers.

Considering the main hypothesis that storage costs are a major determinant of the volume and pattern of trade, scenarios 2 and 3 simulate a reduction is storage costs – including the opportunity cost of capital – in the MMTZZ countries and in all SA6, respectively. Intra-SA6 trade rises by 49% and 94% in each scenario, 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 importance 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 also reveals that other surplus maize producer regions, Tanzania and Mozambique-Center, contribute to supply deficit SA6 regions. This is a clear deviation from an exclusive focus on South Africa as the SA6 sole surplus maize producer and provider. Mozambique-North is also a potential surplus maize producer.

Combined scenario, simulating a SA6 generalized reduction in storage costs – including the opportunity cost of capital, improvement in transportation efficiency for MMTZZ countries and trade liberalization obtains the best performing results among all scenarios, in the deterministic model version. 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%. An economic scenario where these three types of transaction costs are improved shows better results, such that the drawback of one type – e.g. producer welfare losses under trade liberalization – is compensated by the virtue of the other type – e.g. producer welfare gains under a scenario with storage efficiency improvement, in particular lower real interest rates.

References

Arndt, C., R. Schiller, and F. Tarp. 2001. "Grain transport and rural credit in Mozambique: Solving the space-time problem." *Agricultural Economics*, Vol. 25, pp. 59-70.

Benirschka, M., and J.K. Binkley. 1995. "Optimal storage and marketing over space and time." *Am. J. Agric. Econ*. 77 (Aug.), pp. 512-524.

Brooke, A., D. Kendrick, and A. Meeraus. 1992. "GAMS: A user's guide." Washington, DC: The World Bank, 289 pp.

Coulter, J.P. 1996. "Maize marketing and pricing study – Mozambique." Report No. R 2247 (C). Kent: Overseas Development Association, Natural Resources Institute.

Cournot, A.A. 1838. "Mathematical principles of the theory of wealth." Translation.

Dirkse, S.P., and M.C. Ferris. 1995. "The path solver: A nonmonotone stabilization scheme for mixed complementarity problems." Optimization Methods and Software, Vol. 5, pp.123-156.

Enke, S. 1951. "Equilibrium among spatially separated markets: solution by electric analogue." *Econometrica*, Vol. 19, Issue 1 (Jan.), pp. 40-47.

FAO. 2002. "Food balance sheet for 2000." Web site: http://apps.fao.org

FAO. 2002-03. Time series statistics on maize production. Web site: http://apps.fao.org

FAO. 2004. Statistics on external trade for 2000-01. Web site: http://apps.fao.org

FAO, and WFP. 2003a, --b, --c, --d. "FAO/WFP crop and food supply assessment mission to Malawi." Special Reports, including for Mozambique, Zambia and Zimbabwe, respectively. Rome, June.

Ferris, M.C., J.S. Pang. 1997. "Engineering and economic applications of complementarity problems." *SIAM Rev.*, Vol. 39, No. 4 (Dec.), pp. 669-713.

Harker, P.T. 1986. "Alternative models of spatial competition." *Operations Research*, Vol. 34, Issue 3 (May-Jun.), pp. 410-425.

Jayne, T.S., M. Hajek, and J. van Zyl. 1995. "An analysis of alternative maize marketing policies in South Africa." MSU International Development Working Papers, No. 50. East Lansing: Michigan State University.

Jones, W.O. 1984. "Economic tasks for food marketing boards in tropical Africa." *Food Research Institute Studies*, Vol. XIX, No. 2, pp.113-138.

Koopmans, T.C. 1949. "Optimum utilization of the transportation system." *Econometrica*, Vol. 17, Issue Supplement: Report of the Washington Meeting (Jul.), pp. 136-146.

Langyintuo, A.S., J. Lowenberg-DeBoer, C. Arndt. 2005. "Potential impacts of the proposed West African monetary zone on cowpea trade." *Agricultural Economics* 33 (s3), pp. 411-421.

MARD, and MSU. 2001-02a. "Agricultural Market Information System Monthly Bulletin." Bulletins from April 2001 to March 2002. Maputo: MARD. Web site: http://www.aec.msu.edu/agecon/fs2/Mozambique/index.htm

MARD, and MSU. 2001-02b. "Quente-Quente." Weekly information on agricultural markets in Mozambique, in the region and in the world. Various from May 2, 2001 to March 27, 2002. Maputo: MARD. Web site: http://www.aec.msu.edu/agecon/fs2/Mozambique/index.htm

Masters, W.A., and E.A. Nuppenau. 1993. "Panterritorial versus regional pricing for maize in Zimbabwe." *World Development*, Vol. 21, No. 10, pp. 1647-1658.

MIC, and FAO. 2003. Electronic file with data on FOB prices for white maize in Durban.

MIC, FSU-CE, and FAO. 2001. "Análise dos custos de transporte na comercialização agrícola em Moçambique: Estudo de caso dos custos de transporte do milho das zonas Norte e Centro para a zona Sul de Moçambique." Nota de Pesquisa da DNC No. 18, Junho.

MICTUR, FSU-EC, RESAL-EC, and FAO. 1999. "Feasibility study on the establishment of a warehousing and inventory credit pilot scheme in Northern Mozambique." DNCI Research Note No. 9, Report of a Joint Mission, October.

Miller, E. H. 1996. "Maize marketing strategy: Mozambique." A report to USAID, Maputo, September 30.

Mwanaumo, A. 1994. "The effects of maize marketing policy reforms in Zambia." Ph.D. dissertation. West Lafayette, IN: Department of Agricultural Economics, Purdue University.

Mwanaumo, A., W.A. Masters, and P.V. Preckel. 1997. "A spatial analysis of maize marketing policy reforms in Zambia." *Am. J. Agric. Econ*. 79 (May), pp. 514-523.

Nagurney, A., C.F. Nicholson, and P.M. Bishop. 1996. "Spatial price equilibrium models with discriminatory ad valorem tariffs: Formulation and comparative computation using variational inequalities." In van den Bergh, J.C.J.M., P. Nijkamp, and P. Rietveld (Eds.). "Recent advances in spatial equilibrium modeling: Methodology and applications." Berlin: Springer-Verlag, Chap. 9, pp.179-200.

Pingali, P.L. (ed.). 2001. "CIMMYT 1999-2000 World Maize Facts and Trends. Meeting World Maize Needs: Technological Opportunities and Priorities for the Public Sector." Mexico, D.F.: CIMMYT.

Poonyth, D., D. Esterhuizen, S. Ngqangweni, J.F. Kirsten. 2002. "*Trade policies and agricultural trade in the SADC region: Challenges and implications*." South Africa Country Study, July. South Africa: University of Pretoria, Department of Agricultural Economics, Extension and Rural Development.

ProAgri. 2002. "Maize Industry Outlook." By Ernst Janovsky, FNB. (Info: 1 April 2002). Web site: http://www.proagri.co.za/uitgawe_35/35-14_FNB.htm

RATES. 2003a. "Maize market assessment and baseline study for Malawi." RATES Centre in Nairobi, Kenya.

RATES. 2003b. "Maize market assessment and baseline study for Tanzania." RATES Centre in Nairobi, Kenya.

RATES. 2003c. "Maize market assessment and baseline study for Zambia." Prepared by the IMCS Centre (May), Lusaka, Zambia. RATES Centre in Nairobi, Kenya.

RATES. 2003d. "Maize market assessment and baseline study for Zimbabwe." RATES Centre in Nairobi, Kenya.

Rutherford, T.F. 1995. "Extension of GAMS for complementarity problems arising in applied economic analysis." *Journal of Economic Dynamics and Control*, Vol. 19, pp. 1299-1324.

SADC. 2000-01. Electronic files on SADC imports tariff rate disarmament.

SADC. 2002. "Food Security: Quarterly Bulletin." Harare: SADC Regional Early Warning Unit, February.

SAGIS. 2001. "South African Grain Information Service." Weekly Bulletin, Pretoria, September, 18. Web site: http://www.sagis.org.za

Samuelson, P.A. 1952. "Spatial price equilibrium and linear programming." *The American Economic Review*, Vol. 42, Issue 3 (Jun.), pp. 283-303.

Takayama, T., and G.G. Judge. 1971. "Spatial and temporal price and allocation models." Amsterdam: North Holland, 528 pp.

Takayama, T., and N. Uri. 1983. "A note on spatial and temporal price and allocation modeling." *Regional Science and Urban Economics*, Vol. 13, pp. 455-470.

Timmer, C.P. 1974. "A model of rice marketing margins in Indonesia." *Food Research Institute Studies*, Vol. XIII, No. 2, pp. 145-167.

Uaiene, R.N. 2004. "Maize and sorghum technologies and the effects of marketing strategies on farmers' income in Mozambique." Masters thesis. West Lafayette, IN: Department of Agricultural Economics, Purdue University.

Varian, H.R. 1992. "Microeconomic analysis." New York: W.W. Norton & Company, 3rd ed.

Whiteside, M. 2003. "Enhancing the role of informal maize imports in Malawi food security." DFID, Consultancy Report written in conjunction with P. Chuzo, M. Maro, D. Saiti, and M.J. Schouten. Draft from 17 November.

World Bank. 2003. "Commodity price data." Web site: http://www.worldbank.org/prospects/pinksheets/ .

Annex: Figures and Tables

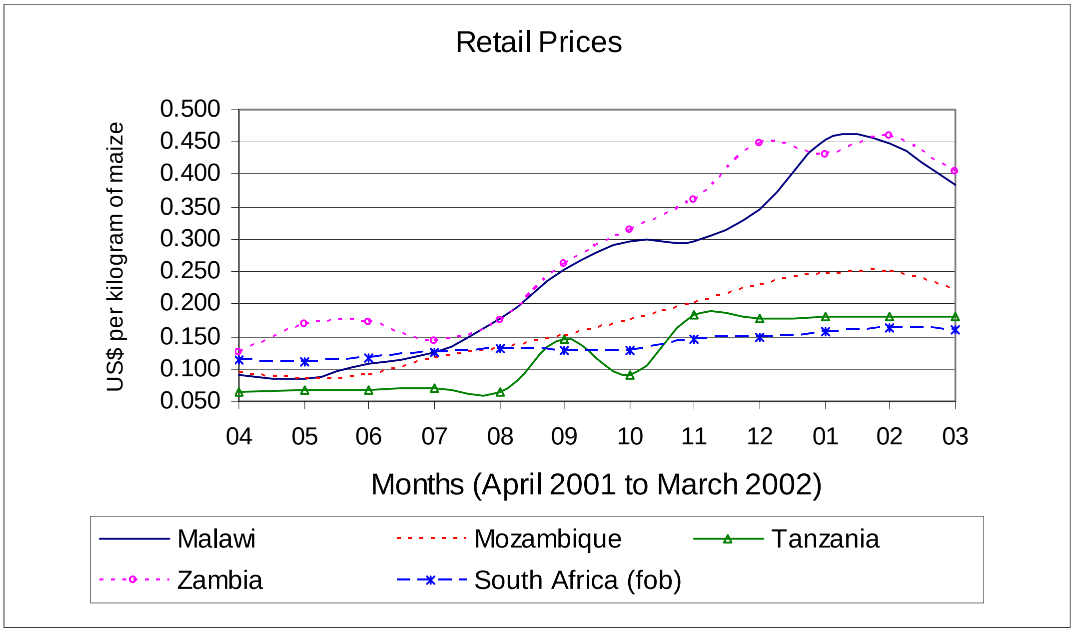

Figure 1. Large intra-seasonal price changes within most of SA6 countries.
Source: MARD, and MSU 2001-02a; MIC, and FAO 2003; and Whiteside 2003.

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.

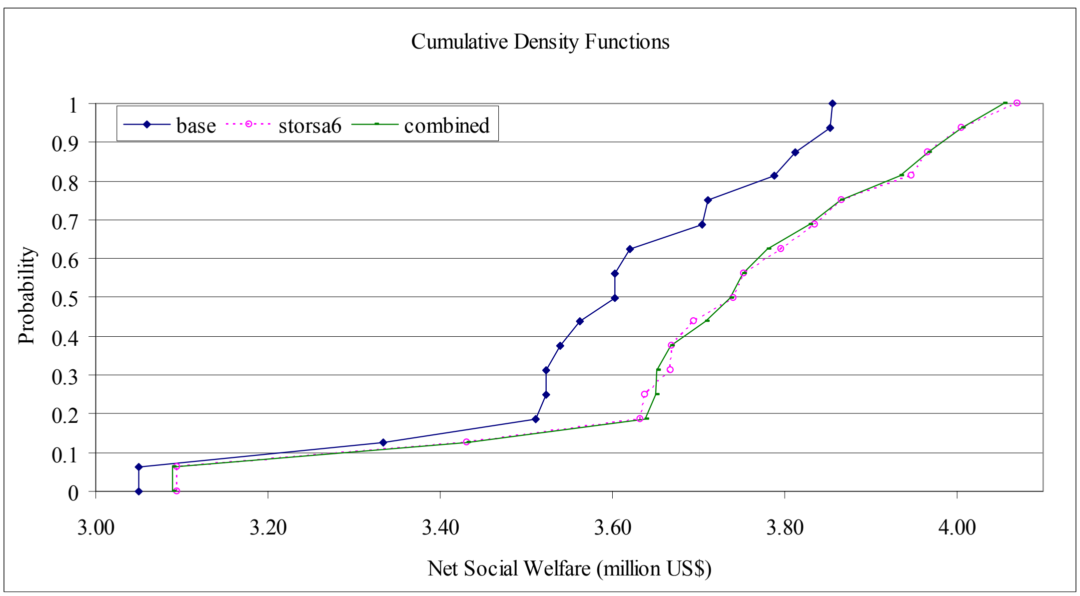

Figure 2. 'Combined' and 'Storsa6' Scenarios First Degree Stochastic Dominate 'Base' Scenario.

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.