ELSEVIER

Agricultural Economics 25 (2001) 59–70

AGRICULTURAL ECONOMICS

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Grain transport and rural credit in Mozambique: solving the space–time problem

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Received 16 June 1999; received in revised form 29 March 2000; accepted 23 May 2000

Abstract

This paper shows how credit market failures can lead to large welfare losses in grain markets by inducing increased transport for seasonal storage in locations with low credit costs. The burden of these welfare losses falls primarily on rural households. These conclusions are obtained from a spatial/temporal model solved using a mixed complementarity formulation that easily handles interest rate differentials across space. Efforts to address credit market failures and to improve the efficiency of rural storage should be given priority as opposed to the creation of large, formal sector grain collection centers. © 2001 Elsevier Science B.V. All rights reserved.

JEL classification: O1; Q1; R1

Keywords: Marketing patterns; Dualistic interest rates; Mixed complementarity problem

1. Introduction

In developing country commodity markets, commodity flows from rural to urban zones in the post-harvest period and then back from urban zones to rural zones in the “hungry season” prior to the subsequent harvest were noticed by Timmer (1974) as early as 1974. Such seasonal flow reversals have been studied by Ellsworth and Shapiro (1989) and Barrett (1996). They indicate that grain is transported out of rural zones to urban zones, stored (with interest accruing on the cost of transport), and then transported back to rural zones. The alternative of simply storing and consuming on location, which avoids transport costs and interest on transport costs altogether, appears more attractive from an efficiency viewpoint.

In a recent paper, Benirschka and Binkley (1995) examine interactions between transport costs and storage costs to explain the phenomenon of backwardation in commodity prices. Here, we use the optic developed by Benirschka and Binkley to model seasonal flow reversals (or backward transport) under market regimes where storage costs near rural production zones are high. High storage costs in rural zones would induce farmers to sell immediately post-harvest and repurchase late in the marketing season in order to benefit from more efficient storage elsewhere.

There are three primary costs associated with storage: (1) direct costs of storage such as the cost of preparing the bin and any pesticides that might be applied, (2) storage losses, and (3) the opportunity cost of capital. For cereal crops in Africa, direct storage

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0169-5150/01/$ – see front matter
PII: S0169-5150(00)00084-0

cost and storage loss estimates vary significantly but are often relatively small (Jones, 1984; Arndt, 1993; Coulter, 1996). In contrast, real interest rates, a proxy for the opportunity cost of capital or the marginal utility of current consumption, are high. The seminal work of Jones (1984) found that price rises for cereals corresponded roughly with prevailing rural interest rates of approximately 36% per year in Nigeria. Ellsworth and Shapiro (1989) report intra-year seasonal price increases of 50% for Burkina Faso with direct storage costs and losses accounting for a relatively small share of that figure. Recent nominal price data for Mozambique show white maize prices more than doubling (often tripling) from post-harvest trough to pre-harvest peak in major markets (SIMA, 1998).

While opportunity costs of capital are widely regarded to be high in developing countries, there is good reason to believe that the opportunity cost of capital to rural dwellers might be particularly high. Bottomley (1975) illustrates the increase in average lending cost as loan volume and income of the borrower decrease. Failure of formal financial intermediaries to reach small borrowers with credit services has been documented by Bourne and Graham (1984), von Pischke (1984) and Larson et al. (1994).

The Larson et al. study focussed on Mozambique. They conclude that formal financial institutions serve less than 15% of the population with almost all of those served concentrated in urban areas. More recent survey work by Amimo (1999) found not one farmer in a sample of 105 from Nampula province of Mozambique engaged in formal sector credit arrangements. Own savings represented the primary credit source with intra-village borrowing arrangements accounting for most of the remainder. However, the vast majority of rural income and activity is agriculturally based (Benfica, 1998). As a result, credit needs of village members tend to be concentrated in the same periods decreasing the utility of intra-village credit schemes. The regularity and rapidity of seasonal grain price increases in Mozambique indicate both a constrained ability on the part of small-holders to hold stocks and a strong desire for cash (likely to finance consumption) in the immediate post-harvest period.

Transaction costs offer a highly plausible explanation for the near total absence of formal sector credit in rural Mozambique. Due to centuries of underdevelopment, a decade of civil war, and failed economic policies, rural dwellers are quite uniformly poor and agricultural production is almost entirely small-holder based (National Institute of Statistics, 1998; Arndt et al., 2000a,b). While agricultural credit needs in the aggregate might be substantial, the credit needs of each individual farmer are small. The information required to match formal sector lenders with small-holder borrowers, such that a reasonable probability of repayment exists, is very high (Larson et al., 1994). The destruction of rural marketing systems due to the civil war without doubt exacerbates transaction costs. As a result, even though a functioning banking system exists in urban areas, rural borrowers cannot access formal credit sources directly. [1]

A few traders, on the other hand, can tap relatively inexpensive formal sector credit sources. For example, the state-owned Instituto de Cereais de Moçambique (ICM) maintains a direct credit line with the major commercial bank. ICM disposed 235 000 t of storage capacity in 1992 (Strachan, 1994). Other formal sector storage amounted to nearly 100 000 t in 1992. [2] This formal sector storage capacity substantially exceeds estimated urban demand for maize (see Table 1) and amounts to about one-third of maize supply.

Marketing patterns are often of significant interest to development economists. They are frequently modeled using an optimization approach of the form suggested by Takayama and Judge (1971). Recent applications include Arndt (1993), Masters and Nuppenau (1993), Bivings (1997), Brennan et al. (1997) and Mwanaumo et al. (1997). Baulch (1997) applies the spatial equilibrium conditions of the Takayama and Judge model in a regression framework. He finds that conventional tests for market integration are often misleading. His approach detects efficient arbitrage in rice markets in the Philippines while other approaches do not. Recent work using the Baulch approach for major maize markets (Manica, Maputo, and Beira) in Mozambique favors the hypothesis of market integration, though the data exhibited a higher frequency of abrogation of efficient arbitrage conditions than Baulch found for the Philippines (Penzhorn, 1999). Here, we apply a modified Takayama and Judge

[1] Some formal banking sector credit quite likely does reach rural borrowers indirectly through informal financial intermediaries.

[2] The trend in formal sector storage capacity since 1992 is unknown, at least to the authors.

Table 1
Demand and supply quantity and prices for the 1996–1997 marketing year

Province	Location	Demand (t)		Demand price ($Mt\,kg^{-1}$)		Supply (t)	Surplus (t)
		Rural	Urban	Rural	Urban		
Cabo Delgado	North	70625	9505	1262	1402	81000	870
Niassa	North	47456	9158	791	879	163000	106386
Nampula	North	149676	39535	1257	1143	101000	(88210)
Zambezia	North	185732	22251	1038	1153	184000	(23983)
Tete	North	59065	8291	850	944	92000	24644
Manica	South	34183	11893	1183	1314	155000	108924
Sofala	South	63390	23102	1355	1505	64000	(22492)
Inhambane	South	73346	8861	2761	2510	65000	(17206)
Gaza	South	74817	16127	2984	2713	27000	(63944)
Maputo	South	29260	86489	2811	2555	15000	(100749)
Total	North	512554	88739			621000	19707
Total	South	274994	146473			326000	(95467)
Total	All	787549	235211			947000	(75760)

approach to focus on storage and transport patterns with explicit accounting for dualistic interest rate structures between formal and informal sectors.[3]

Under the traditional Takayama and Judge optimization approach, accounting for dualistic interest rate structures is hard. Instead, we rely on a mixed complementarity problem (MCP) approach to a spatial and temporal equilibrium model. The MCP approach captures the interactions between transport costs and interest rates, which may differ according to location, in a manner which is simple to program and solve (Ferris and Pang, 1997). To the authors' knowledge, this represents the first detailed examination of the effect of dualistic interest rate structures on marketing patterns.

With very large aid inflows and war-torn infrastructure, the Mozambican government is in the process of making fundamental investment and development strategy decisions. Prominent among these is the choice of whether to pursue an agricultural development led industrialization (ADLI) strategy (Adelman, 1984). An ADLI strategy would imply a concerted program of outreach to rural populations in the overall public investment program. A goal of such a program might be to reduce the transaction costs that underlie rural–urban interest rate differentials.

[3] The model focuses on Mozambique, however, the method is applicable to a wide variety of circumstances where interest rates vary across space. For example, under conditions of liberal maize trade in the Southern Africa region, relatively low capital costs in South Africa might substantially influence marketing patterns.

In the simulations, we are interested in the effects on grain markets of changes in interest rate differentials that might come about through the pursuit of alternative development strategies. A given development strategy would entail numerous other effects. For example, recent research indicates that the economy-wide benefits of even relatively small reductions in the transaction costs related to primary agriculture and processed food product marketing could be large (Arndt et al., 2000a,b). Given the difficulties in allocating costs from an investment program, the focus of this study is on the relative magnitude and incidence of benefits derived from changes in rural–urban interest rate differentials.

The remainder of this paper is organized as follows. Section 2 explains the difficulties encountered by an optimization approach when dualistic interest rate structures are present. Section 3 presents the model, data, and underlying assumptions. Section 4 explains model simulations and discusses model results. Section 5 concludes and suggests topics for future research.

2. Modeling marketing patterns under dualistic interest rates

The Takayama and Judge framework is quite flexible and has been applied to a wide variety of issues related to marketing patterns. The solution reflects a competitive market outcome (Samuelson, 1952; Takayama and Judge, 1971). More recently, the basic framework has been expanded to accommodate imperfect competition (Harker, 1986; Kawaguchi et al., 1997). Under the basic Takayama and Judge framework, the impacts of a large variety of policies and market structures can be examined. This list includes, among other items, specific taxes on transport, tariffs on trade with the rest of the world, and a wide array of quantitative restrictions. Nevertheless, the non-linear programming approach to solving models of the Takayama and Judge form is not straightforward for some situations. For example, it is well known that the presence of ad-valorem taxes on trade flows between regions in a spatial model forces the analyst to solve a sequence of non-linear programming problems (Rutherford, 1995). Formally, the presence of ad-valorem taxes destroys integrability. In these instances, setting up and solving the model as an MCP is likely to be more efficient computationally as well as more transparent (Rutherford, 1995).

Differentials in interest rates through space, implemented as differentials in discount rates, also destroys integrability. We show this formally for a general spatial/temporal model presented below. Consider the single commodity spatial/temporal equilibrium problem in the form propounded by Harker (1986).

where the variables imply the following:

Sets

R	set of regions
R^*	set of non-importing/non-exporting regions (a subset of R)
R^{r}	set of rural regions (a subset of R)
R^{u}	set of urban regions (a subset of R)
T	set of time periods $(1,2,\ldots,T)$
T^*	set of non-harvest time periods (a subset of T)
W	set of origin–destination pairs

Functions

Θ_{rt}	inverse demand function
Ψ_{rt}	inverse supply function

Variables

QD_{rt}	quantity demanded
QS_{rt}	quantity supplied
$\mathrm{TR}_{(ijt)}$	quantity transported
ST_{rt}	quantity stocked
X_{rt}	quantity exported
M_{rt}	quantity imported

Parameters

tc_{ij}	total transport cost between regions i and j
sc_{rt}	unit storage cost
δ	discount factor (rate of interest)

$$\max_{\mathrm{QS}_{rt},\,\mathrm{QD}_{rt},\,\mathrm{TR}_{(ijt)},\,\mathrm{ST}_{rt},\,M_{rt},\,X_{rt},} \sum_{t=1}^{T}\left(\frac{1}{1+\delta}\right)\left(\sum_{r\in R}\int_0^{\mathrm{QD}_{rt}}\Theta_{rt}(s)\,\mathrm{d}s-\sum_{r\in R}\int_0^{\mathrm{QS}_{rt}}\Psi_{rt}(s)\,\mathrm{d}s-\sum_{(ij)\in W}\int_0^{\mathrm{TR}_{(ijt)}}\mathrm{tc}_{(ij)}(s)\,\mathrm{d}s\right.$$
$$\left.-\sum_{r\in R}\int_0^{\mathrm{ST}_{rt}}\mathrm{sc}_{rt}(s)\,\mathrm{d}s-\sum_{r\in R}\int_0^{M_{rt}}\mathrm{pm}(s)\,\mathrm{d}s+\textstyle\sum_{r\in R}\displaystyle\int_0^{X_{rt}}\mathrm{px}(s)\,\mathrm{d}s\right)$$

s.t.

$$\mathrm{ST}_{rt+1}\le\mathrm{ST}_{rt}-\mathrm{QD}_{rt}+\mathrm{QS}_{rt}-\sum_{(ri)\in W}\mathrm{TR}_{(rit)}+\sum_{(jr)\in W}\mathrm{TR}_{(jrt)}-X_{rt}+M_{rt}\quad\forall r\in R,\ t\in T,$$
$$\mathrm{QD}_{rt},\mathrm{QS}_{rt},\mathrm{ST}_{rt},X_{rt},M_{rt}\ge 0\quad\forall r\in R,\ t\in T,$$
$$\mathrm{TR}_{(jit)}\ge 0\quad\forall (ij)\in W,$$
$$\mathrm{QS}_{rt}=0\quad\forall r\in R^{\mathrm{u}},$$
$$\mathrm{QS}_{rt}=0\quad\forall r\in R^{\mathrm{r}},\ t\in T^*,$$
$$X_{rt},M_{rt}=0\quad\forall t\in T,\ r\in R^*$$

px export price net of loading
pm import price including unloading and tariffs

Now, consider the partial Lagrangian with respect to strictly positive values for the variables QD, QS, and TR.

$$\frac{\partial L}{\partial \mathrm{QD}_{rt}} = \theta_r\,(\mathrm{QD}_{rt}) - \lambda_{rt}(1+\delta)^t = 0,$$

$$\frac{\partial L}{\partial \mathrm{QS}_{rt}} = \psi_r\,(\mathrm{QS}_{rt}) - \lambda_{rt}(1+\delta)^t = 0,$$

$$\frac{\partial L}{\partial \mathrm{TR}_{ij}} = -\mathrm{tc}_{ij} + (\lambda_{jt} - \lambda_{it})(1+\delta)^t = 0$$

where λ represents the Lagrange multipliers on the storage constraints. The first-order condition with respect to QD states that the interest rate inflated value of the Lagrange multiplier on the storage constraints, λ, must satisfy the inverse demand relationship. In other words, $\lambda_{rt}(1+\delta)^t$ equals the market price in period t and region r. The first-order condition with respect to QS states that the inverse supply condition must be satisfied. Finally, the first-order condition for the transport variable, TR, states that the market price in destination region j must exceed the market price in source region i by the unit cost of transport.

Note the difficulties that arise in this formulation if the discount rate, δ, varies across space. If the discount rate differs between region i and region j, it is not straightforward to specify the price differential relationship in the first-order condition on the transport variable TR.

Intuitively, one could view an interest rate as an ad-valorem tariff on commodity flows through time. Consider the classic price linkage equation in trade models: $p_{\mathrm{w}}(1+\tau) = p_{\mathrm{d}}$, where p represents price, subscripts w and d world and domestic prices, respectively, and τ the ad-valorem tariff rate. Note the exact analogy with an inter-temporal growth rate in price (abstracting from storage losses and specific storage costs): $p_t(1+\delta) = p_{t+1}$ where p represents price, subscripts t and t+1 represent an arbitrary period and the following period, respectively, and δ represents the interest rate as before.

One can easily cope with a single interest (discount) rate (constant across space) in a classical Takayama and Judge optimization formulation by discounting the objective function; yet the presence of interest rate differentials through space causes difficulties very analogous to the presence of ad-valorem tariffs on trade flows. Specifically, integrability of the system of equilibrium equations is lost. To find the solution, one must solve a sequence of optimization problems. Since the dimensionality of spatial/temporal models tends to be high, solving a sequence of optimization problems is computationally expensive and lacks transparency.

Application of the MCP approach to spatial/temporal problems is well explained in Takayama and Uri (1983) and Rutherford (1995). For an integrable spatial/temporal model, the approach involves solving the first-order conditions of the optimization problem as a system of relational inequalities. In this application, accounting for interest rate differentials between urban and rural zones simply involves applying different interest rates as appropriate to the inter-temporal arbitrage conditions, $p_t^z(1+\delta^z) \geq p_{t+1}^z$, where z={rural, urban}. Recent developments in solvers render the MCP approach quite practical for a range of problems, including the spatial/temporal equilibrium problem considered here (Dirkse and Ferris, 1995). Consequently, the MCP approach is preferred here.

The inability to integrate the system of equations into a single objective function also has implications for welfare analysis. In the non-linear programming Takayama and Judge formulation, the maximand is a measure of welfare in the form of Marshallian surplus. This is the measure of welfare invariably used with this type of model. [4] With integrability gone, this measure is not available directly. Assuming interest rate differentials reflect real resource costs, an approach for measuring welfare is to calculate, for the equilibrium derived via the MCP formulation, the Takayama and Judge welfare measure which would have prevailed if an iterative optimization approach had been chosen. This involves deriving unit storage costs, sc_{rt}, from the MCP solution such that the non-linear programming Takayama and Judge formulation yields the same equilibrium as the one derived

[4] The viability of this measure of welfare is somewhat controversial (Willig, 1976, 1979; McKenzie, 1979). In review of the debate, Varian (1992, p. 167) finds that consumer's surplus "may be a reasonable approximation in more general circumstances". For staple crops in developing countries, the income effects of price changes might be uncomfortably large for the use of consumer's surplus as a welfare measure from a theoretical perspective. Nevertheless, consumer's surplus maintains intuitive appeal and is employed here.

via the MCP formulation. This objective value can then be used as the welfare measure. This is the approach taken for the empirical analysis.

3. Model implementation

3.1. Model structure

The model contains 10 regions, corresponding to the 10 provinces in Mozambique, with each region containing an urban and a rural zone. Thus, 20 locations in space are present in the model. The time span considered is 12 months. The beginning time period is March, corresponding to the beginning of the maize harvest season. [5] Southern regions harvest 85% of their production in March and 15% in April. Northern regions harvest a bit later with 85% of their production arriving in April and 15% in March. Production occurs exclusively in rural zones. Domestic transport is possible between urban and rural zones in the same region and between urban zones of different regions. This implies that rural production must first incur costs to enter the marketing system (represented as the urban zone) and then additional fixed and variable costs to be distributed to other regions. Storage is permitted in all regions and zones. There are no storage capacity constraints.

International trade in the form of imports and exports of maize is permitted. International trade occurs in the urban zone of the three regions containing major international ports: Maputo, Beira (in Sofala province), and Nacala (in Nampula province). [6] Demand and supply functions are linear; consequently, the non-linear programming manifestation of the model (when interest rates are constant across space) is a quadratic program and the MCP manifestation of the model is a linear complementarity problem. The model is solved using GAMS/PATH (Brooke et al., 1992; Dirkse and Ferris, 1995).

[5] The model is restricted to a single year since inter-annual storage volumes tend to be small (FAO, 1997).

[6] Informal international trade of maize with neighboring countries is not modeled explicitly. Unrecorded maize trade with neighboring countries exists. Yet, recent estimates indicate that the quantity is quite small and can reasonably be lumped with formal trade for this analysis (Macamo, 1998).

3.2. Data

Economic collapse and war have not been kind to data gathering and analysis systems in Mozambique. As one might expect, data quality is often poor and large information holes persist. Nevertheless, efforts have been made to collect and analyze data since the cessation of hostilities in 1992. For the benchmark period, which starts with the 1996 harvest, data are available on production of maize by province, unit road transport costs, distances between regions, and retail prices of maize in urban zones by province. As is often the case, demand patterns (let alone the elasticity of demand) are less well known. A per capita consumption level of 57 kg per annum is employed, along with statistics on population, to develop benchmark demand functions. The figure is calculated from famine early warning system food balance sheet (Famine Early Warning System, 1997). We follow Masters and Nuppenau (1993) and assume an elasticity of demand of −0.3. Linear supply functions are benchmarked in order to recreate production patterns in the 1996–1997 marketing year assuming an elasticity of supply of 0.6 for the more favorable northern regions plus Manica and an elasticity 0.3 for the drier southern regions. [7] Region location (north or south), benchmark demand and supply quantities, and the benchmark demand price level are shown in Table 1. The table indicates that only Niassa and Manica are major surplus production regions. In addition, the northern provinces, which are often referred to as major surplus regions, produced only a mild surplus in the 1996–1997 marketing year.

Quality data on real interest rates are difficult to obtain. Existing data are obscured by the banking practice of forcing borrowers to pay a portion (if not all) of the "interest" on a loan up front (Moll, 1996). This practice drives up the true real interest rate substantially. Also, since stockholding of maize by consumers can reduce risk, it is unlikely that data on real interest rates reflect time preferences. The values are set to 2 and 3% per month for urban and rural zones, respectively. These values reflect judgement of the authors and an effort to calibrate model results to available base year data. Storage loss rates are set

[7] Sensitivity analysis with respect to these elasticities yielded qualitatively similar results.

to 0.5 and 1% per month for urban and rural zones, respectively. These values are comparable to those employed by Masters and Nuppenau (1993).

The exchange rate is set at 11 400 Meticais per US dollar which reflects a weighted average of available exchange rate information (National Institute of Statistics, 1997). Transport costs over land are set to 480 Meticais km^{-1} t^{-1}. Per kilometer trucking rates from south to north are set at twice this value to reflect differences in up-haul and back-haul rates (Abt Associates, 1992; Coulter, 1996). Also, a transport loss of 1% is assumed to occur with each shipment. The total cost of moving maize between urban and rural zones is assumed to be 73 000 Meticais t^{-1}. Loading/unloading costs are 60 000 and 66 000 Meticais t^{-1} for truck and ship, respectively (Abt Associates, 1992; Coulter, 1996; Miller, 1996; Oceano Consultores, 1996). Export (FOB) and import (CIF) prices are set at \$132 and \$193 t^{-1} reflecting available data on actual export and import prices for white maize (Coulter, 1996; Miller, 1996).

It is worth noting that large changes in world maize prices occurred during the 1996–1997 marketing year. Bellweather US yellow maize prices dropped by about 40% between July and December 1996 (National Agricultural Statistics Service, 1997). No attempt is made here to recreate this world price decline. Instead, the above-mentioned world prices are employed as reasonable expected price levels for white maize which allows for a more general analysis. The tariff laden import price is \$196 reflecting the tariff rate on maize (1.7%) registered in national accounts data for 1996 (National Institute of Statistics, 1997). Maize arriving by ship is assumed to suffer a 5% loss reflecting inefficiencies in the ports (Castro, 1995; Coulter, 1996). Exports and imports pay half of the loading/unloading cost charged to coastal shipping. The gap between prices received for exports net of loading costs and prices paid for imports including unloading costs, tariffs, and losses amounts to more than \$80 t^{-1}.

4. Simulations and results

4.1. Simulation cases

The alternative simulations performed are presented in Table 2. The base case scenario is run with parameters set at benchmark values. In the remaining simulations, all parameters are set at benchmark values except those explicitly changed to analyze the case. All scenarios aim to examine what would have happened in the 1996–1997 marketing year under alternative values for rural interest rates and storage losses. Case 1 examines the implications of an ADLI type development policy that reduces rural–urban interest rate differentials. For simplicity, we examine the extreme case of elimination of differentials in interest and storage loss rates. Case 2 examines the implications of an equi-proportionate reduction in interest and storage loss rates for both urban and rural zones. Case 3 examines the implications of a development strategy focussed on urban zones or simply a subsidy to urban storage. Reductions in interest and storage loss rates occur in urban zones only. In case 3, the relative magnitudes of interest and storage loss rate reductions for urban zones are set to the same proportionate change levels as the relative magnitudes for rural zones examined in case 1.

4.2. Simulation results

A summary of results for the alternative cases is shown in Table 3. In the base case, production quantities and prices reflect benchmark values. Due to the decline in world market prices for maize during the

Table 2
List of simulations

Case	Description	Parameter values			
		Interest rates (% monthly)		Storage loss rates (% monthly)	
		Urban	Rural	Urban	Rural
Base	Base case	2.00	3.00	0.50	1.00
Case 1	More efficient rural storage	2.00	2.00	0.50	0.50
Case 2	More efficient storage	1.50	2.25	0.33	0.67
Case 3	More efficient urban storage	1.33	3.00	0.25	1.00

Table 3
Selected simulation results

	Base	Case 1	Case 2	Case 3
Average price ($\mathrm{Mt\,kg^{-1}}$)[a]	1829	1803	1799	1815
Average harvest price ($\mathrm{Mt\,kg^{-1}}$)	1340	1377	1369	1369
Average rural price ($\mathrm{Mt\,kg^{-1}}$)	1782	1746	1746	1769
Average urban price ($\mathrm{Mt\,kg^{-1}}$)	1980	1986	1967	1960
Total production (t)	947000	957374	956063	956659
Total demand (t)	938573	949116	947591	942714
Total exports (t)	33876	39695	34477	35492
Total imports (t)	66222	62413	58052	52011
Urban storage (t) for May	340367	0	279623	491838
Rural storage (t) for May	398815	748587	470059	255745
Transport cost ($\mathrm{Mt \times 10^{-9}}$)	166	150	160	196

[a] Average prices are calculated by taking a consumption weighted average.

1996–1997 marketing year, model predicted prices diverge somewhat from observed prices especially in import-dependent regions, such as Maputo, in the final third of the marketing year. As in the 1996–1997 marketing season, exports of maize are small and imports fill the gap between supply and demand. All imports in the model base case scenario arrive through the port of Maputo, which is consistent with actual import patterns.

More than half of the total commodity volume stored in the month of May is located in rural zones. Recall that, regarding storage, the rural zone is conceived of as on-farm storage while the urban zone is conceived of as more efficient (lower interest and storage loss rates) off-farm storage. Transport costs between rural and urban zones (and interest charges on transport costs) are sufficiently high to deter movement of most maize to more efficient off-farm storage sites. Transport of this sort occurs primarily in the southern provinces where maize prices, and consequently opportunity costs of capital, are relatively high. This accords with empirical observation and results in a relatively high value for total transport cost.

Case 1 lowers interest rates and storage losses in rural zones such that values for these parameters are equalized between zones. As one might expect, the impact of lower interest and storage loss rates in rural zones is almost uniformly positive. Average consumption prices decline and consumption increases accordingly. At the same time, average harvest prices increase and supply responds accordingly. The reduction in the rate of growth of prices affords this simultaneous benefit on the demand and supply side. Due to reduced interest and storage loss rates, those wishing to stock maize are willing to pay more at harvest; and growth in prices throughout the marketing year is reduced. This reduction in the rate of growth in prices lowers average demand prices even though the initial base for price increases, harvest prices, are higher.

Impacts on prices are strongest, in relative terms, in rural areas with surplus production which are distant from consumption centers. In these areas, maize prices are low; consequently, the opportunity cost of storage is low and the option of transporting maize to a more efficient storage site is least attractive due to the high relative price of transport costs. For example, in the rural zone of Niassa, hungry season (February) maize prices are 16% lower in case 1 compared with the base case. In contrast, hungry season prices in rural Inhambane, a deficit region located near Maputo (the major consumption center), register only a minute decline.

The only welfare decreasing impact in case 1 is a mild increase in the average urban price paid for maize. The increase in urban prices is confined to the southern provinces (not shown). The increase in average prices in Maputo is a particularly strong driver of this result since Maputo is both a relatively high priced region and by far the largest center of urban consumption. Maputo depends primarily upon imports from the rest of the world for maize supplies. In both the base case and case 1, imports to Maputo begin in September. The import price, which is constant across the scenarios, anchors prices for earlier periods. Lower storage costs imply that prices do not need to fall as far below the import parity price level in the immediate post-harvest periods in order to compensate for the costs of storage. Consequently, average maize prices in southern urban regions rise. The price increases, however, are not large. Prices in Maputo in March, the period for which this effect would be strongest, are lower in the base case relative to case 1 by less than 1%.

As predicted by Benirschka and Binkley, maize storage occurs completely in rural zones when storage costs are equal.[8] Equalization of interest and storage loss rates between zones eliminates any incentive to transport and then store. Rural storage volumes for the month of May, the first non-harvest month of the marketing year, almost double in case 1 relative to the base case. Consequently, trucking volumes (not shown), defined as the sum of all transport variables, fall by about 217 000 t. This implies, in very rough terms, that approximately 108 000 t (half the decline in trucking volume) was first transported out of rural zones and then transported back to rural zones later in the marketing season in the base case. This amounts to about 14% of benchmark rural demand.

As mentioned above, the presence of interest rate differentials between urban and rural zones complicates welfare analysis. In the welfare analysis, interest rate differentials and transport costs are assumed to fully reflect real resource costs. This is not necessarily the case. The interest rate differentials might also reflect market distortions such as interest rate subsidies, imperfect competition in credit delivery to rural areas, and/or simple market inefficiency. In this case, transport to avoid high cost rural storage would be inefficient. By assuming that interest rate differentials reflect real resource costs, we implicitly choose the welfare measure most favorable to urban storage.[9] As mentioned above, welfare is calculated from the Takayama and Judge measure which would have prevailed if an iterative non-linear programming optimization scheme had been employed. This welfare measure is presented in Table 4.

Table 4 also decomposes the welfare changes for each experiment relative to the base. Each element of the decomposition is a component of the Takayama and Judge measure. The Takayama and Judge welfare measure maximizes consumer and producer surplus less costs. The surplus measure is arrived at by subtracting the area under the supply curve from the area under the demand curve. In the decomposition, the areas under the supply and demand curves are separately presented. In addition, the major cost items (transport cost, storage cost, and value of exports less value of imports) are presented. All figures are presented as differences from the base case. Reductions in storage costs, transport costs and imports all contribute to a welfare gain in case 1.

Table 4
Welfare contribution by component — difference from base case (billions of Meticais)

	Case 1	Case 2	Case 3
Area under demand curve	16.4	14.6	7.5
Area under supply curve	−18.0	−15.5	−16.0
Transport cost	18.3	6.1	−36.9
Storage cost	22.3	26.4	43.9
Exports–imports	16.0	18.0	32.4
Total	55.0	49.6	30.9

In case 2, interest and storage loss rates are reduced relative to the base case by 25 and 33%, respectively, for both rural and urban zones. Relative to the base case, average purchase prices decline while average harvest prices increase. Production, demand, exports and rural storage volumes increase while imports, trucking volume, and urban storage volumes decrease. The reasons for these impacts are very similar to the reasons cited for the impacts in case 1. These changes result in welfare gains relative to the base case.

The total welfare gain and the source of the welfare gain between case 1 and case 2 form an interesting comparison. In case 2, agents have access to urban interest and storage loss rates which are 25 and 33% lower, respectively, than in case 1. Rural interest and storage loss rates are 12.5 and 33% higher in case 2 as compared with case 1 (see Table 2). Even though very efficient storage, relative to case 1, is available in the urban zones, the welfare increase is higher in case 1 compared with case 2. The primary contributor to the difference is transport cost. Case 1 obtains a much higher welfare gain from reduced transport cost than case 2. This occurs because, in order to profit from urban storage, transport cost must be incurred.

[8] Urban purchasers of maize, such as millers, stock no more than 1 month's supply.

[9] We also implicitly assume that transport costs reflect the real cost of road usage including depreciation. If transport costs fail to reflect the real cost of road usage, the benefits of reduced interest rate differentials would also be understated due to the reduction in transport volumes.

As a result, while case 2 reaps large gains from less costly storage, these gains are partially offset by higher transport costs.

In case 3, urban interest and storage loss rates are reduced in the same proportions as rural rates in case 1. As in cases 1 and 2, average consumption prices fall and harvest prices rise. However, welfare gains in case 1 are close to double those in case 3. Two factors drive this difference. First, the same proportionate decline in interest and storage loss rates leads to a larger absolute decline in rural rates since rural rates started at higher levels. Second, in case 3 as in case 2, maize must be transported from rural zones to urban zones in order to profit from lower interest and storage loss rates in urban zones. Total transport costs increase by 18% relative to the base case. Using the decomposition in Table 4, one finds that the increase in transport costs offsets 85% of the storage cost benefits derived from lower urban interest rates.

The results obtained have distributional consequences as well. While poverty certainly exists in urban areas, rural poverty in Mozambique is more acute (Addison and McDonald, 1995). In addition, the rural population is approximately four times the size of the urban population (Bardalez, 1997). Table 5 illustrates producer and consumer surplus measures with the consumer surplus measure divided into rural and urban zones. When only urban interest and storage loss rates decline (case 3), rural consumers benefit relatively little. The table also indicates that elimination of the interest rate differential between urban and rural zones (case 1) benefits rural zones exclusively in the form of increased producer and consumer surplus. Producers are particularly large gainers. Urban zones actually experience a mild decline in consumer surplus. This indicates that, unlike many efficiency advances in the agricultural sector, the benefits of reduced rural interest and storage loss rates tend not to get passed on to urban households in the form of lower urban maize prices.

Table 5
Producer surplus and consumer surplus by zone — difference from base case (billions of Meticais)

	Case 1	Case 2	Case 3
Producer surplus	31.6	24.3	25.1
Consumer surplus			
Rural	22.6	23.3	8.6
Urban	−1.3	2.3	3.7
Total	52.8	49.9	37.4

The intuition behind these results is as follows. With friction-free credit markets (i.e., no interest rate differentials) and reasonably efficient rural storage technologies, the bulk of storage would tend to take place on-farm or near farm in rural zones. In the presence of impediments to delivering credit to rural zones, substantial storage can occur in urban zones in order to take advantage of lower costs of credit. To compensate for these credit impediments, rural producers must sell at a lower price in order to either cover high rural storage costs or the costs of transport (plus accrued interest on that transport cost over the duration of storage) to lower cost storage sites. In the periods immediately following harvest, rural zones will tend to rely on local stocks; consequently, price increases must be sufficiently high to cover the costs associated with inefficient rural storage. As the marketing season progresses, the rapid rate of price increase in rural zones may push rural prices sufficiently high to cover costs of transport back from urban zones. Only then do rural household begin to enjoy the benefits of moderate price increases associated with urban storage. Consequently, rural consumers reap a relatively small share of the benefits of lower urban interest and storage loss rates.

If interest rate differentials are eliminated and rural households have access to reasonably efficient storage technology, self-sufficient rural regions pay no transport cost at all (abstracting from movements within that region's rural zone) and all rural households benefit from efficient storage immediately. In contrast, regardless of the presence or absence of an interest rate differential, urban households pay transport costs once and benefit immediately from the most efficient storage option. Given this disparity of impacts of dualistic interest rate structures between urban and rural zones, it is not surprising that rural households reap the lion's share (if not all) of the benefits from reduced or eliminated interest rate differentials.

5. Summary, policy implications, and suggestions for future research

An MCP approach was applied to a spatial/temporal equilibrium model of maize markets in Mozambique.

Relative to traditional optimization approaches, the MCP approach permits examination of the impact of dualistic interest rate structures on maize marketing patterns in a manner which is simple to program and solve. Empirical results indicate that divergences in interest rates and storage loss rates across space may have significant impacts on marketing patterns. Reductions in these divergences improve welfare, and these welfare gains tend to accrue almost exclusively to rural inhabitants, a group that is poor.

The incidence of these gains is a key finding. Benirschka and Binkley (1995) show that, when markets are efficient, long duration storage should occur in production zones distant from consumption centers. Consistent with Benirschka and Binkley, we find welfare gains when progress towards this efficient ideal is realized. Without the aid of a model, the incidence of these gains is unclear. Long experience indicates that the benefits of technical changes in the agricultural sector often accrue to urban consumers in the form of lower prices. We show that policies that reduce interest rate differentials are likely to enhance both efficiency and equity.

Policies that address the transaction costs that underlie rural–urban interest differentials include: energetic provision of market information (both current prices and historical price series), investments in rural communications infrastructure, and provisions of incentives for banks to establish rural subsidiaries. The latter policy option need not entail direct subsidies to banks. Rather, fostering the development of technologies that might enhance the efficiency of credit delivery to rural zones might be a more attractive option. As mentioned in Section 1, information barriers significantly hamper credit distribution. Information age technology seems well suited to lowering at least some of these barriers. Our results indicate that all of these polices should form a part of an ADLI-based development strategy.

A second key finding relates to case 3. Results from this case indicate that establishing a relatively few, but very efficient, grain storage locales while ignoring rural storage technology and credit constraints is not likely to be the best policy. In Mozambique as well as in other parts of Africa, efforts have been made to support more formalized storage depots — presumably at the expense of programs to develop and extend more efficient on-farm storage (Coulter, 1996). As in case 3, this policy could serve mainly to increase transport volumes, with transport costs and interest charges on grain which has been transported and then stocked essentially offsetting the increases in urban zone storage efficiency. If storage cost differentials are the results of subsidies to urban zone storage, the combination of increased transport costs and subsidy burden, could easily lead to significant welfare losses.

In terms of future research, these results highlight the need to study rural credit markets, storage technology, and access to market information. In addition, detailed examination of actual marketing patterns would help in refining analytical approaches and strengthening the empirical basis for parameter values employed. Finally, the role of risk in influencing storage behavior and marketing patterns needs to be examined.

Acknowledgements

We thank an anonymous reviewer for valuable comments.

References

Abt Associates, 1992. Mozambique private sector road transport study. Report Prepared for USAID Contract No. DPE-0016-Q-00-1002-00.

Addison, T., McDonald, I., 1995. Rural livelihoods and poverty in Mozambique. Poverty Alleviation Unit, Ministry of Planning and Finance, Mozambique.

Adelman, I., 1984. Beyond export led growth. World Dev. 12, 11–34.

Amimo, O., 1999. The potential for financial savings in rural Mozambican households: demand and supply side determinants. M.Sc. Thesis. Department of Agricultural Economics, The Ohio State University, Columbus, OH.

Arndt, C., 1993. Analysis of spatial and temporal wheat price variation in Morocco under alternative trade regimes. Cereals Marketing Reform Project. Development Alternatives, Inc, Bethesda, MD.

Arndt, C., Jensen, H.T., Tarp, F., 2000a. Marketing margins and agricultural technology in Mozambique. J. Dev. Stud., in press.

Arndt, C., Jensen, H.T., Tarp, F., 2000b. Stabilization and structural adjustment in Mozambique: an appraisal. J. Int. Dev. 12, 299–323.

Bardalez, J.R., 1997. Moçambique: Projeccoes da Populacao Total do Pais a Nivel Provincial, Distrital e Cidades, Periodo 1991–2000. National Institute of Statistics, Maputo, Mozambique.

Barrett, C.B., 1996. Urban bias in price risk: the geography of food price distributions in low-income economies. J. Dev. Stud. 32, 830–849.

Baulch, B., 1997. Transfer costs, spatial arbitrage, and testing for food market integration. Am. J. Agric. Econ. 79, 477–487.

Benfica, R.M.S., 1998. An analysis of the contribution of micro- and small-enterprises to rural household income in central and northern Mozambique. M.Sc. Thesis. Department of Agricultural Economics, Michigan State University, East Lansing, MI.

Benirschka, M., Binkley, J.K., 1995. Optimal storage and marketing over space and time. Am. J. Agric. Econ. 79, 512–524.

Bivings, E.L., 1997. The seasonal and spatial dimensions of sorghum market liberalization in Mexico. Am. J. Agric. Econ. 79, 383–393.

Bottomley, A., 1975. Interest rate determination in underdeveloped rural areas. Am. J. Agric. Econ. 57, 279–291.

Bourne, C., Graham, D.H., 1984. Problems with specialized agricultural lenders. In: Adams, D.W., Graham, D.H., von Pischke, J.D. (Eds.), Undermining Rural Development with Cheap Credit. Westview Press, Boulder, CO.

Brennan, D., Williams, J., Wright, B.D., 1997. Convenience yield without the convenience: a spatial–temporal interpretation of storage under backwardation. Econ. J. 107, 1009–1022.

Brooke, A., Kendrick, D., Meeraus., A., 1992. GAMS: A User's Guide. The World Bank, Washington, DC, p. 285.

Castro, R., 1995. Mozambique: impediments to industrial sector recovery. The World Bank Report No. 13752-MOZ.

Coulter, J.P., 1996. Maize marketing and pricing study — Mozambique. Report No. R 2247 (C). Overseas Development Administration, Natural Resources Institute.

Dirkse, S.P., Ferris, M.C., 1995. The PATH solver: a non-monotone stabilization scheme for mixed complementarity problems. Optimization Meth. Software 5, 123–156.

Ellsworth, L., Shapiro, K., 1989. Seasonality in Burkina Faso grain marketing: farmer strategies and government policy. In: Shan, D.E. (Ed.), Seasonal Variability in Third World Agriculture: The Consequences for Food Security. John Hopkins University Press, Baltimore, MD, pp. 196–205.

Famine Early Warning System, 1997. Electronic data. Southern Africa Development Community, Harare.

FAO, 1997. Electronic data. www.fao.org.

Ferris, M.C., Pang, J.S., 1997. Engineering and economic applications of complementarity problems. SIAM Rev. 39, 669–713.

Harker, P., 1986. Alternative models of spatial competition. Oper. Res. 34, 410–425.

Jones, W.O., 1984. Economic tasks for food marketing boards in tropical Africa. Food Res. Inst. Stud. 19, 113–138.

Kawaguchi, T., Suzuki, N., Kaiser, H.M., 1997. A spatial equilibrium model for imperfectly competitive milk markets. Am. J. Agric. Econ. 79, 851–859.

Larson, D.W., Zaqueu, F., Graham, D.H., 1994. Why users prefer informal financial market services: the case of Mozambique. In: Selected Papers at the Proceedings of the XXIInd Conference of the International Association of Agricultural Economists, Harare, Zimbabwe.

Macamo, J.L., 1998. Estimates of unrecorded cross-border trade between Mozambique and her neighbors: implications for food security. United States Agency for International Development, Regional Economic Development Supports Office for Eastern and Southern Africa.

Masters, W., Nuppenau, E., 1993. Panterritorial versus regional pricing for maize in Zimbabwe. World Dev. 21, 1647–1658.

McKenzie, G.W., 1979. Consumer's surplus without apology: comment. Am. Econ. Rev. 69, 465–468.

Miller, E.H., 1996. Maize marketing strategy: Mozambique. United States Agency for International Development, Maputo, Mozambique.

Moll, P.G., 1996. Mozambique: agricultural sector memorandum. The World Bank, Washington, DC.

Mwanaumo, A., Masters, W.A., Preckel, P.V., 1997. A spatial analysis of maize marketing policy reforms in Zambia. Am. J. Agric. Econ. 79, 514–523.

National Agricultural Statistics Service, 1997. Electronic data. United States Department of Agriculture.

National Institute of Statistics, 1997. National accounts in electronic form. National Institute of Statistics, Maputo, Mozambique.

National Institute of Statistics, 1998. Preliminary national household survey results. National Institute of Statistics, Maputo, Mozambique.

Oceano Consultores, 1996. The challenge for coastal shipping in Mozambique. United States Agency for International Development, Maputo, Mozambique.

Penzhorn, N., 1999. Market integration and transport costs between major corn markets in Mozambique. Mimeo. Department of Agricultural Economics, Purdue University, West Lafayette, IN.

Rutherford, T.F., 1995. Extension of GAMS for complementarity problems arising in applied economic analysis. J. Econ. Dyn. Control 19, 1299–1324.

Samuelson, P.A., 1952. Spatial price equilibrium and linear programming. Am. Econ. Rev. 42, 283–303.

SIMA, 1998. Electronic data. Economic Studies Unit, Ministry of Agriculture, Mozambique.

Strachan, L.W., 1994. Agricultural marketing and input supply. Mozambique Agriculture Sector Survey. The World Bank, Washington, DC.

Takayama, T., Judge, G.G., 1971. Spatial and Temporal Price and Allocation Models. North-Holland, Amsterdam, 528 pp.

Takayama, T., Uri, N.D., 1983. A note on spatial and temporal price and allocation modeling: quadratic programming or linear complementarity programming? Reg. Sci. Urban Econ. 13, 455–470.

Timmer, C.P., 1974. A model of rice marketing margins in Indonesia. FRI Stud. 13, 145–167.

Varian, H.R., 1992. Microeconomic Analysis, 3rd Edition. W.W. Norton and Company, New York, 506 pp.

von Pischke, J.D., 1984. Improving donor intervention in rural finance. In: Adams, D.W., Graham, D.H. (Eds.), Undermining Rural Development with Cheap Credit. Westview Special Studies in Social, Political and Economic Development Series. Westview Press, Boulder, CO, pp. 284–297.

Willig, R.D., 1976. Consumer's surplus without apology. Am. Econ. Rev. 66, 589–597.

Willig, R.D., 1979. Consumer's surplus without apology: reply. Am. Econ. Rev. 69, 469–474.