SPATIAL ARBITRAGE AND MAIZE PRICE DYNAMICS IN MOZAMBIQUE

By

EMILIO TOSTAO

Bachelor of Science (Honors)
Universidade Eduardo Mondlane
Maputo, Mozambique
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SPATIAL ARBITRAGE AND MAIZE PRICE DYNAMICS IN MOZAMBIQUE

Thesis Approved:

Wade Brorsen

Thesis Adviser

Brian Adam

Daniel S. Tilley

Timothy J. Pettibone

Dean of the Graduate College

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CHAPTER I

INTRODUCTION

" ..., *the newly liberalized food marketing systems created new challenges and risks for governments. In each country, major concerns arose over how to contain food price instability and source adequate supplies of maize grain during local production shortfalls.*" (Jayne et al. 1999, p.6).

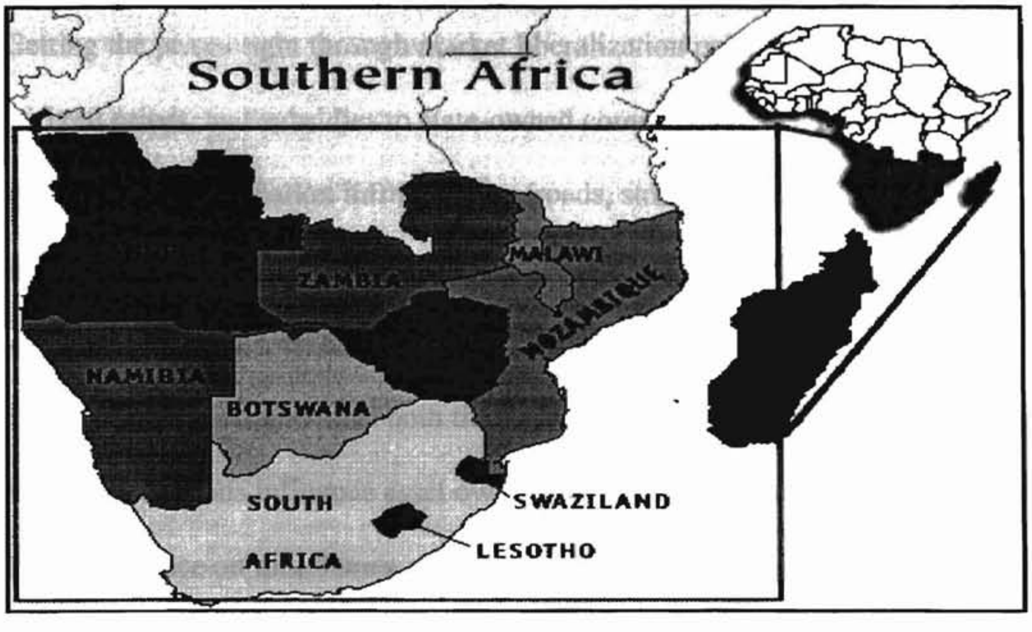
1.1 Background

Until recently, Mozambique and most countries in the Southern Africa (SA) region had centrally planned and controlled economies. The control of the agricultural food sector was pursued by creating large state farms and marketing boards that were granted a monopoly on maize trade, establishing a system of fixed prices over space and time (a policy of pan-territorial and pan-seasonal pricing), and subsidizing consumers.

With varying motivations, scope and speed, most countries in the SA region (see figure 1.1) embraced structural adjustment programs (SAPs) starting from the early 1980s (World Bank; Jayne et al.; Kahkonen and Leathers). In general, the SAP included a gradual privatization of state enterprises, currency devaluation, agricultural food price liberalization and removal of other tariff and non-tariff trade barriers. In addition, countries in the SA region engaged in regional and multilateral trade agreements, and formed trade blocks to facilitate trade among members and discriminate against outsiders.

White maize is the most important food staple in Mozambique and in the SA region. It is both the main source of calories and the largest produced crop (Van Rooyen and Sigwele). However, as reforms influenced sectoral and regional growth patterns, shifted relative prices of goods, and reshaped economic and social institutions, new concerns about maize production, consumption, and trade emerged. Indeed, the effect of food market reforms on the vast majority of the population of the SA region, which is mainly rural and believed to live in poverty and food insecurity (Van Rooyen and Sigwele), remains controversial. While the implementation of SAPs has stalled in some countries of the SA region (e.g. Zimbabwe), the reforms have continued for the last 15 years without significant reversals in Mozambique.

Figure 1.1. Map of the Southern Africa Region



1.2 Research Problem

More than ten years have passed since Mozambique and most countries of the SA region reformed their food-crop market and made trade agreements to promote market-based economies, yet price instabilities and maize shortages are still puzzling local populations and governments (Jayne et al.). Inefficiency in spatial arbitrage is a possible explanation of why food shortages continue to be a problem in spite of the market reforms in Mozambique. When spatial trade is efficient, food shortages in deficit regions are transmitted to surplus regions via prices, and arbitrage triggers flows of food across space. Consumers from deficit regions pay lower food prices and producers from surplus regions receive higher prices and, therefore, have an incentive to increase production. Through efficient spatial arbitrage, the risk of crop failure in some regions is shared over a large market area, prices are more stable, and food shortages may be prevented. It is, therefore, difficult to overemphasize the need for spatial trade between spatially dispersed maize markets.

Getting the prices right through market liberalization policies such as ending the system of fixed prices, and subsidies to state-owned companies may not be sufficient to trigger spatial arbitrage if market infrastructure (roads, storage facilities), and institutional arrangements (financial institutions, market information, trading norms, dispute settlement mechanisms) are inadequate. Poor road infrastructure may impose high transportation costs and limit both the diffusion of price information and the market area. Market institutions influence asset ownership (physical, financial) and business practices such as reliance on middlemen and investment and specialization in agricultural trade.

Empirical evidence suggests that many countries implementing market reforms have failed to grow partly due to undeveloped public infrastructure such as roads (World Bank).

In the transition to a market-based economy when marketing boards and state companies are dismantled, the questions are how did maize markets respond? How integrated are spatially dispersed maize markets? Are they functioning well enough to drive maize from surplus regions to deficit ones? Is the road network adequate? The assessment of spatial market integration and price dynamics is the starting point to measure the performance of the food market in the post-reform period. Knowledge of how shocks in one regional maize market are transmitted to other markets is an empirical question, and has implications for economic policy (e.g. mitigation of food shortages; food security).

1.3 Research Objectives

The general objective of this research is to assess spatial maize trade and price dynamics during the post-reform period in Mozambique. More specifically this study aims to:

1) Estimate the efficiency of spatial maize price arbitrage after maize price liberalization in Mozambique;

2) Determine lead-lag relationships among interregional maize prices in Mozambique.

1.4 Contribution to Literature and Summary of Procedures

The literature on market integration is vast, and the techniques used to assess spatial arbitrage are increasingly sophisticated. However, studies on spatial trade in the SA region are very few. The SA region is an unusual region because: a) the food market reforms have been carried out simultaneously in most countries in the region, b) the food market reforms have been implemented in a hostile environment (regional wars and climate shocks), c) the vast majority of the population is poor (Van Rooyen and Sigwele), d) the phasing of reforms have generated some controversy, e) some countries have been experiencing policy reversals (Jayne et al.), and f) the data quality tends to be poor (here many observations that are missing). For example, the food reforms in Mozambique were initiated while the country was in its third successive war and had millions of displaced (poor) people. Yet, attempts to assess trade links between spatial maize markets in Mozambique are very few. Using price correlations, Tschirley and Santos, and Zavala found evidence that maize markets are becoming integrated in Mozambique. However, these studies rely on price correlations that often lead to erroneous conclusions (Harris; Baulch; Li and Barrett).

This study contributes to the literature in two ways. First, it uses more data (eight years of weekly and monthly maize price data) and covers a larger geographical area (entire Mozambique) than past studies. Second, unlike previous studies, this work combines two approaches: the Baulch's parity bound model (PBM) is used to directly measure the efficiency of spatial arbitrage, and time-series procedures are used to model price dynamics. The PBM is a switching regression that accounts for nonstationary transfer costs and trade discontinuities that often cause bias and inconsistency of parameter estimates from models that use only prices to make inferences about market integration (Barrett). In this study, time-series procedures are used to capture price dynamics, and measure causal flows between spatial maize prices, not as a test of market integration.

1.5 Organization of the Thesis

This paper is organized in six chapters. Chapter II provides further background about Mozambique. It provides the history of Mozambique's economic reforms since 1975, including a description of the maize marketing sector. Chapter III presents the theoretical framework relevant to analyzing maize markets in Mozambique. The data, data sources and the modeling procedures are detailed in chapter IV. This chapter describes the data used to accomplish the study objectives, and builds up the switching regression model used to test for arbitrage efficiency, and the time series models used to analyze price dynamics. The results are presented, and discussed in chapter V. The interpretation of empirical results provides an understanding of the extent to which markets are integrated in Mozambique, and the lead-lag relationships between spatial maize markets. Finally, chapter six summarizes the results of the research, discusses study limitations, and makes suggestions for future research in light of lessons learned.

CHAPTER II

THE MAIZE MARKETING CHANNEL IN MOZAMBIQUE

2.1 Introduction

This chapter describes the organization of the maize marketing channel and gives some historical background of the market environment and food market transformations in the past decade in Mozambique. The discussion includes trader's access to transportation infrastructure, information, and credit. Harris, and Benson and Faminow argue that empirical models should be derived from the general economic theory by choosing appropriate constraints or assumptions that reflect the market structure and organization. Further, an understanding of the data generating process allows correct interpretation of the results (Harris).

The plan of the chapter is as follows. First, a general background about the market environment in Mozambique in the past two decades is briefly provided in section 2.2. The regulation and the deregulation of the Maize sector are discussed in section 2.3 and 2.4 respectively. Next, maize market information and the transportation infrastructure are described in section 2.5. A description of the maize marketing channel and its participants is provided in section 2.6. Section 2.7 discusses storage and credit arrangements, and section 2.8 concludes.

2.2 General Background About Mozambique

Mozambique is located in the Southern African (SA) region, and has approximately 17 million inhabitants over an area of 799,380 square kilometers. Agriculture is the main economic sector in Mozambique. It makes up 30% of GDP, employs over 80% of the active population (PARPA; DPDS-UEM-IFPRI), and provides more than 80% of foreign exchange earnings (Jeje et al.). Maize is the main staple food. It is both the largest produced and consumed crop (DPDS-UEM-IFPRI).

After 500 years of colonization, Mozambique gained its independence from Portugal in 1975. Since then, Mozambique faced military incursions of the (then) Rhodesia (1976 to 1979), floods (1977 and 1978), border closure and continuous layoff of Mozambican miners working in South Africa, internal civil war fueled by cold war interests (1981-1991), and droughts (1982). These events led the Mozambique into a deep recession that brought much of the population near starvation (World Bank; Landau). The wars destroyed almost all infrastructure and displaced millions of people. The country was considered the poorest in the world in the early 1990's (Landau; World Bank). By 1992 the civil war was over, and in 1994 Mozambique successfully held its first national democratic elections.

Economic development during the colonial period was very modest (Mucavele). The (few) investments made by the colonizers were channeled to plantations intended to supply Portugal with raw materials such as sugar cane, tea, cotton and cashew (Jeje et al.). After independence in 1975, the new Government of Mozambique (GoM) continued operating a command economy, adopted Marxist-Leninist policy, and attempted to collectivize agriculture (White). The procurement, distribution, and processing of food was exclusively undertaken by heavily subsidized government-owned companies. These policies, combined with the effect of the wars, droughts, and weakening support from the Soviet Union, resulted in budget deficits and food shortages.

The policy change in Mozambique began in 1983 (see table 1) when the ruling party, *FRELIMO*, acknowledged that it had made a mistake in emphasizing state farms rather than the "family sector". The GoM began to reduce some controls and offer more opportunities to the private sector (White).

In September 1984, Mozambique joined the International Monetary Fund (IMF) and World Bank (WB), and in July 1987 launched the Economic Rehabilitation Program (ERP), a structural adjustment package supported by the IMF and the WB. The objective of ERP was, among others, to end budget deficits and stabilize the economy through currency devaluation and reduced public expenditures (World Bank). The economic policy also included rehabilitation and privatization of state enterprises, trade liberalization, and some deregulation of prices and interest rates (see table 1, p.7). The ERP was implemented in a hostile environment as droughts and the escalating civil war continued to ruin the economy. In 1990, the Economic and Social Rehabilitation Program (ESRP) succeeded the ERP, providing the basic framework for current economic and social policy.

Table 2.1. Policy Changes in Mozambique, 1975-2000.

	1975-83: Building a centrally-planned economy	1983-86: Partial liberalization	1987-present: More intensive reform
Fiscal policy and public sector reform	Party and state merged, expansionary fiscal policy partly due to war.	Fiscal restraint with prioritization of completing ongoing projects and rehabilitation.	1987: income tax reform; 1997 onwards: reform of the budget system; 1998: tax reforms; public sector salary decompression; 1999: VAT introduced; new civil service salary structure.
State owned enterprises / private sector development	Nationalization of social activities (e.g. rented housing and funeral services).	Some encouragement to private activity, but no reform of state owned enterprises.	1987: privatization begun with 30 small enterprises; 1989: law for privatization; by 1998 over 900 enterprises privatized; 1999: completion of privatization of small and medium-sized enterprises (by mid-99 1,200 privatizations).
Monetary and financial policy	1980: new currency (metical) introduced.	Directed credit at subsidized rates continued.	1987: increase in interest rates; separation of Bank of Mozambique (BoM) into BoM and Commercial Bank of Mozambique (BCM); 1996: privatization of BCM, interest rates liberalized; 1999 end of credit ceilings; BoM authorized to issue T-Bills for monetary control purposes.
Price policy	Price controls extended over a large range of commodities.	Controls on fruits and some vegetables and meats removed, and price of staples rose by up to four times the original level.	1987: many subsidies eliminated; minimum prices replace fixed prices for several crops (1989), extended to maize and rice (1990), beer and tobacco (1991), and consumer prices of rice, sugar and milk (1992 also beef producer price fell); all other prices except those produced under monopolistic conditions (1993).
Exchange rate Policy	Fixed exchange rate (and licenses/ quotas on external trade).	Export retention scheme introduced (on case- by-case basis).	1987: 400 % devaluation (January) and subsequent further devaluations; 1989: The *Sistema nao-Administrativo de Alocacao de Divisas* established; 1990: secondary market established; 1992: official rate linked to secondary market, leading to unification of official and secondary markets.
Policy Trade	State monopolies of external trade and domestic wholesale activities.	Authorization of some agricultural enterprises to engage in external trade. Reduction in number of commodities covered by monopoly trading company and/or with centrally administered inter- regional trade.	1989: start of tariff reform and strengthening of customs; 1991: six tariff rates, maximum 35%; 1996: import tariffs simplified, with 18% average tariff; 1997: customs management privatized; 1999: maximum tariff reduced to 30%.

Source: Adapted from White (1999)

Table 2.1. Policy Changes in Mozambique, 1975-2000 (Continued)

	1975-83: Building a centrally-planned economy	1983-86: Partial liberalization	1987-present: More intensive reform
Agricultural policy	Large project approach, state farms and communal villages. State farms received most government support, so communalization limited, and 90 per cent rural population on individual farms outside this system.	Price decontrol for selected commodities and trade permitted (see other categories in table).	1987: break up of largest state farms; 1995: cashew liberalization; 1997: land Law; 1999: begin implementation of Agricultural Program (PROAGRI).
Social sectors	Expansion of social services.	Destruction of social infrastructure during war.	Attempts to protect social spending from early 90s and to increase quality from mid-90s. 1995: adoption of Health Sector Recovery Program. 1999: Poverty Action Plan adopted by Council of Ministers; adoption Education Sector Strategic Program.
Foreign investment	Little foreign investment from Western countries.	Foreign investment code.	Further encouragement, including sale of land to foreigners.
Labor markets	Controlled labor market in state/modern sector.	New labor law gives managers greater autonomy in hiring, firing and pay.	Rise of trade union movement, but real minimum wage falls.
Politics/ Governance	1977: Marxist-Leninism adopted as official ideology, FRELIMO remodels itself as a vanguard party; 1982: FRELIMO reverts to populism to rebuild party.	1983: 4th FRELIMO party congress marks shift in policy; 1984: Nkomati Accord (March).	1990: new constitution; 1992: peace accord; 1994: multi-party elections (October); 1999: elections; one of 11 countries to draft and the 25 Principles to Combat Corruption in African Countries.
Aid	Reliance on Soviet aid, some support from Progressive Development Assistance Committee (DAC) donors.	1984: joined IMF/World Bank (IFIs); USAID starts aid; 1986: start policy discussions with IFIs.	1987:first IMF loan; Paris and London Club rescheduling; 1992: end of Soviet aid; 1995:bilateral donors publicly disagree with IMF; 1999: HIPIC (Highly Indebted Poor Country) completion point.

Source: Adapted from White (1999)

Since 1996, albeit from a tiny base, Mozambique has been experiencing remarkable economic growth reflecting the expansion in agriculture and exports, and inflow of new investments (World Bank). Such economic growth has come with single digit[1] inflation, stable foreign exchange rate, and a 7-10 % GDP growth rate[2] (PARPA; UNDP). Despite the reported economic progress, over two thirds of Mozambicans, living predominantly in rural areas, fall below the poverty line and are believed to live in absolute poverty (DPDS-UEM-IFPRI; PARPA). Foreign debt has doubled from 1986 to 1997, and the country still depends on foreign aid to balance the budget (World Bank).

2.3 The Regularization of the Maize Market

State intervention in the Mozambican maize sector dates from colonial times, and was continued in post-independence Mozambique. Like many other countries of the SA region, maize was the foundation of an implicit "social contract" that the new GoM made with the people to restore smallholder agriculture that was abandoned during the colonial period (Jayne et al.). Yet, government intervention did not emphasize smallholder agriculture. Rather, the GoM adopted a system of fixed prices over time and space, and created large state farms and geographic maize monopolies.

In 1981, with support of Nordic aid, the GoM founded its main grain marketing company AGRICOM. AGRICOM had a mandate to guarantee disbursement of maize to consumers and inputs to producers of all regions of the country while "protecting" maize producers from losses via pan-territorial and pan-seasonal pricing. The fixed-price system also

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[1] The inflation rate was between 30 – 70% since 1986 (WB). According to the GoM, the inflation grew to 13% in 1999/2000 mainly due to floods.

[2] The GDP growth of only 2.1% in 2000 is due to floods (IMF).

aimed to control the margins earned by private traders whose selection was under tight regulatory scrutiny. The approval and licensing of private traders was directly controlled by the Ministry of Trade and Industry (Coulter; Macamo).

Notably important during the civil war period (1982-1992) that ruined physical infrastructure and the economy as a whole, AGRICOM accumulated debts that could no longer be covered by either the Nordic aid or the GoM (Coulter; Macamo). In 1994, and under the ERP-ESRP, AGRICOM was restructured and renamed the *Instituto de Cereais de Mocambique* (ICM), a grain-marketing para-statal with a similar mandate.

2.4 The Deregulation of the Maize Market

By the mid 1980's the GoM realized that the planned economy had failed. Mozambique was facing severe budget deficits and was not able to feed its people. The ongoing civil war eroded the infrastructure, disrupted production, trade, social services, and displaced millions of people (World Bank). These compound problems led the GoM to adopt the donor-supported structural adjustment program (SAP).

One of the ERP-ESRP policies was gradual elimination of subsidies on state enterprises followed by privatization. The ICM was created under this policy. It inherited part of AGRICOM's personnel and all physical assets, which included 120 storage facilities and 235,000[3] metric tons of usable storage (Coulter). However, AGRICOM's liabilities were passed to the GoM. The mandate of ICM was thought to be a modest one. It included the supply of inputs to producers, statistical data gathering, and diffusion of storage

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[3] Jayne et al. estimate AGRICOM's storage capacity at 160,000 metric tons.

techniques (Coulter). The ICM main task, however, was to act as the maize buyer of last resort at pan-territorial and pan-seasonal prices. By the time ICM was created, Mozambique was pursuing a tight monetary and fiscal policy that included eliminating subsidies to state enterprises and a market-based money-lending policy. Paradoxically, this meant that ICM had to generate funds to cover its own operations, yet always observing fixed prices set by the GoM.

The privatization of the banking system in 1996 compounded the liquidity problems faced by ICM, since it meant that ICM had to operate at the (then) commercial interest rate of 43 % (Coulter). The inability of ICM to carry out its mandate allowed the development of a strong informal sector (Macamo). Further measures of ERP-ESRP led to replacing the system of fixed prices with maize "reference" prices in 1990 (White), followed by liberalization of maize pricing in 1996/7.

2.5 Description of the Maize Marketing Channel

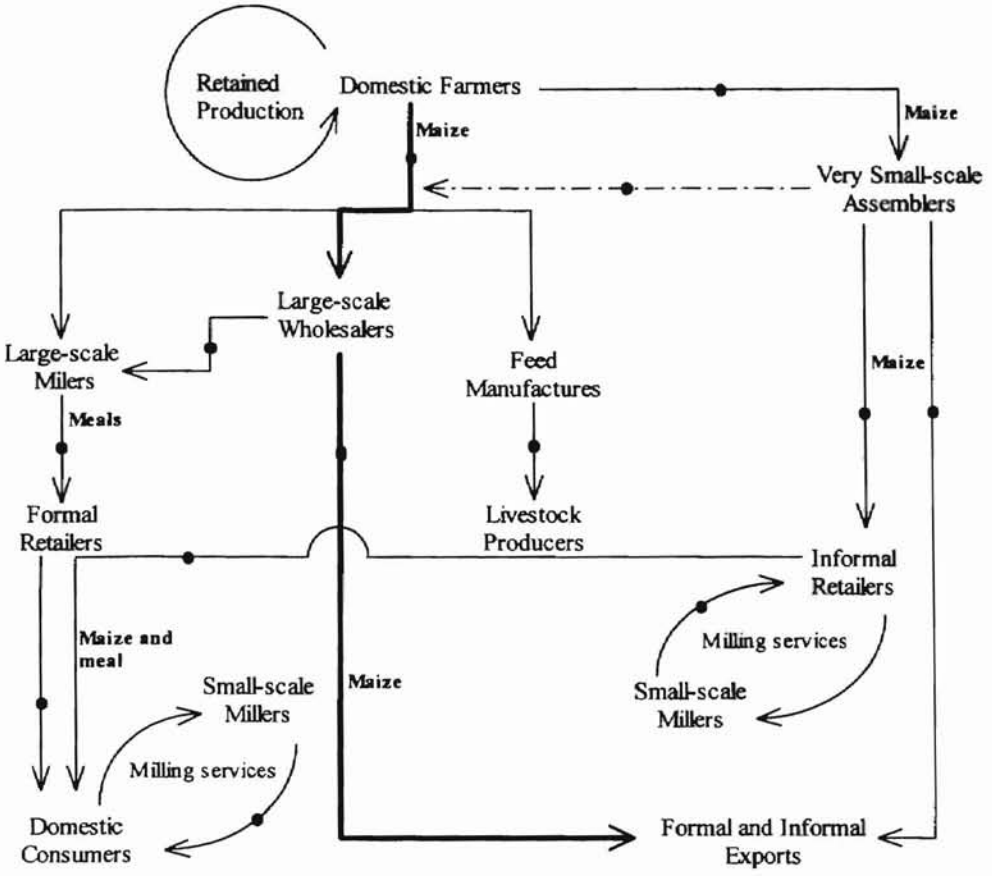
This section describes the maize marketing channels in Mozambique. As such, the characteristics and functions of market participants are provided. The structure of the maize market reflects demand and supply conditions (including legal constraints) that determine the pricing behavior. Hence, an understanding of the maize market structure is essential for modeling spatial maize trade and price dynamics, which is the objective of this study.

Both formal and informal traders participate in maize marketing in Mozambique. Formal traders are those who hold a trading license. To be eligible, candidates must submit several certificates (a certificate of literacy, clean criminal record, commercial and property registry, and of paying taxes), and a declaration that they are not public servants. In addition, import private traders must hold an import license, a certificate of commercial registry, certification of paying taxes, and a certification from custom duties. Formal traders are subject to inspections involving the Ministries of Commerce, Health and Labor and State Administration.

Becoming a formal trader requires money, massive paper work, and much time. The costs of becoming a formal trader are believed to have triggered the emergence of informal trading (Coulter; Macamo; MOA/MSU). Traders are considered informal if they market maize without a legal license. Informal traders are not officially recognized and do not pay taxes. However, they pay a symbolic stall fee to municipal authorities (MOA/MSU). Formal traders (who pay taxes) have pressured the GoM to ban informal trading. The Government's responses to informal trading have been inconsistent: tolerance from the Ministry of Commerce, and hostility by health and customs authorities (Macamo).

The main participants in the maize markets, their links, and market's pricing points are summarized in figure 2.1. Thicker lines indicate the most important maize flow in the marketing channel. As figure 2.1 indicates, northern Mozambique relies solely on maize produced within the region while southern Mozambique imports maize from central Mozambique and from South Africa. Generally, maize is paid upon delivery using cash.

Figure 2.1.a. The Maize Marketing Channel in Northern Mozambique.



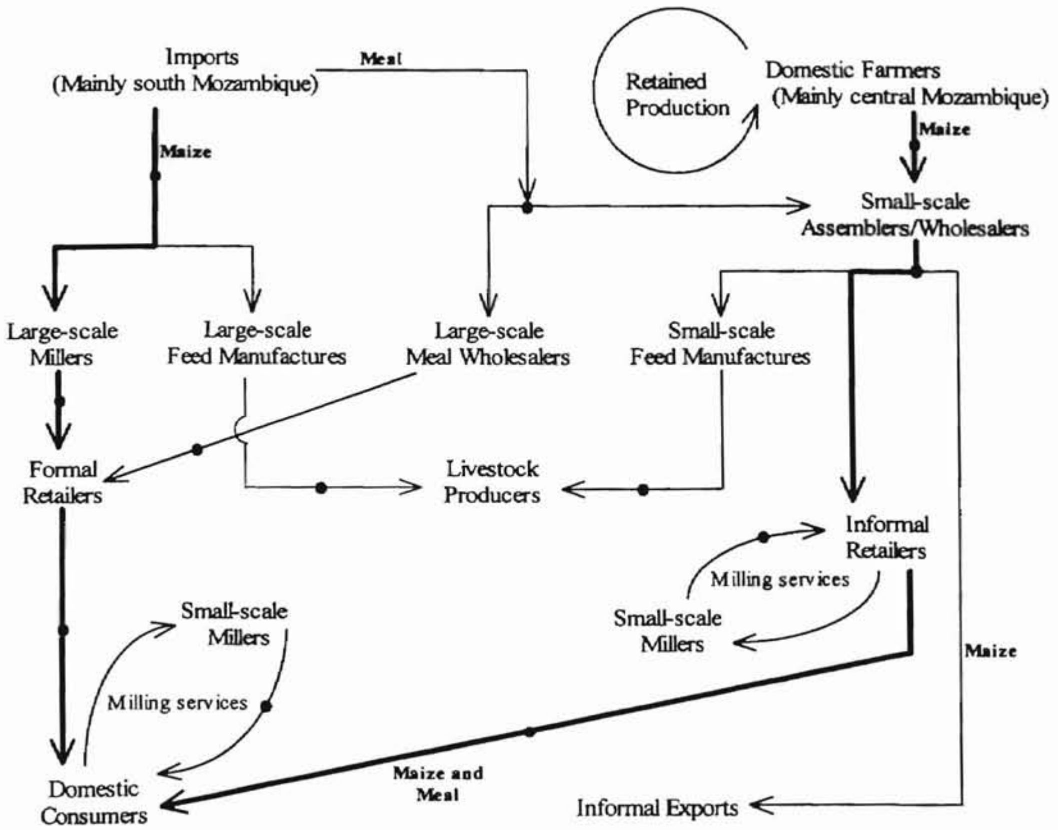
• Means pricing point.

Source: Adapted from Arlindo (2001)

2.5.1 Maize Producers and Technologies

Agroecological conditions and technology determine, in large extent, the potential for maize production in Mozambique. With few exceptions, maize production is rainfed and varies across the country. Southern Mozambique has sandy soils and erratic rainfall and, therefore, is less suitable for maize production than the central and northern regions. The south has historically been a maize deficit region (Jayne et al.; Tschirley and Santos).

Figure 2.1.b. The Maize Marketing Channel in Central/Southern Mozambique



• Means pricing point.

Source: Adapted from Arlindo (2001)

Depending upon rainfall fluctuations, central Mozambique may experience either maize deficits or surpluses. Northern Mozambique is a maize surplus region even during regional droughts (Jayne et al.; Tschirley and Santos). Despite the fact that the south is a deficit region in all years, and northern Mozambique has a favorable agroecological conditions for intensive agriculture (Jeje et al.), interregional maize shipments records show that grain is not being shipped from northern to southern Mozambique. Maize exports from Northern Mozambique to neighboring countries (Jayne at al.; Tschirley) occurred when neighboring countries experienced bad harvests (1997 and 1998). Maize prices remain very low in northern Mozambique, and subsistence agriculture is a common practice (Jeje et al.).

Maize producers are usually classified based on the size of land they work. Producers having less than 5 acres compose the "family sector". Large producers, locally known as the "private sector", are those who farm at least 50 acres and have a truck or a tractor or both. Approximately 80% of the maize sold in the market is produced by the family sector (Coulter). However, smallholder agriculture is labor intensive with low usage of capital. Smallholders rely on hand hoes and, when available, some animal traction, especially in southern Mozambique. The usage of agrochemicals and mechanized agricultural equipment (such as tractors) is limited to a small number of large private companies and joint ventures concentrated mainly in northern Mozambique. The average smallholder's maize yield ranges from 0.3 to 1.3 ton/ha across provinces (Jeje et al.). As figure 2.1 indicates, smallholders in southern Mozambique sell part of their maize production to small-scale assemblers/wholesalers while those in northern Mozambique sell maize to large-scale wholesalers as well.

2.5.2 Maize Wholesalers

Most domestic maize that is not consumed on-farm is from maize surplus provinces of Cabo-Delgado and Nampula in the north, and from Zambezia and Manica in central Mozambique (Coulter). Despite that, only 25 % of a total of 2,724 operational wholesaler shops are located in north and central Mozambique. The south has 75 % of the wholesaler shops[4].

Usually, wholesalers are formal agents that have considerable experience, some access to credit either from commercial banks or non-governmental organizations (NGOs), and trade other goods in addition to agricultural commodities (DNCI No. 11). In northern Mozambique, wholesalers are mostly large-scale. These wholesalers buy maize from domestic producers within the northern region, and sell it to large-scale maize millers, non-governmental agencies (e.g. World Food Program) and/or export maize to neighboring countries (e.g. Malawi). In contrast, dynamic small-scale wholesalers make up the bulk of the maize wholesale sector in south/central Mozambique (Arlindo). On average, informal wholesalers operating in central/south Mozambique transact less than 10 tons/month (DNCI, No. 11).

2.5.3 Maize Retailers

The majority of maize retailers are informal, in the sense that they are not licensed and do not pay taxes (DNCI, No. 3). Informal retailing began to appear openly in the late 1980's, soon after the beginning of the ERP-ESRP (MOA/MSU). Informal retailers have limited access to formal credit, and they depend upon informal or family credit (DNCI, No. 11). In 1992, the majority of maize retailers transacted about 50 kg/day and earned 6-27 % of income needed to feed an average family (Tschirley). The size of the transactions is likely to remain unchanged. Formal retailers usually have access to formal credit and

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[4] Figures were computed using data from DNCI, No. 12

own a truck. In addition to buying maize from farmers, they provide other services such as transportation and maize milling, particularly in rural areas (DNCI, No. 11).

There are 10,718 operational formal retail shops in Mozambique of which 58 % are located in the south, 18 % in central Mozambique and 25 % in the North[5]. Maputo in the south, Beira in the central region, and Nampula in the north, represent the main retail markets in Mozambique. Maputo, the capital of the country with over 1 million people in 2000, is fed by maize from the central region of Mozambique and by maize meal imports from South Africa. Beira is the second largest city of Mozambique. It is fed by maize surpluses from center, particularly Manica. Nampula city, the major consumer center in the north, is primarily fed by surpluses from within the province but occasionally receives maize from Zambezia (Mocuba) (Tschirley and Santos).

2.5.4 Maize Millers

There are both formal and informal maize processors operating in Mozambique. The formal milling sector comprises medium-scale and large-scale industrial millers that produce fully de-germen meal (without germ and bran), and have a total milling capacity of 132,500 metric tons a year. Of these, 74 % are in southern Mozambique, 3 % in the central region, and 6 % in northern Mozambique (Muendane). Large-scale millers in south Mozambique (e.g. CIM) rely on maize imports from South Africa, while those in other regions buy maize locally. The formal milling sector produces less than 15 % of the maize meals produced in Mozambique (Muendane).

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[5] Figures were computed using data from DNCI, No.12

The informal sector consists of small-scale hammer mills spread throughout the country. Hammer mills and traditional hand-milling methods produce more than 80 % of the maize meals produced in Mozambique (Muendane). Small-scale mills offer milling services to their customers (consumers, small scale wholesalers/informal retailers) who bring their own maize (own production or purchased) for milling. The main product made by the informal hammer mills is whole meal. However, they also produce some fully de-germen meal when customers bring maize clean of germ and bran (MOA/MSU).

2.5.5 Maize Consumption

Maize is the main staple food in Mozambique. Despite the fact that most households consume maize from their own production, maize still accounts for 15 % of the total food expenditure on average (DPDS-UEM-IFPRI). White maize is preferred to yellow and more processing is preferred to less. Hence, less refined yellow maize is the cheapest and more refined white meal is the most expensive (MOA/MSU).

There are three main methods used to produce maize meal consumed in Mozambique. There is hand-pounded meal, hammer-mill meal, and meal manufactured by large commercial millers. Hand-pounded meal is a high-quality meal prepared at home by manually removing the germ and bran of the maize grain by hand pounding and hand sifting. The clean grain is refined through a second hand-pounding in *pilao*, or hand-pounding in *aldidar*. The *pilao*-meal (maize flour) can be kept for several days but the *aldidar*-meal (a pasta of maize and water) is cooked and consumed immediately as corn bread or as *chima*. The *chima* is prepared by placing maize paste in boiling water, little by little until it gains the desired consistency, and then letting it cook in low heat. To produce whole meals using hammer mills, dry maize is placed into the hammer-mill and then grounded to produce several grades of maize flour. Sometimes consumers first pound the grain by hand, to remove germ and bran, and then take it to a small custom hammer miller to produce high quality meal. Large commercial millers can also mechanically sift the maize grain and produce high quality meal (MOA/MSU).

2.6 Market Information and Transportation Infrastructure

Information has economic value. Market prices, resulting from actions of both buyers and sellers, often reflect storage availability, transportation costs, political environment, weather and prices in neighboring countries. Usually, market participants observe market prices, and then decide how and when to allocate their scarce resources. The key is getting timely market information.

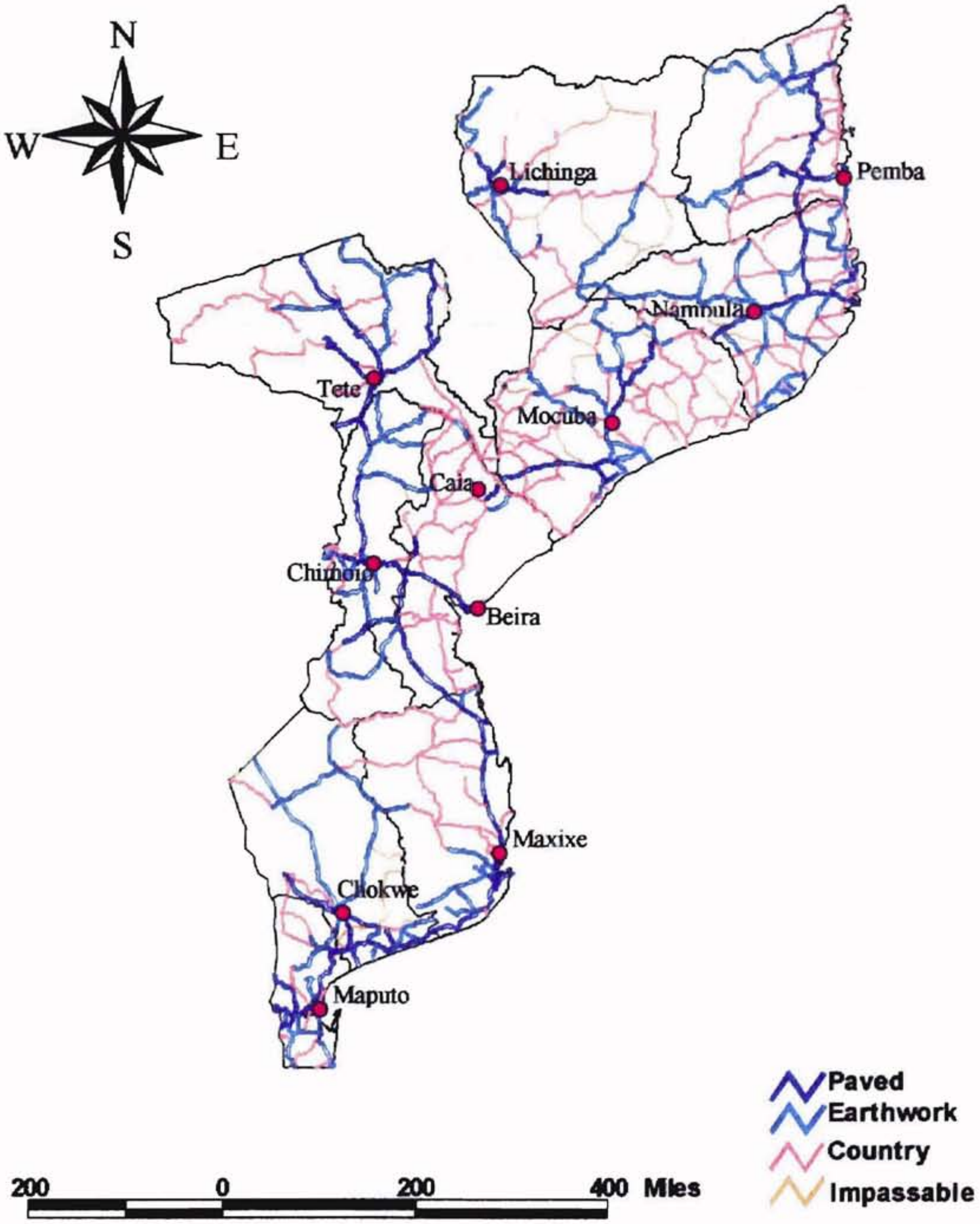
The *Sistema de Informacao the Mercado* (SIMA), a public outlook program in Mozambique, monitors maize prices in twenty-five domestic maize markets and in neighboring countries. However, given that the SIMA information is provided in printed weekly bulletins and via e-mail, it can only be timely acquired in major urban centers. Under these circumstances, some market agents will have systematic informational advantages over others, and long lags in maize price transmission across space are to be expected.

In addition to limited access to market information, maize traders in Mozambique face transportation problems (DNCI, No. 3; DNCI No. 11). Most of the transportation system in Mozambique was built during the colonial period and is underdeveloped. The network design suggests that the concern was to link Mozambique with her neighboring countries rather than establishing transportation linkages between different regions within the country. The approach does not seem to have changed in post-independence Mozambique. While the corridors (Maputo, Beira and Nacala) linking Mozambique to the hinterland were improved, and have well maintained roads, railways and ports, there is no single railway or roadway connecting northern with southern Mozambique (see figure 2.2). Foreign markets are "closer" than the nearest domestic market in much of Mozambique (World Bank).

Approximately 13 % of the total load and almost all maize are transported by roadways in Mozambique. However, the road network is poor. Approximately 53 % of the roads in Mozambique are not paved (DNC, No 18). As a result most roadways are impassable during the rainy season. In 2001, maize transportation costs ranged between $0.03 to $0.21 ton/kilometer. Transportation cost was about 50 % of the maize price in Maputo (DNC, No. 18).

Currently, there is no road connection between northern Mozambique and other regions of the country. The road between maize surplus regions in northern Mozambique, and maize deficit regions in southern Mozambique, stops at Caia on the border between Sofala (Beira) and Zambezia (Mocuba) provinces (see figure 2.2). A ferry is used to cross

Figure 2.2. Type of Roads in Mozambique and Location of the Markets Included in the Study.



Source: Adapted from the Administracao Nacional de Estradas, 1997 the Zambezi River until Zambezia where the road resumes again. However, the ferry is not always available. For example, in early 2001 the ferry was shut down for nearly two months because the Zambezi River was flooding, and in July 2001 the ferry service was interrupted again but for a different reason: there was not enough water in the river (AIM, No. 211). In much of the rainy season, road traffic between Zambezia and other regions of central Mozambique is forced to go through Malawi (DNCI, No 18). A proposed bridge crossing the Zambezi River at Caia is budgeted at $80 million, and is among the priorities of the GoM. While this bridge would allow North-South road connection and ease the transportation of maize and other products within Mozambique, critics (including the World Bank) claim that there is not enough traffic to justify the investment (AIM, No 209).

Although more than 80% of the total load in Mozambique is carried on railways and maritime transportation, maize is mainly transported on trucks. The reasons are as follows. First, there is no railway connecting northern with southern Mozambique. The railways link Mozambique to neighbors in the west. For example, the railway connection between central and southern Mozambique goes through Zimbabwe. Hence, using railways would result in long transportation distances. Second, while Mozambique has a high potential for maritime transportation due to its long seacoast to the east, secondary ports have some operational problems and tertiary ports beg for rehabilitation (DNC, No. 18). For example, in early 2001 maritime transport cost of shipping maize from Canada to Maputo was lower than the cost of shipping maize from central/Northern Mozambique to Maputo (DNC, No. 18).

As a result, the connection between (maize surplus/deficit) districts with secondary/primary ports, which would ideally be made through tertiary ports, is made by roadways (which are at times impassable), and/or through railroads where they exist. In summary, although the average nominal fees for railways ($0.03 - $0.05 ton/km) and for maritime transport are lower than the average cost of road transportation, maize traders prefer the latter due to lack of security, high handling losses, and higher transportation time in the former.

2.7 Storage and Credit Arrangements

The pattern of maize demand and supply in Mozambique is affected by geographical maize storage concentration. On-farm or near rural areas, storage costs are higher than in urban areas (Arndt et al.) where previous state monopolies concentrated about 235,000 metric tons of usable storage. In general, maize producers store some maize for their own consumption, and traders can only afford to store maize in quantities equal to the size of the current (small) transaction. Because most farmers sell their maize shortly after harvest (March-April), maize prices fall shortly after harvest, but increase rapidly as the stock of maize held by households decreases. As maize sellers become maize buyers, price inversions and flow reversals between urban centers and rural producing areas can occur (Timmer).

The majority of maize traders also face high capital costs. First, formal credit institutions serve less than 15% of the Mozambican population mostly in urban areas (Larson).

Second, the nominal rate of interest offered by the commercial banking system (23% to 28% in 1999) and NGOs-based micro-finance programs (64 % to 107 %) remains high. Further, the maturity period is about three months while maize transactions often last three to nine months (DNCI, No. 11). Third, while most of the traders are poor and have agriculture as the main source of income in Mozambique (Benfica), formal lending institutions require an up front payment of 25-30 % of the loan. In addition, the formal financial institutions require borrowers to own possessions equal to the loan amount (DNCI, No. 11). Traders' working capital depends upon personal savings and informal credit schemes.

High capital costs contribute to small-scale maize transactions. For example, the average maize retailer trades less than 50 Kg/day, and an informal wholesaler does not transact more than 10-15 ton every two weeks. In 1997, a wholesaler working in the route Chimoio-Maputo had annual capital returns of 381 % for transactions of 3.5 ton per two weeks, and 107 % for transactions of 12.5 ton per two weeks (Tschirley). These high nominal returns to capital reflect high cost of capital, and small size of maize transaction.

2.8 Summary

Maize is the main staple crop in Mozambique, an overwhelmingly agricultural country with high poverty incidence. Despite the fact that the south is a deficit region in all years, and northern Mozambique has a potential to greatly increase production, interregional maize shipments records show that grain is not being shipped from northern to southern Mozambique, and subsistence agriculture is the common practice in much of

Mozambique. The majority of maize producers are smallholders that rely on rainfed agriculture and manual tools. Although most rural households farm maize, maize and maize meals still account for 15% of their food budget.

The number of maize traders has increased in the post-reform period, but the size of maize transactions remains small. Maize is inspected and paid upon delivery. Usually, cash payments are made without invoicing, a practice that complicates accounting. Lack of accounting further limits the possibility of getting a loan from formal lending institutions. Because traders face limited access to roads, credit and information, lagged price responses are expected in spatial price transmission. Further, poor access to roads, credit and information limit trader's ability to arbitrage maize prices throughout Mozambique. Some inefficiency on spatial maize arbitrage is expected.

CHAPTER III

CONCEPTUAL FRAMEWORK

3.1 Introduction

Throughout the past 15 years, Mozambique has liberalized its food markets and promoted market based solutions, yet food shortages persist. The persisting problem of maize shortages and price instability can be minimized if spatial maize markets are linked by trade. When markets are linked by trade, price signals from maize deficit regions are (timely) transmitted to maize surplus regions, and arbitrageurs trigger flow of food from food surplus regions to food deficit areas minimizing food shortages. This is the basic notion of Walrasian transfer of excess demand.

This chapter provides the theory used to measure the efficiency of spatial arbitrage and the lead-lag relationships between spatial maize prices in Mozambique. The concepts of arbitrage efficiency and market integration are discussed in section 3.2. Section 3.3 discusses maize price dynamics, and section 3.4 presents the chapter's summary.

3.2 Arbitrage Efficiency and Market Integration

The concept of market integration is related to (free) flow of goods and information over space, time, and form. However, operational definitions of market integration used in empirical studies are far from reaching a consensus. The term market integration is often used to describe spatial price efficiency (Barrett). Here, markets are defined as integrated if there are physical flows of product from one to another. Integration, therefore, implies (Walsarian) transfer of excess demand from one market to another. This transfer of excess demand is noticeable through physical maize flows, or transmission of price shocks from one market to another, or both (Barrett). Because spatial trade depends upon prices, transfer costs and commodity flows, attempts to make inference about market integration using only prices, like much of current literature, can be hazardous (Harris; McNew and Fackler; Baulch; Li and Barrett; Obstfeld and Taylor; Barrett). The main inferential difficulty is caused by trade discontinuities (due to a third trading partner, and/or large transaction costs) and nonstationary prices and transfer costs (due to inflation, climate shock or population).

Here, a measure of spatial arbitrage efficiency is combined with records of interregional trade shipments to make inference about market integration. Although they are closely related, market integration and market efficiency are not the same (Li and Barrett). Arbitrage is efficient if arbitrageurs force maize prices to converge toward transfer costs whenever the maize price differential exceeds transfer costs. Thus, trade occurring is a sufficient condition for market integration, but spatial arbitrage efficiency requires that sufficient trade occur so that price spreads are less than transfer costs.

Throughout the past decade, the Mozambican maize market has been increasingly liberalized. The proponents of the reforms claimed that by removing official prices, producer prices would rise creating incentives for farmers to increase production. With higher prices, farmers would then regard maize as cash crops and shift their orientation from subsistence to commercial producers (Dembélé and Staaz). Further, elimination of market constraints (legal, institutional) would reduce transaction costs, attract more traders into the market, lead to trader's specialization further reducing unit marketing costs (Dembélé and Staaz). Without restriction to trade, maize shortages and gluts would be eliminated. A well functioning market would encourage private investment in maize production and marketing.

The study hypothesis follows from the discussion above: liberalizing maize markets leads to efficient arbitrage and market integration. When arbitrage is efficient, food shortages in deficit regions are transmitted to surplus regions via prices, and arbitrage triggers flows of food across space. The risk of crop failure in some regions is shared over a large market area, prices are more stable, and food shortages may be prevented. Trade and specialization is the key for economic growth (Drucker), especially in Mozambique where agriculture is the main source of family income (Benfica) and 75 % of the population grows maize (DPDS-UEM-IFPRI).

To examine interregional maize trade in Mozambique, where the northern and central regions are maize surplus regions (in normal years) and the south is a maize deficit region, consider a two-region trade model (see figure 3.2.1) in which excess demand (E_t^D) and excess supply (E_t^S) at time t are:

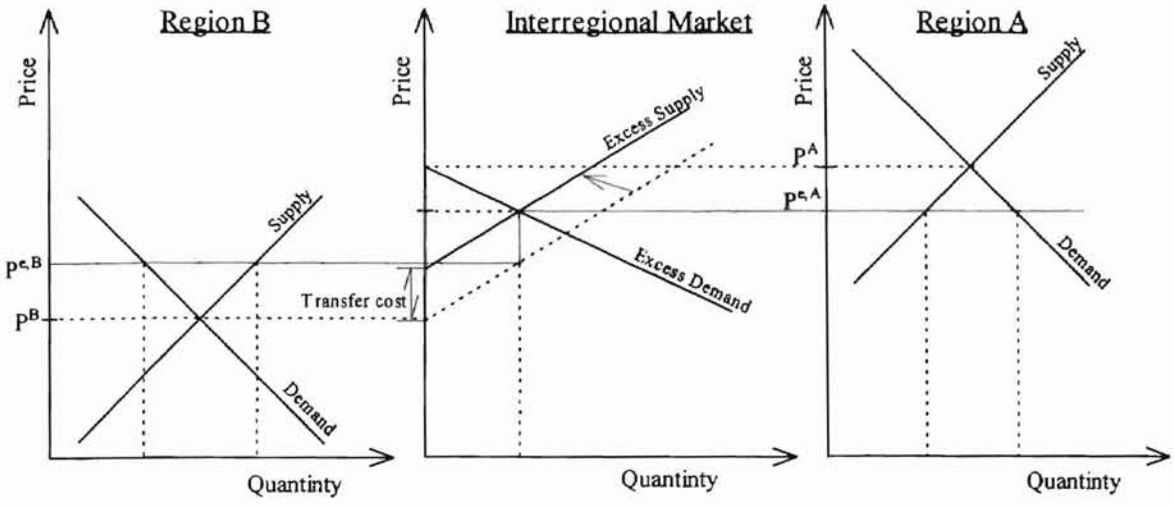
(1) $$E_t^D = f(P_t^A, \eta_t)$$

$$(2) \qquad E_t^S = h(P_t^B, \xi_t)$$

where P^A and P^B are respectively the prices in the importing region (A) and in the exporting region (B); and η_t and ξ_t represent respectively exogenous demand and supply shifters such as weather or population. Let C be the transfer cost of shipping maize from B to A in period t. When markets A and B are linked by trade, arbitrageurs ship maize from B to A and force the price differential between regions A and B to be less than or equal to C. That is,

$$(3) \qquad P_t^B - P_t^A \leq C_t$$

Figure 3.2.1: Schematic of Two-Region Maize Trading Model



Note: $P^{e,B}$ and $P^{e,A}$ are equilibrium prices in markets B and A respectively.

The equality in (3) defines spatial arbitrage conditions consistent with maize spatial market integration (Ravallion; Harris; Baulch; Sexton, Kling and Carman). Expression (3) indicates that transfer costs determine the bounds within which a commodity is tradable, and is consistent with markets that produce and consume maize, as in Mozambique and most countries in the SA region.

Most approaches used to test spatial market integration (e.g. bivariate price correlations, cointegration, error correction models, threshold autoregression, and cointegration) use price data alone and, therefore, are inconsistent with the spatial arbitrage conditions described by (3). When these price-based methods are used to make inferences about market integration, unaccounted nonstationary transfer costs and trade discontinuities may cause biased and inconsistent parameter estimates (McNew and Fackler; Barrett). As a result, well functioning markets are deemed to be functionally isolated, and regions without trade links are found to be price correlated and, therefore, deemed to be spatially integrated (Harris; Baulch; Barrett).

Newly developed methods to assess spatial arbitrage (e.g. Baulch's PBM, and Barrett and Li's BLM) use switching regressions to account for multiple regimes that can emerge from considering prices and transfer costs (Sexton, Kling and Carman; Baulch), and from considering prices, transfer costs, and trade flows (Li and Barrett). These methods account for nonstationary transfer costs, recognize discontinuous trade patterns, and are consistent with characteristics of Mozambique food markets where markets are not specialized, and time-series data are short. When trade data are available, these methods can account for interseasonal flow reversals that are common when transportation and storage infrastructure is poor (Barrett). Here, the Baulch's parity bound model (PBM) is used to test for arbitrage efficiency and, together with records of interregional maize shipments, make inferences about market integration.

3.3 Maize Price Dynamics

While the spatial trade model in (3) uses switching regression to prevent inferential flaws caused by nonstationary transfer costs and trade discontinuities (McNew and Fackler; Li and Barrett; Baulch; Barretl; Ravallion), the procedure does not capture lagged price adjustments to tradability or equilibrium[6]. At equilibrium, the market clears if,

$$E_t^D = E_t^S \tag{4}$$

By simultaneously solving the static equations (1), (2) and (4), a reduced form of equilibrium maize price can be obtained,

$$P_t^{e,i} = g_i(\theta_t) \tag{5}$$

---

[6] When markets trade continuously, a perfectly competitive market must be integrated (Goldberg and Knetter). However, when trade is discontinuous (corner solutions indicate no trade), it is possible to have a segmented equilibrium. Given that trade can occur without perfect competition (like in the presence of binding quotas), integration is neither a necessary nor sufficient condition for equilibrium, nor vice versa (Li and Barrett)

where $P_t^{e,i}$ are the equilibrium prices (i = A, B) and $\theta = (P^A, P^B, \eta, \xi)$. Reduced form equations similar to (5) are simple, easy to estimate and were found to be useful in analyzing the effects of shifts on demand or supply on commodity price by Gardner. Given that many of the roads in Mozambique are poor and market information is acquired with some delay, transportation and information lags are likely to occur. Frictions due to information and interregional shipping costs generate dynamic price adjustment. Some markets may lead others in the price discovery process resulting in lead-lag price relationships. In these circumstances, an understanding of how fast maize markets adjust to (exogenous) shocks is important for economic policy formation because it provides information about the price discovery process and the characteristics of the market (e.g. size). With time lags, however, static models like equation (5) are unsuitable because they do not capture dynamic price adjustments. Nevertheless, they can be made dynamic by incorporating information contained in both past and present structural shifters. Thus, equation (5) can be rewritten as,

$$(6) \qquad P_t^{e,i} = j(\theta_t, \theta_{t-1}, \ldots, \theta_0).$$

In practice, however, expression (6) is difficult to estimate because it is complex to measure the effects of all excess demand and supply shifters at any period of time. If one is willing to assume that these shifters generate a stochastic process that is identifiable, then time series modeling can be used to indirectly model and estimate such stochastic processes (Boyd and Brorsen). Hence, equation (6) can be expressed as,

$$P_t^{e,i} = T_t + S_t + e_t, \tag{7}$$

where T_t is the deterministic component representing trends (e.g. seasonality, road quality) and $S_t + e_t$ is the stochastic component reflecting how markets respond to new information. The process S_t is assumed to be covariance stationary (short memory). It would be equal to zero if the market adjusted instantaneously. The error term e_t is assumed to be white noise, which implies that all information embedded in the data has been captured.

Equilibrium prices (described by (7)) at a given market are expected to be simultaneously determined by their own past prices and past prices of other regional markets trading with it. Multivariate time series procedures can be used to model simultaneous dynamic relationships underlying the stochastic process of equation (7).

3.4 Summary

The study hypothesis and the spatial trade theory used to measure the efficiency of market arbitrage and make inferences about market integration were discussed in this chapter. The liberalization of maize markets in Mozambique is expected to foster spatial trade links and minimize food shortages and price instability.

This chapter also found that price-based methods often overlook transfer costs and trade discontinuities leading to erroneous conclusions about market integration. Unlike price-based methods, switching regression methods (combining price and transfer cost) prevent faulty inference because they account for multiple trade regimes that emerge from considering transfer costs and trade discontinuities.

Because simple switching regressions, like the one proposed in this study, do not account for lagged price adjustments that are expected in Mozambique maize markets (where market agents have different access to roads and information), time series procedures will be used to capture maize price dynamic price adjustments and measure the lead-lag relationships between spatial maize prices in Mozambique.

CHAPTER IV

DATA AND MODELING PROCEDURES

4.1 Introduction

This chapter presents the data and methods used to accomplish the objectives of the study. The plan of the chapter is as follows. The data, time periods covered, and data sources are presented in section 4.2. Next, section 4.3 discusses the switching regression used to measure maize price arbitrage efficiency. Time series procedures used to capture dynamic price relationships between maize markets are discussed in section 4.4. Finally, section 4.5 concludes.

4.2 Data

The test for spatial arbitrage efficiency uses monthly white maize retail prices and monthly transportation cost data. Weekly maize retail prices are utilized in dynamic time-series models to capture dynamic relationships between spatial maize prices. All maize price data (1994 - 2001) were gathered in the post-reform period, and are from the *Sistema de Informacao de Mercados* (SIMA), a public outlook program. The SIMA data are gathered by interviewing randomly selected retailers in each province (three interviews per week). Trained technicians conduct the interviews. Monthly retail maize prices of the ten markets considered in this study are plotted in figures 4.1 and 4.2, and

Figure 4.1. Monthly Retail Maize Prices in Northern Mozambique (Meticais/Kg), between March 1994 and May 2001.

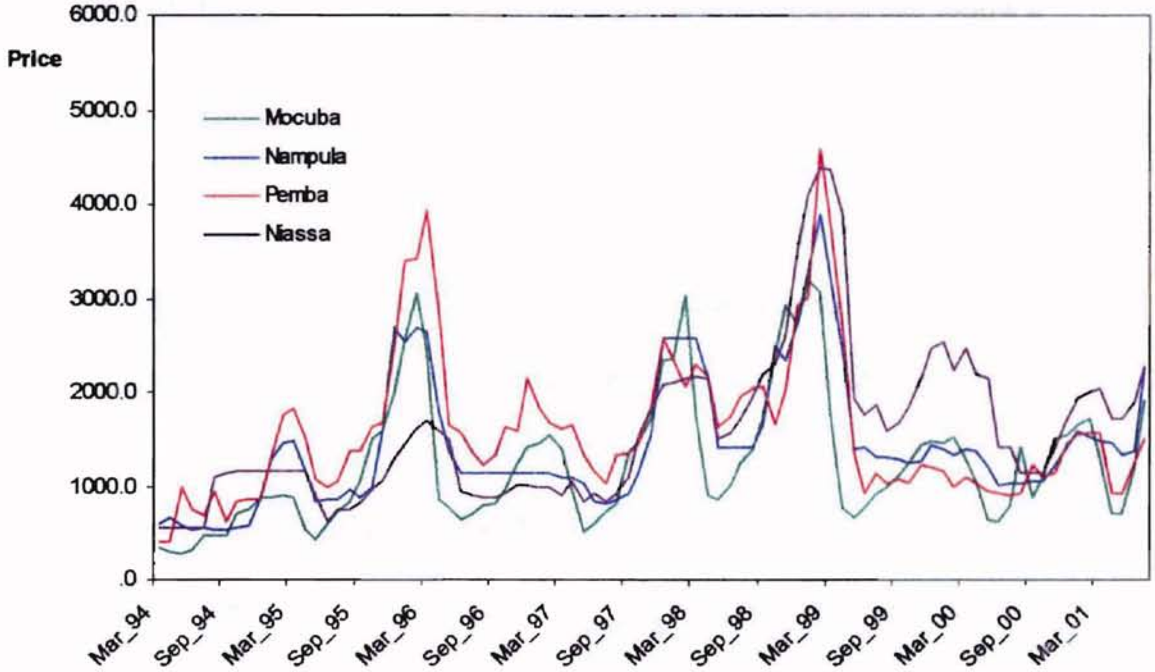
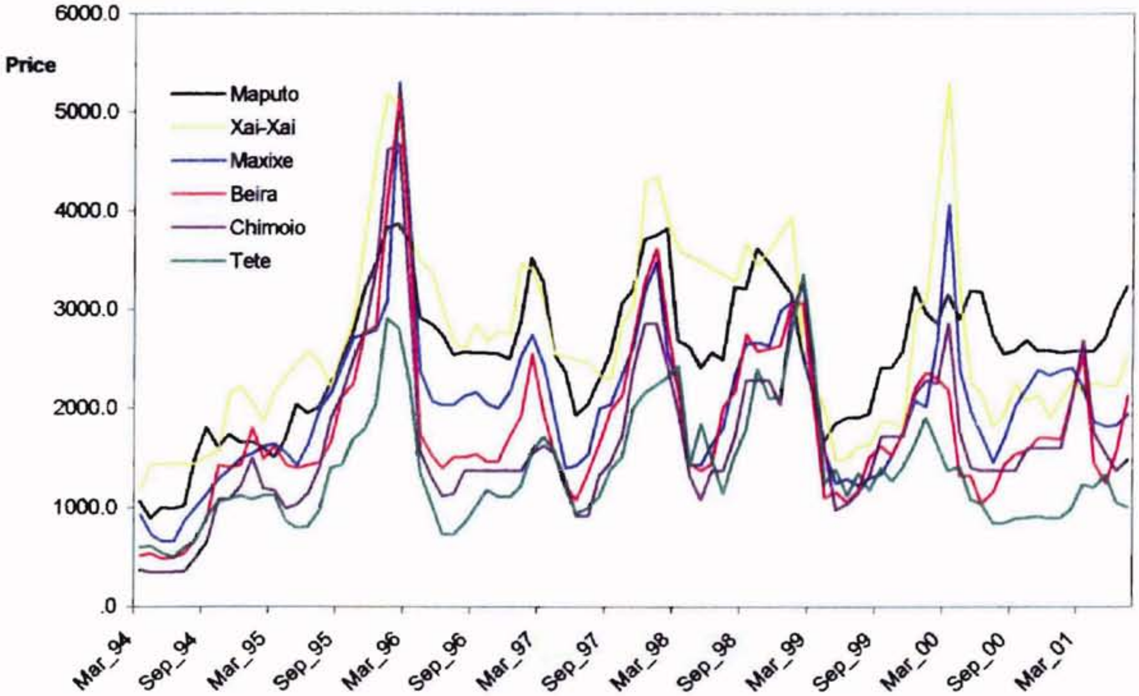


Figure 4.2. Monthly Retail Maize Prices in Central and Southern Mozambique (Meticais/Kg) between May 1994 and March 2001.



descriptive statistics of weekly retail maize prices are presented in table 4.1. As figures 4.1 and 4.2 show, nominal retail maize prices show no distinct trend and follow a seasonal pattern. The prices begin rising around September reaching a maximum around March. Seasonal maize price decreases are correlated with maize harvest season, which extends from March to late April. As table 4.1 indicates, average prices in southern Mozambique are almost a double the prices in central/northern Mozambique but price volatility around the mean is higher in northern/central Mozambique (see table 4.1). Southern Mozambique is a maize deficit region but has better market infrastructure than the northern maize surplus regions. As table 4.1 also indicates, price data have large information gaps. The number of missing values varies from one (Maputo) to one hundred and seven (Lichinga).

Table 4.1. Descriptive Statistics for Weekly Maize Retail Prices in Mozambique (Meticais/Kilogram) between July 2, 1994 and April 4, 2001.

Variable	N	Mean	Standard Deviation	Minimum	Maximum	Number of Missing Values
Maputo	356	2608.36	665.21	941.18	4042.95	1
Chokwe	260	2470.20	898.05	857.14	6095.24	96
Maxixe	352	2112.20	735.35	800.00	5600.00	4
Beira	329	1887.92	813.81	457.14	5657.14	27
Chimoio	347	1745.42	807.23	342.86	5428.57	9
Tete	313	1423.21	607.10	552.38	3430.30	43
Mocuba	305	1308.20	712.12	314.29	3714.29	51
Nampula	343	1472.59	719.86	514.29	4313.73	13
Pemba	294	1616.50	717.12	450.00	4571.43	62
Lichinga	249	1677.70	895.39	485.71	4666.67	107
Monthly CPI 2001 = 100	89	73.65	20.59	29.19	100	0

Note: The monthly price index (CPI) for the period January 1994 - May 2001.

Missing values represent lost information and make regression estimation more difficult. Despite that, the price data used in the regression estimation does not include any interpolated values.

Road transportation cost data used to extrapolate eight years of time-series transportation cost are presented in tables 4.2 and 4.3. The data are from the Ministry of Trade and

Table 4.2. Interregional Maize Transportation Cost in Mozambique (Meticais/bag) between August 29 and November 29, 2001.

	Destination Market						
Maize Source	Maputo	Xai-Xai	Maxixe	Beira	Tete	Vilanculos (Maxixe)	Quelimane (Mocuba)
Chokwe	17, 000 (n = 1)						
Chimoio		65, 000 (n = 8)		30,000 (n = 1)		30,000 (n = 1)	
Manica				50,000 (n = 1)		55,000 (n = 1)	50,000 (n = 2)
Tete			100,000 (n = 1)	40,000 (n = 1)			
Angonia (Tete)			70,000 (n = 1)		25,000 (n = 2)		
Nampula	150,000 (n = 1)	148,000 (n = 4)	127,000 (n = 7)	120,000 (n = 2)			
Lichinga	124,000 (n = 5)		85,000 (n = 1)		100,000 (n = 2)		
South Africa	31,000 (n = 9)						

Notes: The number of observations is given in parentheses. Maize bags have a capacity of 75-100 kilos. U.S. $1 ≈ 23,000 Meticais. The data were compiled from the SIMA weekly bulletins (August 29 and November 29, 2001).

Table 4.3. Road Maize Transportation Costs in Mozambique (MZM/ton/Km), June 2001

	Destination									
Source	Maputo	Xa-Xai (Chokwe)	Inhambane (Maxixe)	Sofala (Beira)	Manica (Chimoio)	Tete	Zambezia (Mocuba)	Nampula	Pemba	Lichinga
Maputo		1,120	1,122	800	800	800	1,440	1,440	1,440	1,440
Xai-Xai (Chokwe)	909									
Manica (Chimoio)	400									
Tete	637			633	615					
Nampula	1,303	1,338	1,260	1,572	1,532	1,142	1,483		1,231	
Pemba	905							1,198		
South Africa	960									

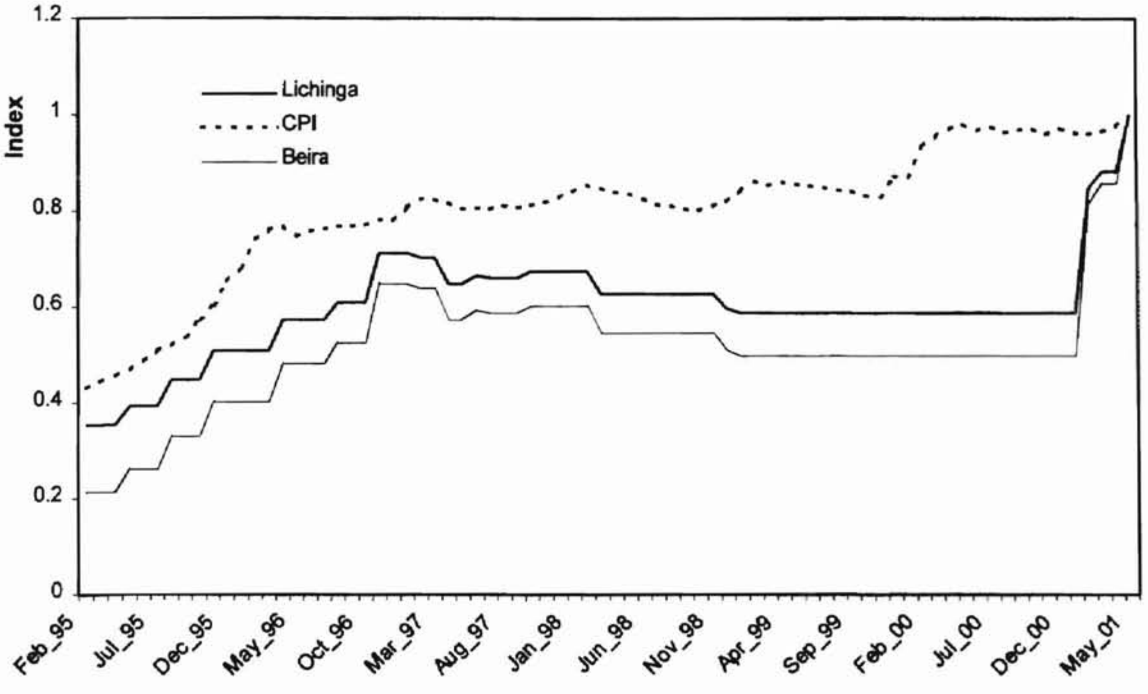
Note: The exchange rate during data gathering was $1 = 16,000 MZM.

Source: Ministry of Trade and Industry, DNC No. 18

Industry (one observation in June 2001) and from the SIMA (weekly data gathered between August and September 2001). When the average per unit transfer cost between the two sources of data (SIMA and Ministry of Trade and Industry) is different, the value used to project time-series cost data is the highest between the two, except when the average transfer cost of one of the sources is based on more observations than the other. This choice allows conservative estimates of cost data. Transport costs are established by bag and by location, and vary between U.S. $0.03 and U.S. $0.1 per kilometer. Per unit maize transportation costs decrease with the distance and the size of the truck. Nampula, which has the poorest roads, has the highest transportation charges per kilometer.

As suggested by Baulch, a consumer price index (CPI) was used to extrapolate available cost data into eight years of monthly time-series transportation cost data (a proxy for transfer cost). The monthly CPI for all Mozambique is from the *Instituto Nacional de Estatistica* (INE), a Mozambican public institution. Monthly diesel prices are used as an alternative deflator, to provide a test of fragility. The *Direccao Nacional de Energia* provided the diesel prices. Both CPI and diesel price indexes for Lichinga and Beira are plotted in figure 4.3. All other diesel-index curves fall in between Lichinga and Beira curves. As figure 4.4 shows, the CPI is higher than diesel prices (almost a double the diesel prices in Beira) during the period considered. Using diesel prices as a deflator leads to higher estimated transportation costs and, therefore, less spatial arbitrage inefficiency.

Figure 4.3. Monthly CPI for All Mozambique, and Monthly Diesel Price Indexes for Beira and Lichinga Provinces between February 1995 and June 2001.



The extrapolated cost data, which are used as initial transfer-cost estimates on the PBM, seems to be higher but reasonable. For example, using initial cost estimates on the PBM seems to be higher but reasonable. For example, using the CPI as a deflator, the extrapolated transfer cost for the route Chimoio-Maputo in December of 1995 (U.S. \$0.07/ton/kilometer) is more conservative than Coulter's (1995) estimate of U.S. \$0.03 - \$ 0.05/ton per kilometer for the same period. The Ministry of trade and Industry's (DNCI No. 3) estimate of transportation costs to transport maize from Chimoio to Maputo in December of 1998 (369 Meticais per kilogram) is less than the deflated value of (487 Meticais/ton per kilometer) used in this study. High values of cost estimates may lead to conservative estimates of spatial arbitrage efficiency.

4.3 Testing for Arbitrage Efficiency

The test for spatial arbitrage efficiency uses Baulch's parity bound model (PBM), a switching regression with three regimes. The probability for each regime is established in two stages. First, the transfer-cost data are extrapolated into time-series data by deflating them with a consumer price index or diesel price. Second, a maximum-likelihood estimator (MLE) is used to estimate the lower and upper parity bounds (the range in which price spreads are considered equal to transfer costs).

The three regimes involved in the PBM estimation are as follows. Regime I is at the parity bounds, and is defined when maize price spreads between two provinces equal transfer cost[7]. That is,

$$\ln | P_t^B - P_t^A | = \ln C_t + e_t \tag{8}$$

where P_t^A and P_t^B are maize retail prices in markets *A* and *B* (e.g. Maputo and Beira provinces); C_t is the nominal transfer cost; e_t is the error term that captures variations on transfer costs due to seasonality or changing capacity utilization on the transportation sector. This error term is assumed to be *iid* Normal$(0, \sigma_e^2)$. Regime II is inside the parity bounds, and is defined when price spreads are less than transfer costs,

$$\ln | P_t^B - P_t^A | = \ln C_t + e_t - \mu_t \tag{9}$$

---

[7] This study uses transportation costs as a proxy for transfer costs, which include transportation costs, tariffs, indirect costs and unobservable profit margins.

where u_t is an error term that captures the extent to which prices fall short of parity bounds when there is no incentive to trade. It depends upon relative differences in demand and supply in individual markets, and is assumed to be *iid* Normal$(0,\sigma_u^2)$ and truncated from above (at zero). Regime III is outside the parity bounds and is defined when price spreads exceed transfer costs. That is,

$$\ln|P_t^B - P_t^A| = \ln C_t + e_t + v_t \tag{10}$$

where v_t is an error term capturing the extent to which price spreads are in excess of transfer costs when spatial arbitrage conditions are violated. Its size depends upon the extent to which intermarket trade is prevented due to government controls, transportation restrictions or any other impediments to trade such as lack of roads.

The problem consists of estimating the probability of each trade regime, given maize prices and transfer cost data. Regime one and two are consistent with efficient spatial arbitrage, and regime III indicates market inefficiency. The likelihood function of the PBM is defined as (Weinstein; Sexton, Kling and Carman; Baulch):

$$L = \prod_{t=1}^{T}[\lambda_1 f_1^t + \lambda_2 f_2^t + (1-\lambda_1-\lambda_2) f_3^t] \tag{11}$$

where λ_1 and λ_2 are the probabilities for regime I when price spreads equal and fall below transfer costs respectively. The function f_1^t is the density function for regimes I (i.e. spreads equal transfer costs) defined as:

$$f_1' = \frac{1}{\sigma_e}\phi\left(\frac{Y_t - C_t}{\sigma_e}\right); \tag{12}$$

f_2' is the density function for regime II (i.e. spreads less than transfer costs), and is defined as:

$$f_2' = \left(\frac{2}{(\sigma_e^2 + \sigma_u^2)^{1/2}}\right)\phi\left(\frac{Y_t - C_t}{(\sigma_e^2 + \sigma_u^2)^{1/2}}\right)\left[1 - \Phi\left(\frac{-(Y_t - C_t)\sigma_u/\sigma_e}{(\sigma_e^2 + \sigma_u^2)^{1/2}}\right)\right]; \tag{13}$$

and f_3' is the density function for regime III when price spreads exceed transfer costs. The density functions for regime III is:

$$f_3' = \left(\frac{2}{(\sigma_e^2 + \sigma_u^2)^{1/2}}\right)\phi\left(\frac{Y_t - C_t}{(\sigma_e^2 + \sigma_u^2)^{1/2}}\right)\left[1 - \Phi\left(\frac{(Y_t - C_t)\sigma_v/\sigma_e}{(\sigma_e^2 + \sigma_v^2)^{1/2}}\right)\right] \tag{14}$$

where Y_t is the natural logarithm of the absolute value of price difference between markets *i* and *j*; σ_e, σ_u, and σ_v are standard deviations of the error term, respectively e_t, u_t, and v_t; C_t is the logarithm of the nominal transportation cost in period *t*, and $\phi(.)$ and Φ (.) represent the standard normal density and distribution function respectively. The estimates of the parameters λ_1, λ_2, σ_e, σ_u and σ_v are obtained by maximizing the likelihood function (14) using TSP version 4.4 (see appendix A). The selected option

ML(HCOV = D, HITER = D, TOL = 0.01) calls for the Davidon-Fletcher-Powell algorithm (that uses numeric derivatives and is helpful with bad starting values) with a convergence criterion of 0.01 (TSP User's Guide). The option ANALYZ (in TSP version 4.4) is used to compute the standard errors of the unconstrained regime probabilities and conduct (Wald) t-tests.

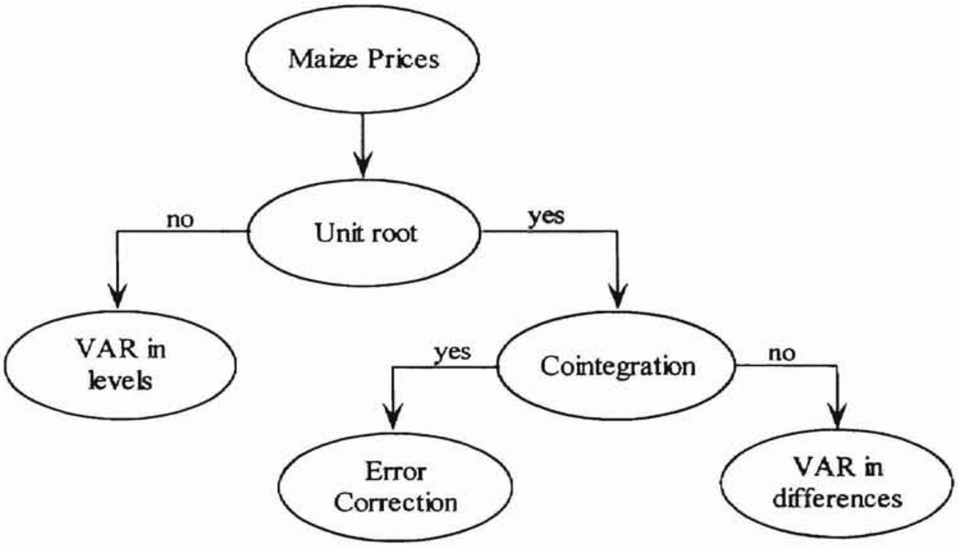
Mozambique has poor roads and information lags. Therefore, instead of testing the null of perfect spatial efficiency ($\lambda_1 + \lambda_2 = 1$), this study focuses on the magnitude of the regime probabilities. The sum of probabilities of regime one (i.e. spreads equal to transfer costs) and two (i.e. price spreads less than transport costs) is interpreted as the frequency of market efficiency. That is, the more efficient spatial arbitrage is, the closer to zero is the index of market inefficiency λ_3 ($\lambda_3 = 1-\lambda_1 + \lambda_2$).

4.4 Maize Price Dynamics

The switching regression discussed in section 4.3 provides information about the extent to which spatial markets trade together. However, dynamic adjustments that are expected due to information and transportation lags are not captured. This section uses time-series models to determine the lead-lag relationships between spatial maize prices and make inferences about maize-price discovery.

With lagged price transmission, the quantity of maize traded in each market, the distance between markets, and the quality of roads between markets are expected to influence the size or length of dynamic adjustments. Larger markets (e.g. Maputo, Beira and Nampula) are expected to lead the price discovery process, and shorter distances and paved roads are expected to favor rapid spatial price transmission and adjustment. The procedures used to determine the appropriate form of dynamic models are presented in figure 4.4. As figure 4.4 shows, maize prices are first tested for unit roots. If the null of a unit root is rejected, maize price dynamics are modeled with a vector autoregression (VAR) using price levels. However, if the null hypothesis of a unit root is not rejected, maize prices are treated as if they were unit root processes and, hence, tested for cointegration. Maize prices with a unit root are modeled with an error correction model if they are cointegrated, or with a VAR in first differences if they are not cointegrated. A VAR is preferred over a vector autoregressive moving average (VARMA) because it is easier to identify and to interpret its results.

Figure 4.4: Procedures to Specify Dynamic Time-Series Models



Note: VAR means vector autoregression

4.4.1 Stationarity and Unit Root Testing

Time series data are stationary if they have a constant mean over time, and the covariance between two members depends only on the time span between them (Judge et al.). When data are not stationary, they have a "unit root". Inflation, population, weather and other common trends may make agricultural prices nonstationary (Ravallion; Harris; Barrett). Regression of one unit root process on another may result in spurious regression in that the R^2 would be high, the t-statistic significant but the results lack economic meaning (Enders; Davidson and Mackinnon).

The SAS software version 8e is used to test the null of a unit root on maize prices. The macro %dftest (AR =, DLAG =1, TREND = 2) calls for the augmented Dickey–Fuller (ADF) test with three lags, an intercept and a time trend. The procedure is repeated without a time trend (i.e. TREND = 1). When a time trend and an intercept are included, the ADF regression is,

$$\Delta y_t = \mu + \beta t + \gamma y_{t-1} + \sum_{j=1}^{p-1} \phi_j \Delta y_{t-j} + \varepsilon_t \qquad (16)$$

where p is the lag length, and ε_t is a white noise error term and y is the price series considered. Under the null hypothesis of no unit roots, the test statistic does not have a t-distribution, but Davidson and Mackinnon (p. 708) tabulated asymptotic critical values using Monte Carlo experiments. A number of unit-root testing procedures are available in the literature (e.g. Phillips-Oularis test; Phillips-Perron test) but they all have low power and none of them is uniformly more powerful than others (Maddala and Kim; Davison and Mackinnon; Enders). If the null of a unit root is rejected, a VAR is used to model price dynamics. However, if the null is not rejected, maize prices are treated as if they were unit root processes and, hence, tested for cointegration.

4.4.2 Cointegration Tests

In the long run, common stochastic trends (such as inflation, population and weather) may prevent non-stationary agricultural commodity prices from drifting too far apart. In Engle and Granger's own words (p. 251), "if each element of a vector of time-series y_t achieves stationarity after differencing but a linear combination $\theta' y_t$ is already stationary, the time-series y is said to be cointegrated with a cointegrating vector θ."

There are many procedures to test for cointegration, but none of them is uniformly most powerful. Maddala and Kim reviewed Monte Carlo studies assessing the performance of cointegration tests and found conflicting results. For example, they point out that while Gregory (1994) found that the ADF and the Phillips-Perron (PP) statistics have better size and power properties than the Johansen cointegration statistics, Haug found that the Johansen and Juselius cointegration statistic (λ_{max}) has the least size distortions. Further, Eitrheim argues that the Johansen statistics have low power against near cointegration alternatives.

The Engle and Granger (EG) two-step procedure can be used to test for cointegration on maize prices that have a unit root and the same order of integration. First, each maize price series is regressed against all other (non-stationary) prices and an intercept,

$$y_{1t} = \beta_0 + \beta_2 y_{2t} + \ldots + \beta_k y_{kt} + \ldots + e_t \tag{17}$$

where y_{it} $(i = 1 \ldots k)$ are non-stationary maize prices, β_j $(j = 0, 2 \ldots k)$ are the cointegrating parameters and e_t is a vector of error terms. Second, the residuals from the first step are tested for unit root using the ADF test. The EG test is based on the following auxiliary regression,

$$\Delta \hat{e}_t = \gamma \hat{e}_{t-1} + \sum_{j=1}^{p-1} \phi_j \Delta \hat{e}_{t-j} + \varepsilon_t \tag{18}$$

under the null hypothesis of a unit root in the residuals (no cointegration), the test statistic does not follow a t-distribution, but Davidson and Mackinnon (p.722) tabulated critical values using Monte Carlo simulations. If the null of unit root (no cointegration) is rejected, the dynamic model is specified as an error-correction model. However, if the null is not rejected a VAR in first differences is estimated.

4.4.3 Vector Autoregression and Error Correction Models

The procedure used to measure maize price dynamics of regional maize markets in Mozambique will utilize a multivariate vector autoregression or an error-correction model depending on whether or not prices are cointegrated (see figure 4.5)[8].

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[8] Since maize prices were found to be stationary in levels (see section 5.3), two vector autoregressions were estimated using maize price levels. One VAR used maize prices in southern/central Mozambique, and the other VAR used maize prices of the markets in northern Mozambique. The decision of which markets to include in each VAR was based upon PBM estimates and data on interregional maize shippments discussed in section 5.2.

A VAR can be thought of as the reduced form of a structural model in which all variables in the system are endogenous. Such a specification obviates subjective decisions as to which variables are exogenous and, hence, prevents spurious dynamic specification (Greene). The VAR can be represented as,

$$(19) \qquad Y_t = \pi + \sum_{i=1}^{P} \begin{bmatrix} \alpha_{11,i} & \dots & \alpha_{1K,i} \\ \vdots & & \vdots \\ \alpha_{K1,i} & \dots & \alpha_{KK,i} \end{bmatrix} \times Y_{t-p} + \eta(season) + v_t$$

where Y_t is a $K \times 1$ vector of maize prices ($(Y_t = (y_{1t},\dots,y_{Kt})')$) in logarithm form; π is a K-dimensional vector of constants $(\pi = (\pi_1,\dots,\pi_K)')$; α_j is a $K \times K$ matrix parameters; v_t is a vector of multivariate white noise error terms $(v_t = (v_{1t},\dots,v_{kt})')$; $\eta(season)$ captures periodicity,

$$(20) \qquad \eta(season) = \beta \sin(2\pi t/26) + \omega \sin(2\pi t/52) + \varphi \cos(2\pi t/26) + \phi \cos(2\pi t/52),$$

and β, ϖ, φ, and ϕ are vectors of parameters similar to π. The time subscript is indicated by *t*, and *p* is the order of the VAR.

If maize prices are cointegrated, an ECM is specified to capture maize price dynamics:

$$\Delta Y_t = \Gamma + \Pi Y_{t-1} + \sum_{i=1}^{P} \Psi_i \Delta_{t-i} + \eta(season) + \mu_t \tag{21}$$

where ΔY_t is a vector of maize prices in first differences; Γ is a vector of constants; Π is a matrix of coefficients π_{ij} such that at least one π_{ij} is not zero; Ψ_i is a matrix of coefficients; μ_t is a vector of error terms, and $\eta(season)$ is as defined in (19). Notice that if all elements of Π are zero, expression (23) is simply a VAR in first differences. Seemingly unrelated regression is used to estimate the coefficients of the VAR and/or ECM (Gonzalez-Rivera and Helfand) using SAS software version-8e.

4.4.3.1 Lag Length Selection

Before estimating a VAR or an ECM it is necessary to estimate the lag length of the stochastic process. The Akaike Information Criterion (AIC), the Schwartz's Criterion (BIC), and sequential F-tests can be used to estimate the lag length (Greene). In addition to using a pretest estimator whose properties are unknown, sequential F-tests are also disadvantageous when the sample data are short because they can result in longer lags (Greene). Both the AIC and the BIC reflect trade offs between accuracy and parsimony, but the BIC uses heavier penalty for additional parameters (Greene), which leads to a simpler model.

In this study, both AIC and sequential F-tests were discarded because they yielded long lags lengths and insufficient degrees of freedom for hypothesis testing. The BIC+2 (Pantula, Gonzalez-Farias, and Fuller) is used in this study. The BIC+2 procedure consists of finding the lag length with the BIC and then adding two more lags. This procedure allows a balance between shorter lags, which would result from using the "usual" BIC, and long lags that would result from using other procedures such as the AIC or sequential F-tests. With randomly occurring missing values, long lags would "generate" more missing values resulting in fewer degrees of freedom, and bias and inconsistency of parameter estimates.

To allow differences in lag lengths between equations that may arise due to differences in roads and information lags, the BIC+2 is implemented in two steps. First, each maize price regressed on its own lags, and the lag order with minimum BIC is selected. Second, each maize price is regressed against the lags of all other prices (due to missing values, the maximum lag allowed was five) given its own lag length selected in the first step. The lag length with minimum BIC is selected and two more lags added for all regressors. The TSP- 4.4 software is used to estimate the BIC. The BIC weights parsimony and accuracy and is given by (Judge et al.),

$$BIC(p) = \log(\det \tilde{\sum}_n) + M^2 n \frac{\ln T}{T} \qquad (22)$$

where M is the number of variables in the system, T is the sample size, and $\det \tilde{\sum}_n$ is the determinant of the estimated residual covariance matrix which is computed as,

$$\tilde{\sum}_n = \frac{(Y - X\hat{B})'(Y - X\hat{B})}{T}.$$

With the BIC+2 procedure, the value of the lag length *(p)* is found that minimizes (22), and the length of lag selected is *p*+2.

4.4.3.2 Diagnostic Procedures

Time series techniques are intended to take advantage of autocorrelation embedded in the data to explain the economic phenomenon of interest. When all past information have been used to explain the variable of interest, the error term should be white noise. That is,

$$\varepsilon_t \text{ is white noise if } \begin{cases} E(\varepsilon_t) = 0 \\ \\ E(\varepsilon_t, \varepsilon_s) = \sigma^2 \text{ if } t = s \\ \qquad\qquad = 0, \text{ otherwise.} \end{cases}$$

If in addition to being white noise the residuals are normally distributed, then they are Gaussian white noise, and the standard T-test and F-test are valid. This section tests the assumptions that residuals of dynamic models are white noise and normally distributed.

Following a recommendation by McGuirk, Driscoll, and Alwang, Engle's two-step Lagrange Multiplier (LM) statistic is used to jointly test for general autoregressive conditional heteroskedasticity (ARCH). As such, the estimated residuals from each equation of the VAR or ECM are recovered and then used to estimate an auxiliary regression:

$$\hat{e}_t^2 = \alpha_0 + \alpha_1 \hat{e}_{t-1}^2 \qquad (23)$$

under the null of no ARCH (or GARCH) and a sample of *N* observations, the statistic NR^2 converges in distribution to a chi-squared distribution with one degree of freedom ($NR^2 \sim \chi_1^2$). In this study, an asymptotic F-type test is used to jointly test the residuals for heteroskedasticity. The F-test is also asymptotic but is preferred to an asymptotic chi-squared test in small samples (McGuirk et al.). If the null hypothesis of homoskedaticity is rejected, then maximum likelihood may be used to correct for heteroskedasticity.

The Breusch-Godfrey LM test is used to test for autocorrelation on the error of the system of equations (VAR or ECM). The procedure tests for autoregressive or moving average error terms of any order whether or not lagged dependent variables are included as regressors (Greene; McGuirk et al.). Hence, this test is preferred to other tests (e.g. Durbin-Watson test). An asymptotic F-test is used to test the joint null hypothesis of no autocorrelation using the regression,

$$\hat{e}_t = \beta' X_t + \Lambda' \hat{e}_{t-1} + u_t, \qquad (24)$$

where $\hat{e}_t$ is a vector of residuals from the VAR or ECM; *X* is a vector of regressors and β', and Λ' are matrix of parameters to be estimated. Before estimating equation (26), missing values are replaced with zeros. If the null hypothesis of no autocorrelation is rejected, the remedy is to increase the lag length of the VAR or ECM, stopping when the null hypothesis is no longer rejected.

The Kolmogorov – Smirnov test is used to test the residuals for normality. The procedure compares the hypothesized theoretical normal distribution with the empirical one. The null hypothesis is that the error terms are normally distributed (Conover):

$$T = \sup | F^{*}(y) - S(y) | \tag{25}$$

where $F^{*}(y)$ and $S(y)$ are respectively the hypothesized and the empirical distribution of the stochastic process. The SAS software-8e canned procedure used to test for normality prints the p-values of the test. If the assumption of normality is violated, hypothesis testing (t-test and F-test) can still be carried out appealing to the central limit theorem, provided that the variance is homoskedatic. Some power, however, may be lost.

4.4.4 Lead-Lag Relationships Among Spatial Maize Markets

Factors such as the size and the location of the market (and, hence, access to roads, credit and information) often affect the speed of the market's response to exogenous shocks. During the price discovery process, some markets may Granger cause or anticipate others resulting in lead-lag relationships. Following Granger, a market X causes market Y if and only if Y is better predicted by using the past history of X than by not doing so, with the past history of X being used in either case. That is, if $f(Y_t | Y_{t-i}, X_{t-i})$ equals $f(Y_t | Y_{t-i})$ then X does not Granger cause Y.

If X causes Y and Y does not cause X, then X causes Y unidirectionaly. If X does not causes Y, and Y does not cause X, then X causes Y are statistically independent or related contemporaneously. If X causes Y and Y causes X, then there is feedback between X and Y. If X causes Z and Z causes Y, then X indirectly causes Y.

By definition, if prices of two or more markets are cointegrated, there must be some causality between them. However, cointegration says nothing about the direction of the causal relationship. In a VAR context, a joint F-test is used to test the null hypothesis that the coefficients of each independent variable do not (jointly) Granger cause the dependent variable. Rejecting the null implies that the dependent variable under consideration leads the dependent variable in the price discovery process.

4.5 Summary

This chapter has presented the data and modeling procedures used to accomplish the objectives of this study. The test for arbitrage efficiency utilizes the PBM, a switching regression model that combines price and transfer cost information. The PBM, which accounts for discontinuous trade and nonstationarity of transfer cost data that cause inferential problems on the popular price-based regressions, is estimated in two steps. First, the average transfer cost for each maize route is extrapolated into a time-series by deflating it with a consumer price index and diesel prices. Second, estimates of the lower and upper parity bounds are obtained using maximum likelihood.

The analysis of price dynamics (that may occur due to information and transportation lags) uses a VAR and/or ECM depending on whether or not prices are cointegrated. In the VAR context, a joint F-test is used to test for Granger causality tests and determine the lead-lag relationships between interregional maize prices. Since the concept of cointegration implies causality by itself, cointegrated markets must have some causal relationship between them. Larger markets are expected to lead the price discovery. Short distances, and access to information and roads, favor rapid spatial price transmission and adjustment after exogenous shocks.

CHAPTER V

RESULTS AND DISCUSSION

5.1 Introduction

The results of this study are provided and discussed in this chapter. First, section 5.2 discusses the PBM results used to make inferences about the efficiency of spatial arbitrage. The sum of regime I probability (when price spreads equal transfer costs) and regime II probability (when price spreads fall below transfer costs) provides a measure of arbitrage efficiency. The probability of regime III (when price spreads exceed transfer costs) reflects impediments to trade, and is interpreted as arbitrage inefficiency. Finally, section 5.3 provides the results of the multivariate dynamic models. Multivariate Granger causality tests between maize markets are used to make inferences about lead-lag relationships between spatial maize prices.

5.2 Spatial Arbitrage Efficiency

The estimates of the PBM using monthly maize retail prices and transportation costs deflated by the CPI for all Mozambique are presented in table 5.1. As indicated by the sum of the probabilities of regime I and II, spatial arbitrage is efficient 64 % to 66 % of the time between markets within southern Mozambique (Maputo, Xai-Xai and Maxixe), and 73 % to 83 % of the time between markets within central Mozambique (Tete, Beira,

Table 5.1. Estimates of the PBM Regime Probabilities for Mozambique Maize Retail Markets Using CPI as a Deflator to Project Transfer Costs.

	PBM Regime Probabilities		
Maize Route	Regime I	Regime II	Regime III
Chimoio → Xai-Xai	0.653	0.2E-02	0.346
	(0.00)	(0.425)	(0.00)
Maputo → Beira	0.491	0.1E-02	0.507
	(0.00)	(0.58)	(0.00)
Chimoio → Maputo	0.1E-02	0.916	0.083
	(0.05)	(0.00)	(0.122)
Maputo → Mocuba	0.1E-02	0.1E-02	0.998
	(0.00[a])	(0.00[a])	(0.00[a])
Pemba → Maputo	0.043	0.1E-02	0.956
	(0.254[a])	(0.00[a])	(0.00[a])
Maputo → Xai-Xai	0.1E-02	0.658	0.341
	(0.01)	(0.00)	(0.00)
Nampula → Beira	0.1E-02	0.1E-02	0.998
	(0.00[a])	(0.00[a])	(0.00[a])
Nampula → Tete	0.1E-02	0.1E-02	0.998
	(0.00[a])	(0.00[a])	(0.00[a])
Chimoio → Mocuba	0.302	0.413	0.556
	(0.63)	(0.00)	(0.00)
Tete → Maputo	0.449	0.698	0.283
	(0.00)	(0.01)	(0.01)
Tete → Beira	0.019	0.733	0.266
	(0.928)	(0.00)	(0.00)
Chimoio → Beira	0.835	0.1E-02	0.163
	(0.00)	(0.016)	(0.275)
Maputo → Maxixe	0.641	0.1E-02	0.358
	(0.00)	(0.00)	(0.00)
Nampula → Maxixe	0.090	0.034	0.876
	(0.01)	(0.12)	(0.00)

Notes: Regime I, II, and III are defined respectively when price spreads equal, fall below, and equal transfer cost. P-values are in parentheses. Superscript *a* indicates that parameter estimates and p-values may not be valid since the edge of the parameter space was encountered.

Mocuba and Chimoio) except for the pair Mocuba-Chimoio that is efficient only 44 % of the time. Results also indicate that spatial arbitrage between southern and central Mozambique is efficient 50 % to 92 % of the time, but price spreads between maize markets in northern Mozambique and those in central/southern Mozambique are less than or equal to transportation costs less than 15 % of the time. These results suggest that maize markets in the northern region function in relative isolation. As expected, when diesel prices are used as a deflator of transportation cost observations, there is an average decrease of 18% in arbitrage inefficiency (see table 5.2). However, results are consistent.

Li and Barrett, and Barrett argue that spatial trade is best measured by interregional shipments rather than price-cost based indicators. Records of interregional maize flows in Mozambique (see table 5.3) agree with the PBM results discussed above. Consistent with the PBM results, table 5.3 indicates that there are flows of maize within and between south/central Mozambique, but no records of maize flows from northern Mozambique to central/southern regions. While it is likely that some maize is shipped from northern surplus regions to central/southern regions, the average frequency of shipments is expected to be low. Together, the PBM estimates and interregional maize shipments suggest that the probability of market integration between southern and central Mozambique is higher than between northern Mozambique and central/southern Mozambique. Recall that northern Mozambique is a maize surplus (even during regional droughts) and southern Mozambique is perpetually a maize deficit region (Jayne et al.).

Table 5.2. Estimates of the PBM Regime Probabilities for Mozambique Maize Retail Markets Using Diesel Prices as a Deflator to Project Transfer Costs.

	Probabilities		
Maize Route	Regime I	Regime II	Regime III
Chimoio → Xai-Xai	0.774 (0.00)	0.1E-02 (0.00)	0.225 (0.02)
Maputo → Beira	0.456 (0.08)	0.175 (0.39)	0.368 (0.00)
Chimoio → Maputo	0.1E-02 (0.00)	0.938 (0.00)	0.061 (0.189)
Maputo → Mocuba	0.1E-02 (0.02)	0.1E-02 (0.00)	0.997 (0.00)
Pemba → Maputo	0.1E-02 (0.00[a])	0.1E-02 (0.00[a])	0.999 (0.00[a])
Maputo → Xai-Xai	0.1E-02 (0.13)	0.818 (0.00)	0.181 (0.01)
Nampula → Beira	0.1E-02 (0.00[a])	0.1E-02 (0.00[a])	0.998 (0.00[a])
Nampula → Tete	0.1E-02 (0.00[a])	0.1E-02 (0.00[a])	0.998 (0.00[a])
Chimoio → Mocuba	0.5E-02 (0.00)	0.500 (0.39)	0.494 (0.00)
Tete → Maputo	0.3E-02 (0.00)	0.617 (0.00)	0.379 (0.00)
Tete → Beira	0.029 (0.91)	0.805 (0.00)	0.167 (0.02)
Chimoio → Beira	0.835 (0.00)	0.1E-02 (0.016)	0.163 (0.275)
Maputo → Maxixe	0.1E-02 (0.03)	0.699 (0.00)	0.299 (0.00)
Nampula → Maxixe	0.353 (0.00)	0.1E-02 (0.00)	0.646 (0.00)

Notes: Regime I, II, and III are defined respectively when price spreads equal, fall below, and equal transfer cost. P-values are in parentheses. Superscript *a* indicates that parameter estimates and p-values may not be valid since the edge of the parameter space was encountered.

Table 5.3 Recorded Interregional Maize Flows in Mozambique (1998-2001).

	Percent of Destination Market					
Exporting Market	Maputo	Inhambane	Sofala	Manica	Zambezia	Nampula
Maputo	14.17	-	-	-	-	-
Gaza (Chocke)	25.25	7.17	-	-	-	-
Maxixe	0.84	17.29	-	-	-	-
Sofala (Beira)	-	5.36	17.25	-	-	-
Manica (Chimoio)	36.61	59.26	34.73	86.14	-	-
Tete	11.78	0.41	9.32	1.14	-	-
Zambezia (Mocuba)	2.52	4.35	-	-	98.71	90
Nampula	-	-	-	-	-	6
Pemba	-	-	-	-	-	-
Lichinga	-	-	-	-	-	-
Others	8.42	6.16	39	12.71	1.29	4
Total	100	100	100	100	100	100

Notes: Author's computations based on data from the SIMA database.

The PBM estimates are also consistent with access to roads in Mozambique. The road that would connect northern with central/southern Mozambique stops at Caia in the border the between the Sofala (Beira) and Zambezia (Mocuba) provinces (see figure 2.2). The ferryboat crossing the Zambezi River until Zambezia province is not always available and there is no railway connecting northern with southern Mozambique

The possibility of maritime transportation is limited by obsolete/inefficient tertiary and secondary ports (DNCI, No. 18). Very often, road connection with northern Mozambique is made through Malawi, especially during the rainy season (DNCI, No. 18). Despite poor roads (about 53% of the roads in Mozambique are feeder roads), maize is primarily transported by truck. Poor access to roads appears to be limiting trade between southern (maize deficit) and northern (maize surplus) Mozambique.

The inefficiency of spatial arbitrage, as measured by regime III probabilities, is high when compared to the results obtained for rice markets in the Philippines by Baulch, and those obtained by Li and Barrett while studying soybean meal trade between the United States, Canada, Japan and Taiwan. These studies used switching regressions similar to the one used here.

5.3 Maize Price Dynamics

The results of the ADF and Phillips-Perron (PP) unit root test on maize price logarithms are presented in table 5.4. The ADF test indicates that the null hypothesis of a unit root cannot be rejected for Chokwe, Nampula, Pemba, and Lichinga prices. With the PP test, however, the null hypothesis is rejected for all but Lichinga. Note that Lichinga has the largest number of missing values (107). Given that unit root tests have low power (Maddala and Kim) with small samples (none of the unit root tests are uniformly more powerful than the others), and there is no reason to believe that Lichinga prices are structurally different from the others, all maize prices are treated as if they were stationary. Following the procedure presented in figure 4.3, a VAR is used to model maize price dynamics and measure the lead-lag relationships between spatial maize prices.

Table 5.4. Unit Root Test Statistics on Weekly Maize Prices (Meticais/Kilogram) of Mozambique, 1994-2001.

	ADF Test Statistic		Phillips-Perron Test Statistic	
Market	with a Linear Trend and Drift	with a Drift Only	with a Linear Trend and Drift	with a Drift Only
Maputo	-3.44*	-3.68*	3.95*	-4.05*
Chokwe	-2.77	-2.64	-2.95	-2.87*
Maxixe	-3.66*	-3.74*	-3.48*	-3.58*
Beira	-4.09*	-4.13*	-3.98*	-4.05*
Chimoio	-4.08*	-4.20*	-3.65*	-3.81*
Tete	-3.06	-3.13*	-3.32	-3.39*
Mocuba	-3.67*	-3.72*	-3.28	-3.44*
Nampula	-2.61	-2.73	-2.84	-2.91*
Pemba	-2.89	-2.79	-4.26*	-4.15*
Lichinga	-2.06	-1.83	-2.46	-2.54

Notes: An asterisk denotes significance at the 5% level. Asymptotic critical value for ADF unit root test with drift and trend is -3.41 at 5 % level. The critical value for ADF unit root test with a drift is -2.86 at 5% level of significance.

To be consistent with the PBM results, access to roads, and maize shipments reported in table 5.3, two VAR systems are estimated. The first system includes maize markets in southern/central Mozambique that are connected by roads (see figure 2.2) and have inter-market maize shipments (see table 5.3). The second VAR includes maize markets in northern Mozambique (Mocuba, Nampula, Niassa and Pemba). These markets are not connected by roads with central/southern Mozambique, and there are little or no records of maize shipments from these regions to central/southern Mozambique. Further, except for Mocuba, spatial arbitrage between northern and central Mozambique is inefficient 85 % of the time.

The lag lengths of the VAR equations estimated by the BIC+2 procedure are provided in table 5.5. As table 5.5 shows, univariate lag selection yielded different lag lengths. Markets in central Mozambique (Tete, Beira and Chimoio) have the lowest lag lengths, suggesting that they have higher speed of price adjustment when compared northern and southern Mozambique. For both VAR equations, multivariate lag length was limited to a maximum of seven to avoid shortages of degrees of freedom due to missing values. Multivariate lag estimation also yielded different lag lengths.

Table 5.5. Estimated Lag Length for Weekly Maize Prices (Meticais/Kilogram) for the period 1994 - 2001 Using the BIC+2 Procedure

	Lag Order	
Dependent Variable	When Only the Dependent Variable is Considered	Lag Length of the Remaining Regressors in the System
Maputo	4	4
Chokwe	5	4
Maxixe	4	3
Beira	3	4
Chimoio	3	4
Tete	3	3
Mocuba	6	3
Nampula	5	4
Pemba	4	3
Lichinga	3	6

Note: The variables included in each equation depend upon which trading region is considered. The first VAR includes Maputo, Xai-Xai, Maxixe, Beira, Chimoio, and Tete. The second VAR includes Mocuba, Nampula, Pemba, and Lichinga.

Joint misspecification tests on the residuals of the VAR of central/southern Mozambique are provided in table 5.6. The joint LM autocorrelation test indicated mild autocorrelation that was corrected by adding one more lag for Chimoio and Beira maize prices. The joint RESET test failed to reject the null hypothesis of linear equations against an alternative hypothesis of quadratic specification. Given the joint ARCH test could not reject the null hypothesis of homoskedasticity of the residuals, these were treated as if they were white noise.

Table 5.6. Summary F-Statistics of Misspecification Tests on the Residuals of the VAR for Central and Southern Mozambique.

Misspecification Test	Joint F-Statistic
Joint test for seasonality	2.08* (0.00)
Joint Reset2 test	1.30 (0.26)
Joint ARCH test	1.25 (0.28)
LM test for autocorrelation	1.36 (0.23)

Note: The numbers in parentheses are p-values. Asterisk indicates significance at the 5 % level. The markets included in the VAR are (Maputo, Chokwe, Maxixe, Chimoio, Beira, and Tete

Misspecification tests on the residuals of the VAR of northern Mozambique are provided in table 5.7. As table 5.7 indicates, while the joint LM autocorrelation test indicates that does not reject the null hypothesis of independent residuals, the joint ARCH test rejected the joint null of homoskedasticity. Further testing indicated that the source of

Table 5.7. Summary F-Statistics of Misspecification Tests on the Residuals of the VAR for Northern Mozambique

Misspecification Test	Joint F-Statistic
Joint test for seasonality	3.47** (0.00)
Joint Reset2 test	1.39 (0.240
Joint ARCH test	6.62** (0.00)
LM test for autocorrelation	1.12 (0.34)

Note: The numbers in parentheses are p-values. Asterisk indicates significance at the 5 % level. The markets included in the VAR are Mocuba, Nampula, Pemba, and Lichinga.

heteroskedasticity was Nampula. Since the Kolmogorov-Smirnov nonparametric test for normality did not reject the null of normally distributed residuals for Nampula, and the correction for heteroskedasticity is impractical (in a SUR) with missing values, no correction for heteroskedasticity is made. Caution is necessary when interpreting the results of the Granger causality tests for northern Mozambique, since the estimator may not be efficient. The joint RESET test failed to reject the null hypothesis of linear equations against an alternative hypothesis of a quadratic specification.

The Kolmogorov-Smirnov normality test (see tables 5.8 and 5.9) indicates that the null hypothesis of normally distributed residuals is rejected at 5 % level for nearly all equations in the VAR for both southern/central and northern Mozambique. Given that the variance is homoskedastic, hypothesis tests using t-tests and F-tests are still carried out appealing to the central limit theorem. However, these tests may lack power.

Table 5.8. Summary F-statistics of Causality Tests between Retail Maize Prices in Central and Southern Mozambique.

Dependent Variable	Lagged Independent Variable						Kolmogorov-Smirnov Normality test
	Maputo	Chokwe	Maxixe	Beira	Chimoio	Tete	
Maputo	0.96	0.64	0.30	0.63	0.76	0.18	0.09**
	(0.43)	(0.63)	(0.88)	(0.64)	(0.55)	(0.95)	(0.02)
Chokwe	0.34	30.22**	0.92	1.22	2.35**	1.16	0.16**
	(0.85)	(0.00)	(0.49)	(0.30)	(0.05)	(0.33)	(0.01)
Maxixe	0.68	1.19	7.66**	0.61	1.46	0.62	0.15**
	(0.57)	(0.31)	(0.00)	(0.61)	(0.22)	(0.60)	(0.01)
Chimoio	0.22	0.93	1.60	0.13	11.30**	3.38**	0.09*
	(0.93)	(0.45)	(0.17)	(0.97)	(0.00)	(0.01)	(0.07)
Beira	1.38	1.13	2.08*	5.28**	1.41	2.07*	0.13**
	(0.24)	(0.34)	(0.08)	(0.00)	(0.23)	(0.09)	(0.01)
Tete	1.14	1.33	0.64	1.61	1.13	5.16**	0.06
	(0.33)	(0.27)	(0.59)	(0.19)	(0.34)	(0.00)	(0.15)

Notes: p-values are in parentheses. Two asterisks indicate significance at 5 % level and one asterisk indicates significance at 10 % level. The Variables included in the VAR are Maputo, Chokwe, Maxixe, Tete, Chimoio and Beira.

Misspecification tests indicated that both VARs are adequate to conduct causality tests. The results of multivariate Granger causality between spatial maize prices in Mozambique are presented in tables 5.8 and 5.9. Contrary to what was found in the U.S. markets (Brorsen, Chavas and Grant; Schroeder and Goodwin), the joint F-test indicates that Maputo, the largest retail market in Mozambique, does not lead maize prices in south/central Mozambique. Chokwe prices follow Chimoio prices, and Maxixe leads

Table 5.9. Summary F-statistics for Causality Tests on Retail Maize Prices of Northern Mozambique

Dependent Variable	Lagged Independent Variable				Kolmogorov-Smirnov
	Mocuba	Nampula	Pemba	Lichinga	Normality test
Mocuba	11.50**	1.07	0.74	0.59	0.08*
	(0.00)	(0.36)	(0.53)	(0.62)	(0.09)
Nampula	7.68**	16.64**	0.95	3.25**	0.06**
	(0.00)	(0.00)	(0.42)	(0.02)	(0.15)
Pemba	1.12	2.77**	6.00**	1.18	0.08*
	(0.34)	(0.04)	(0.00)	(0.32)	(0.07)
Lichinga	0.23	1.19	1.27	36.67**	0.06*
	(0.97)	(0.31)	(0.27)	(0.00)	(0.15)

Note: p-values are in parentheses. Two asterisks indicate significance at 5 % level and one asterisk indicates significance at 10 % level. The variables included in the VAR are Mocuba, Nampula, Pemba, Lichinga.

Beira. Maxixe is closer to the central region than Maputo and Chokwe. Recall that there are road connections between southern and central Mozambique and there are records of maize shipments from central and southern Mozambique (see table 5.3).

The lack of Maputo's dominance in the price discovery process in southern/central Mozambique may be due to arbitrage inefficiency or to its closeness to South Africa, which is a bigger market than Maputo. There are good roads between Maputo and Randfontein (South Africa), and there are reports of strong formal and informal maize and maize meal imports from South Africa to Maputo (Macamo). The PBM estimates indicate that the arbitrage efficiency between Maputo and Randfontein (90 %) is higher than other markets within Mozambique, except Chimoio (see appendix c).

In central Mozambique, Tete emerges as the price leader. Tete maize prices lead Beira and Chimoio prices, and Chimoio prices lead Chokwe price. Hence, Tete indirectly Granger causes Chokwe maize prices through Chimoio. Tete, located in central Mozambique, has good road links with other provinces in central Mozambique and exports maize to Malawi and Zambia (DNCI, No.3). Beira, located in the heart of the Beira Corridor (a 100 km wide international trade channel linking Zimbabwe, Mozambique, Zambia, Malawi and South Africa to the port of Beira on the Indian ocean), was expected to lead the price discovery process in central Mozambique.

In northern Mozambique (see table 5.9), Mocuba and Lichinga lead Nampula prices, which in turn lead Pemba. None of these markets clearly dominates the others in the maize price discovery process. Like Maputo and Beira in southern and central Mozambique respectively, Nampula is considered the main maize retail market in northern Mozambique, and was expected to lead the price discovery process in the northern region.

Results also indicate that maize prices in Mozambique (refer to tables 5.6 and 5.7) follow seasonal cycles suggesting that storage is not free. Arndt et al. argue that storage costs in rural or near rural areas is higher than in urban areas where previous maize monopolies have about 235,000 of usable storage capacity. All maize markets in Mozambique areresponsive to past prices within one to six weeks. These lag lags are similar to the lags found by Schroeder and Goodwin, and by Baulch. Schroeder and Goodwin found that slaughter steers prices in the U.S. cattle industry have lagged price responses between two and three weeks. Baulch found lags between one and two months in the Philippines rice industry. Lagged price responses in Mozambique are consistent with poor roads and lack of access to market information faced by market agents in the maize marketing channel.

5.4 Summary

The results of the tests for spatial arbitrage efficiency and lead-lag relationships between spatial maize prices were presented in this chapter. The test for spatial arbitrage efficiency used both CPI and diesel prices to deflate transportation cost. Although the PBM estimates are slightly higher when diesel prices are used as a deflator, results are consistent. The PBM estimates indicate that arbitrage is efficient 85 % of the time within central Mozambique (85%), and 66% in southern Mozambique (66%). The probability of efficient spatial arbitrage between central and southern Mozambique varies between 50 to 92 %, and spatial arbitrage between northern (maize surplus) Mozambique and other regions is inefficient 85 % of the time. Existing records of interregional maize shipments are consistent with the PBM estimates in that there are shipments of maize between central and southern Mozambique, and few between northern Mozambique and central/southern Mozambique. Hence, markets in southern and central Mozambique are integrated with each other, but not with markets in northern Mozambique.

Granger causality tests indicated that none of the markets in southern Mozambique dominates the others in the maize price discovery process. Only Maxixe appears to anticipate maize prices in central Mozambique, particularly Beira. Maxixe is closer to central Mozambique than Maputo and Chokwe. In central Mozambique, Tete appears to lead the price discovery process, and in northern Mozambique there is no clear price leader. The distance from producing areas appears to be more important in spatial price transmission than the size of the market. This is not surprising given the quality of roads in Mozambique. In general, both PBM and Granger causality tests suggest that maize markets in southern/central Mozambique have trade links but spatial arbitrage remains inefficient.

CHAPTER VI

SUMMARY AND CONCLUSIONS

6.1 Research Problem, Objectives, Methods and Conclusions

More than a decade has passed since Mozambique reformed food crop markets and liberalized maize prices. Yet, price instabilities and maize shortages are still puzzling the population and the government. This study maintains that the persisting problem of maize spatial arbitrage inefficiency is a possible explanation of why food shortages and price instability continue to be a problem in Mozambique despite market liberalization.

When spatial trade efficient, food shortages in deficit regions are transmitted to surplus regions via prices, and arbitrage triggers flows of food across space. Consumers from deficit regions pay lower food prices and producers from surplus regions receive higher prices and, therefore, have an incentive to increase production. Through efficient spatial arbitrage, the risk of crop failure in some regions is shared over a large market area and, prices are more stable. This study aimed to measure the efficiency of spatial trade in Mozambique.

Maize trading in Mozambique is dominated by informal traders who transact small quantities of maize depending upon their own capital. Maize is inspected and paid upon delivery. Usually, cash payments are made without invoicing, a practice that complicates accounting. Lack of accounting further limits the possibility of getting a loan from formal lending institutions. Formal lending institutions serve less than 20 % of the Mozambican population (Larson). Maize transported on trucks, and maize transportation costs are the largest portion of maize transfer costs. Access to roads and credit appear to be the most important constraints faced by traders. There is no road connection between maize surplus regions (mainly northern Mozambique) and southern maize deficit regions, and most roads are impassable during the rainy season.

To accomplish the objectives of this study, two complementary procedures were used. The Baulch's switching regression (PBM) is used to measure spatial arbitrage efficiency, and time-series models used to determine lead-lag relationships between spatial maize prices and provide further information about spatial price transmission and the relevant maize market area. The PBM is a switching regression that combines maize prices and interregional shipping costs, and accounts for nonstationary transfer costs and trade discontinuities that often cause inferential problems on models that use only prices to test for market efficiency and integration. Time series models are used to model maize price dynamics.

Spatial arbitrage efficiency tests indicated that maize markets in central Mozambique have the highest probability of being efficient (85%), followed by markets in southern Mozambique (66%). Spatial arbitrage between central and southern Mozambique is efficient 50 to 92% of the time. But arbitrage conditions between northern Mozambique and other regions are violated 85% of the time indicating that it would pay to ship maize from the north to the south. Yet, records of interregional maize shipments show that grain is not being shipped from northern to southern Mozambique. Access to roads and distance between markets appear to be more important in spatial arbitrage and maize price transmission than the size of the market.

Results indicate that a decade after food market liberalization, spatial maize arbitrage remains inefficient in much of Mozambique. While market reforms have undoubtedly helped, inefficient spatial arbitrage limits the benefits obtained from freeing markets. Under these circumstances, reports of food shortages and price instability are likely to continue.

Poor roads and trader's lack of access to capital are possible explanations of spatial trade inefficiency. Most roads have seasonal circulation limiting interregional maize shipments. Interest rates are high for most maize traders. High interest rates force traders to transact small quantities of maize resulting in high per-unit transaction costs. The end result is unexploited arbitrage opportunities and inefficiency.

While specific policy recommendations can hardly be drawn directly from the results of this study, non-price policies could enhance spatial efficiency. Policy interventions should be directed to (i) reduce transaction risks and (ii) reduce marketing costs. Transaction risks in maize trading contribute to rudimentary business practices. Maize is inspected and paid upon delivery. Cash payments are made without invoicing, a practice that complicate accounting. The lack of accounting skills by borrowers and small scale of operation results in low probability of loan repayment and, hence, high interest rates. Poor roads raise trader's costs, limit access to local markets, and discourage trade. Investment in roads (particularly north-south roads) and, perhaps, lowering the costs of licensed traders would help reduce food shortages and price instabilities.

6.2 Study Limitations

There are three limitations of the PBM that are worth mentioning. First, the quality of the PBM estimates used to make inferences about spatial arbitrage efficiency depend largely on the quality of transfer cost observations used to extrapolate times series cost data. If transfer costs are overstated, functionally isolated markets may be deemed efficient. On the other hand, if transfer costs are underestimated, well functioning markets may be found functionally inefficient. Monte Carlo studies have shown that when transfer cost data are overstated or understated by more than 12.5 %, the PBM fails to converge or parameter estimates reach the edge of the parameter space (Baulch). In this study there were no cases when convergence was not achieved and there were only four cases when the edge of parameter estimates was encountered (see table 5.1 and 5.2). Further, single point transport costs reported by Coulter (1995) and by DNCI (No.3, 1998) have the same magnitude when compared with corresponding points of the extrapolated series suggesting that the extrapolated cost data are acceptable.

Second, while the PBM detects violation of spatial arbitrage conditions that indicate inefficiency, it does not identify the reasons that lead to such violations. Spatial arbitrage inefficiency may indicate that some market controls still exist, or that there are institutional constraints (i.e. lack of information or credit), or that transportation infrastructure is inadequate, or both.

Third, the assumptions of independence between transfer cost data and maize prices, and of half-normal error terms are questionable. While the specification of the PBM likelihood function as a mixture of distributions is a flexible way of modeling unknown probability distributions (Baulch), there is no prior justification why the two error terms should be truncated. However, Monte Carlo studies indicate that the half-normality assumption does not cause considerable bias of the PBM estimates (Baulch).

With regard to the dynamic time series model used to determine the lead-lag relationships between spatial maize prices, two weakness need to be pointed out. First, the specification of a linear model is somehow inconsistent with trade discontinuities between spatial markets. However, the misspecification tests (RESET-test) failed to reject the hypothesis of a linear model in favor of a quadratic specification.

Finally, the restriction of the VAR equations lag length to a maximum of five lags was ad-hoc, and intended to avoid excessive loss of degrees of freedom due to missing values. With such a restriction and lack of prior information on price adjustments, it is possible that the lag lengths selected by BIC+2 procedure are different from the "true" lag. However, the LM test of no autocorrelation failed to reject the null, indicating that no significant bias was introduced by such ad-hoc procedures.

6.3 Suggestion for Future Research

The model used to measure spatial arbitrage efficiency can detect violations of spatial arbitrage conditions but it does not identify the causes of such violations. Further studies need to measure the effect of institutional constraints (e.g. access to roads, credit and information) on spatial price arbitrage, so that specific policy recommendations could be drawn. For example, given precise information about beginning/ending of road construction on a given maize route, one could measure the welfare gains from road improvement by examining maize marketing margins before and after road improvement.

LIST OF REFERENCES

Arlindo, P. "Forecasting Agricultural Prices in an Underdeveloped Open Economy: The Case of Maize in Mozambique." Unpublished M.S. Thesis. Department of Agricultural Economics, Michigan State University, East Lansing, MI, 2001.

Arndt, C., R. Schiller, and F. Tarp. "Grain Transport and Rural Credit in Mozambique: Solving the Space-Time Problem." *Agricultural Economics*, 25 (2001): 49-70.

Banco de Mocambique. Statistical Bulletins No. 09/3. Maputo, 1995.

Banco de Mocambique. Statistical Bulletins No. 17/5. Maputo, 1997.

Banco de Mocambique. Statistical Bulletins No. 29/8. Maputo, 2000.

Banco de Mocambique. Statistical Bulletins No. 31/9. Maputo, 2001.

Barrett, C.B. "Market Analysis Methods: Are Our Enriched Toolkits Well Suited to Enlivened Markets?" *American Journal of Agricultural Economics*, 78 (1996): 825-829.

Barrett, C. B. "Measuring Integration and Efficiency in International Agricultural Markets." *Review of Agricultural Economics*, 23 (2001): 19-32.

Baulch, B. "Transfer Costs, Spatial Arbitrage, and Testing for Food Market Integration." *American Journal of Agricultural Economics*, 79 (1997): 477-487.

Benfica, R.M.S., " An Analysis of the Contribution of Micro- and Small Enterprises to Rural Household Income in Central and Northern Mozambique." Unpublished M.S. Thesis. Department of Agricultural Economics, Michigan State University, East Lansing, MI, 2001.

Boyd, M. S., and B. W. Brorsen. "Dynamic Price Relationships for US and EC Corn Gluten Feed and Related Markets." *European Review of Agricultural Economics*, 13 (1986): 199-215.

Brorsen, B.W., J.-P. Chavas, and W. R. Grant. "Market Structure and Spatial Price Dynamics." *Southern Journal of Agricultural Economics*, (1991): 65-73.

Conover, W. J. *Practical Nonparametric Statistics*. New York: John Wiley & Sons, Inc., 1999.

Coulter, J. P. "Estudo da Comercializacao e a Politica de Precos de Milho em Mocambique." England: Natural Resources Institute Central Avenue, Chatham Maritime Kent ME 4TB, 1995.

Davidson, R., and J. G. Mackinnon. *Estimation and Inference in Econometrics*. New York: Oxford University Press, Inc., 1993.

Direccao Nacional de Energia - DECO. "Estrutura de Precos de Combustiveis." Unpublished energy price reports from 1994 to 2001. Maputo.

DPDS (Departamento de Populacao e Desenvolvimento), UEM (Universidade Eduardo Mondlane) and IFPRI (International Food Policy Institute). "Understanding Poverty and Well Being in Mozambique: First National Assesment." Maputo: Ministerio do Plano e Financas, 1998.

Drucker, P.F. " Marketing and Economic Development." *Journal of Marketing*, (1958): 252-259.

Engle, R. F., and W. J. Granger. "Co-integration and Error Correction: Representation, Estimation, and Testing." *Econometrica,* 55 (1987): 251-276.

Enders, W. *Applied Econometric Time Series*. New York: John Wiley & Sons, Inc., 1995.

Gallant, A. R., and A. Holly. "Statistical Inference in an Implicit, Nonlinear, Simultaneous Equation Model in the Context of Maximum Likelihood Estimation." *Econometrica,* 48 (1980): 679-720.

Gardner, B.L. "The Farm-Retail Price Spread in a Competitive Food Industry." *American Journal of Agricultural Economics*, 57 (1975): 399-409.

Gonzalez-Rivera, G., and S. M. Helfand. "The Extent, Pattern, and Degree of Market Integration: A Multivariate Approach for the Brazilian Rice Market." *American Journal of Agricultural Economics*, 83 (2001): 576-592.

Goldberg, P. K., and M. M. Knetter. "Goods Prices and Exchange Rates: What Have We Learned?" *Journal of Economic Literature*, 35 (1997): 1243-1272.

Granger, C. "Investigating Causal Relationships by Econometric Models and Cross-Spectral Models." *Econometrica*, 37 (1969): 242-438.

Greene, W. H. *Econometric Analysis*, Fourth Edition. Upper Saddle River, NJ: Prentice-Hall, Inc., 2000.

Harris, B. "There Is Method in My Madness: Or Is It Vice Versa? – Measuring Agricultural Market Performance." *Food Research Institute*, 2 (1979): 197-218.

Harris-White, B. "Efficiency and Complexity: Distributive Margins and the Profits of Market Enterprises." In Gregory J. Scott, ed. "*Prices, Products and People; Analyzing Agricultural Markets in Developing Countries*." Boulder, Co: Lynne Rienner Publishers, Inc., 1995, pp. 301-324.

IMF Country Report No. 01/17. International Monetary Fund, Washington, D.C., 2001.

Instituto Nacional de Estatistica. "Estatisticas do Comercio Externo: Exportacoes e Importacoes, 1996." Maputo, 1996.

Instituto Nacional de Estatistica. "Estatisticas do Comercio Externo: Exportacoes e Importacoes, 1997." Instituto Nacional de Estatistica. 1997.

Instituto Nacional de Estatistica. "Estatisticas do Comercio Externo: Exportacoes e Importacoes, 1997 and 1998." Instituto Nacional de Estatistica, in Press.

Jayne, T.S., M. Mukumbu, M. Chisvo, D. Tschirley, M. T. Weber, B. Zulu, R. Johansson, P. Santos, and D. Soroko. "Successes and Challenges of Food Market Reform: Experience from Kenya, Mozambique, Zambia, and Zimbabwe." MSU International Development Working Paper No. 72 1999.

Jeje, J. J., C. Machungo, J. Howard, P. Strasberg, D. Tschirley, E. Crawford, and M. Weber. "What Makes Agricultural Intensification Profitable for Mozambique Smallholders? An Appraisal of the Inputs Subsector and the 1996/1997 DNER/SG2000 Program: Main Report." Ministry of Agriculture and Fishers, Directorate of Economics, Research Report No.32, 1998.

Judge, G.G., R. C. Hill, W. E. Griffiths, H. Lutkepohl, and T. C. Lee. *Introduction to the Theory and Practice of Econometrics,* Second Edition. New York: John Wiley & Sons Inc., 1988.

Kahkonen, S., and H. Leathers. " Transaction Costs Analysis of Maize and Cotton Marketing in Zambia and Tanzania." SD Publication Series, Office of Sustainable Development Bureau for Africa, Technical Paper No.105, 1999.

Landau, L. "Rebuilding the Mozambique Economy. Assessment of a Development Partnership." The World Bank, Washington, D.C., 1998.

Larson, D.W., F. Zaqueu, D.H. Graham. "Why Users Prefer Informal Financial Market Sevices: The Case of Mozambique." In Selected Papers at the Proceedings of the XXIInd Conference of the International Association of Agricultural Economists, Harare, Zimbabwe, 1994.

Li, J. R., and C. B. Barrett. "Distinguishing between Equilibrium and Integration in Market Analysis." ISSN 1098-9218, Working Paper No. 99, 1999. Available at http://www.umn.edu/iatrc, Accessed in August 2000.

Maasdorp, G. "Regional Trade and Food Security in SADC." *Food Policy,* 23 (1998): 505-518.

Macamo, J. L. "Estimates of Unrecorded Cross-Border Trade between Mozambique and Her Neighbors." SD Publication Series, Office of Sustainable Development Bureau for Africa, Technical Paper No. 88, 2000.

Maddala, G. S., and I. M. Kim. *Unit Roots, Cointegration and Structural Change.* Cambridge University Press: Cambridge, 1998.

McGuirk, A. M., P. Driscoll, and J. Alwang. "Misspecification Testing: A Comprehensive Approach." *American Journal of Agricultural Economics*, 75 (1993): 1044-1055.

MOA/MSU Reseach Team. "The Organization, Behavior, and Performance of the Informal Food Marketing System in Maputo." Ministerio da Agricultura e Pescas, Working Paper No.10, 1993.

Mozambique News Agency. AIM Reports No. 139 (1998). Available at http://www.poptel.org.uk/mozambique-news/, Accessed in October 2001.

Mozambique News Agency. AIM Reports No. 209 (2001). Available at http://www.poptel.org.uk/mozambique-news/, Accessed in October 2001.

Mozambique News Agency. AIM Reports No. 211 (2001). Available at http://www.poptel.org.uk/mozambique-news/, Accessed in October 2001.

Mucavele, F. G. "Analysis of Food Security and Nutrition in Mozambique." Paper Presented at the Seminar on Food Insecurity in ACP Countries: Policy and Program Interventions Affecting Vulnerable Groups Leuven, Belgium, 26-30, October 1998.

Muendane, C. T. "Mercado de Cereais em Mocambique – Producao, Transformacao e Consumo de Milho, Arroz e Trigo." Unpublished Paper, Maputo, 2001.

Obstfeld, M., and Alan M. Taylor. "Nonlinear Aspects of Goods-Market Arbitrage and Adjustment: Heckscher's Commodity Points Revisited." National Bureau of Economics Research, Working Paper No. 6053, 1997.

Pantula, S.G., G. Gonzalez-Farias, and W. A. Fuller. "A Comparison of Unit-Root Test Criteria." *Journal of Business And Economic Statistics* 12 (1994): 449-459.

Phillips P. C. B., and S. Ouliaris. "Asymptotic Properties of Residual Based Tests for Cointegration." *Econometrica*, 58 (1990):165-193.

Ravallion, M. "Testing Market Integration." *American Journal of Agricultural Economics*, 68 (1986): 102-126.

SAFEX, 2001. Electronic Database. South African Stock Exchange, South Africa.

Schroeder, T. C., and B. K. Goodwin. "Regional Fed Cattle Price Dynamics." *Western Journal of Agricultural Economics*, 15 (1990): 111-122.

Sexton, R.J., C. L. Kling, and H. F. Carman. "Market Integration, Efficiency of Arbitrage, and Imperfect Competition: Methodology and Application to U.S. Celery." *American Journal of Agricultural Economics*, 73 (1991): 568-580.

Sistema de Informacao de Mercado (SIMA). Electronic Database: Ministry of Agriculture and Rural Development, Maputo, 2001.

Stringer, R. "Food Security in Developing Countries." Australia, Centre for International Economic Studies, University of Adelaide, Policy Discussion Paper 0011 (2000). Available at http://www.adelaide.edu.au/cies/, Accessed in August 2000.

The Government of Mozambique. "Plano de Accao Para a Reducao da Pobreza Absoluta. 2001-2005 (PARPA): Versao Final Aprovada pelo conselho de Ministros, April 2001." Available at http://www.mozambique.mz/governo/parpa/. Accessed in September 2001.

The Government of Mozambique. "Analise dos Custos de Transporte na Comercializacao Agricola em Mocambique – Estudo de Casos dos Transportes de Milho das Zonas Norte e Centro Para a Zona Sul de Mocambique." Ministerio da Industria e Comercio, DNC No. 18, 2001.

The Government of Mozambique. "Caracterizacao do Comercio de Milho na Regiao Centro – Os intervenientes e o Desenvolvimento do Mercado." Ministerio da Indutria Comercio e Turismo, DNCI No. 3, 1998.

The Government of Mozambique. "Opcoes Financeiras Para a Comercializacao Agricola em Mocamique – Documento Principal." Ministerio da Indutria Comercio e Turismo, DNCI No.11, 1999.

The Government of Mozambique. "Estatisticas do Comercio Externo: Exportacoes e Importacoes, 1994." Ministero do Plano e Financas, Maputo, 1994.

The Government of Mozambique. "Estatisticas do Comercio Externo: Exportacoes e Importacoes, 1995." Ministero do Plano e Financas, 1995.

The SAS System Software, Release 8.2e. Copyright (c) 1999-2001 by SAS Institute Inc., Cary, NC, USA.

The World Bank. "Mozambique, Growth Prospects and Reform Agenda." Country Economic Memorandum, Report 20601-Mz (2001). Available at http://www-wds.worldbank .org/, Accessed in October 2001.

The World Bank. "World Development Report 2000/2001: Attacking Poverty." New York: Oxford University Press Inc, 2001.

Timmer, C. P. "A Model of Rice Marketing Margins in Indonesia." *Food Research Institute Studies*, 13 (1974): pp145-167.

Tomek, W. G., and K. L. Robinson. *Agricultural Product Prices*, Third Edition. Ithaca: Cornell University Press, 1995.

Transportes Lalgy. Unpublished Road Freight Rates, Maputo, 2001.

Tschirley, D. "Planning for Drought in Mozambique: Balancing the Roles of Food Aid and Food Markets." Ministry of Agriculture and Fishers, Directorate of Economics, Research Report No.29, 1998.

Tschirley, D., and Santos, A. P. "The Effects of Maize Trade with Malawi on Price Levels in Mozambique: Implications for Trade and Development." Ministry of Agriculture and Fishers, Directorate of Economics, Department of Policy Analysis, Research Report No.34, 1999.

TSP User's Guide: Online Manual. Available at http://www.tspintl.com/support/tsp/ug_online.htm, Accessed in December 2001.

TSP Software, Version 4.4. Copyright (c) 1997 by TSP International.

UNDP. Mozambique National Human Development Report. Maputo, Mozambique, 2000.

UNDP. Mozambique National Human Development Report. Maputo, Mozambique, 2000.

Van Rooyen, J., and H. Sigwele. "Towards Regional Food Security in Southern Africa: A (New) Policy Framework for the Agricultural Sector." *Food Policy*, 23 (1998): 491-504.

White, H. "Reform, Rehabilitation and Recovery - Program Aid to Mozambique." Stockholm, Sweden: A Sida Evaluation Report ISBN 9158678247, 1999.

Zavala, H. "Analise da Integracao dos Mercados de Cereais e Feijoes." Unpublished Bsc thesis, Universidade Eduardo Mondlane, 2001.

APPENDIX A

The PBM Code

The PBM code used to estimate the efficiency of spatial arbitrage is provided in this section. The code uses TSP 4.4. Three sets of starting values were used in the PBM estimation. The PBM estimates reported are those with the highest likelihood value. The averages of the PBM estimates are presented in annex B.

```
OPTIONS CRT,LIMWARN=0,LIMERR=10000,LIMNUM=2000;
?**********************************************************************
? Purpose: Msc Thesis
? Date: 11/14/01
?
? Switching regresion with 3 regimes
? Regime 1: Y=p1-p2=C : Yt=Ct+Et
? Regime 2: Y=p1-p2<K : Yt=Ct+Et-Ut
? Regime 3: Y=p1-p2>K : Yt=Ct+Et+Vt
?***********************************************************************
read(file ='c:\tostao\chi_Bei.xls') chi_bei chi bei;
? get some descriptive statistics to verify the data
msd chi bei chi_bei;

? define the regimes and the ML estimator

b=log(chi_bei); y=log(abs(chi-bei));

?likelihood function
 FRML RL1 L1=0.001+(0.999-0.001)*CNORM(LAM1);
 FRML RL2 L2=0.001+(1-(0.001+(0.999-0.001)*CNORM(LAM1))
   -0.001)*CNORM(LAM2);
 FRML RL3 L3=1-(0.001+(0.999-0.001)*CNORM(LAM1))
   -(0.001+(1-(0.001+(0.999-0.001)*CNORM(LAM1))-0.001)
   *CNORM(LAM2));
 FRML LOGLEQ LOGL=LOG(L1*F1+L2*F2+L3*F3);
 FRML REGIME1 F1=(1/SQRT(SIGV**2))*NORM((Y-B)
        /SQRT(SIGV**2));
 FRML REGIME3 F3=(2/(SQRT(SIGU1**2+SIGV**2)))
        *NORM((Y-B)/SQRT(SIGU1**2+SIGV**2))
        *(1-CNORM(((Y-B)*(SQRT(SIGU1**2)/SQRT(SIGV**2)))
        /SQRT(SIGU1**2+SIGV**2)));
```

```
 FRML REGIME2 F2=(2/(SQRT(SIGU2**2+SIGV**2)))
   *NORM(((Y-B))/SQRT(SIGU2**2+SIGV**2))
   *(1-CNORM((-(Y-B)*(SQRT(SIGU2**2)/SQRT(SIGV**2)))
        /SQRT(SIGU2**2+SIGV**2)));
? Substitute constituents parts into likelihood function
 EQSUB LOGLEQ RL1 RL2 RL3 REGIME1 REGIME2 REGIME3;

 ? Set starting values for sigu1, sigu2,sigv,lam1 and lam2
 SET SIGU1=1;
 SET SIGU2=2;
 SET SIGV=0.79;
 SET LAM1=1.3;
 SET LAM2=0.7;
 PARAM SIGU1,SIGU2,SIGV,LAM1,LAM2;
? Perform maximum likelihood estimation
 ML(HITER=D,HCOV=D,MAXIT=200,TOL=0.01) LOGLEQ;
 SET N=@NOB;

 ? Use Gallant-Holly method to compute standard errors and
 ? T-statistics of the unconstrained regime probabilities
 ANALYZ(NOPRINT) RL1;
 SET TPROB1=@TA;
 ANALYZ(NOPRINT) RL2;
 SET TPROB2=@TA;
 ANALYZ(NOPRINT) RL3;
 SET TPROB3=@TA;
 ? Check whether ML routine converged
  SMPL 1, 89;
  IF @LOGL=0;
    THEN;
  CONV1=0;
   ELSE;
    CONV1=@IFCONV;
 IF CONV1=1;
  THEN;
   DO;
    CONV2=-1;
? If convergence achieved, compute unconstrained "lambdas"
 SET L1=0.001+(0.999-0.001)*CNORM(LAM1);
 SET L2=0.001+(1-(0.001+(0.999-0.001)*CNORM(LAM1))
                -0.001)*CNORM(LAM2);
 SET L3=1-(0.001+(0.999-0.001)*CNORM(LAM1))
        -(0.001+(1-(0.001+(0.999-0.001)*CNORM(LAM1))
        -0.001)*CNORM(LAM2));
```

```
? Saved uncontrained vs if they are significant at 5% level
  IF ABS(TPROB1)>1.96;
   THEN;
        PROBREG1=L1;
   ELSE;
        PROBREG1=9.999;
  IF ABS(TPROB2)>1.96;
   THEN;
         PROBREG2=L2;
   ELSE;
        PROBREG2=9.999;
  IF ABS(TPROB3)>1.96;
   THEN;
        PROBREG3=L3;
  ELSE;
        PROBREG3=9.999;

 PRINT PROBREG1 PROBREG2 PROBREG3;

? PBM with second set of starting values

 FRML RL12 L12=0.001+(0.999-0.001)*CNORM(LAM1);
 FRML RL22 L22=0.001+(1-(0.001+(0.999-0.001)*CNORM(LAM1))
   -0.001)*CNORM(LAM2);
 FRML RL32 L32=1-(0.001+(0.999-0.001)*CNORM(LAM1))
   -(0.001+(1-(0.001+(0.999-0.001)*CNORM(LAM1))-0.001)
   *CNORM(LAM2));
 FRML LOGLEQ2 LOGL=LOG(L12*F12+L22*F22+L32*F32);
 FRML REGIME12 F12=(1/SQRT(SIGV**2))*NORM((Y-B)
        /SQRT(SIGV**2));
 FRML REGIME32 F32=(2/(SQRT(SIGU1**2+SIGV**2)))
        *NORM((Y-B)/SQRT(SIGU1**2+SIGV**2))
        *(1-CNORM(((Y-B)*(SQRT(SIGU1**2)/SQRT(SIGV**2)))
        /SQRT(SIGU1**2+SIGV**2)));
 FRML REGIME22 F22=(2/(SQRT(SIGU2**2+SIGV**2)))
   *NORM(((Y-B))/SQRT(SIGU2**2+SIGV**2))
   *(1-CNORM((-(Y-B)*(SQRT(SIGU2**2)/SQRT(SIGV**2)))
        /SQRT(SIGU2**2+SIGV**2)));
? Substitute constituents parts into likelihood function
 EQSUB LOGLEQ2 RL12 RL22 RL32 REGIME12 REGIME22 REGIME32;

 ? Set starting values for sigu1, sigu2,sigv,lam1 and lam2

 SET SIGU1=1.1;
```

```
 SET SIGU2=2.15;
 SET SIGV=1.1;
 SET LAM1=2.2;
 SET LAM2=0.7;
 PARAM SIGU1,SIGU2,SIGV,LAM1,LAM2;
 ML(HITER=D,HCOV=D,MAXIT=200,TOL=0.01) LOGLEQ2;
 SET N=@NOB;
 ANALYZ(NOPRINT) RL12;
 SET TPROB11=@TA;
 ANALYZ(NOPRINT) RL22;
 SET TPROB22=@TA;
 ANALYZ(NOPRINT) RL32;
 SET TPROB33=@TA;
IF ABS(TPROB11)>1.96;
  THEN;
        PROBREG11=L12;
  ELSE;
        PROBREG12=9.999;
 IF ABS(TPROB22)>1.96;
  THEN;
        PROBREG22=L22;
  ELSE;
        PROBREG22=9.999;
 IF ABS(TPROB33)>1.96;
  THEN;
        PROBREG32=L32;
 ELSE;
        PROBREG32=9.999;

? PRINT PROBREG11 PROBREG22 PROBREG33;

? If convergence achieved, compute unconstrained "lambdas"
 SET L12=0.001+(0.999-0.001)*CNORM(LAM1);
 SET L22=0.001+(1-(0.001+(0.999-0.001)*CNORM(LAM1))
        -0.001)*CNORM(LAM2);
 SET L32=1-(0.001+(0.999-0.001)*CNORM(LAM1))
        -(0.001+(1-(0.001+(0.999-0.001)*CNORM(LAM1))
        -0.001)*CNORM(LAM2));

 ? Third second set of starting values for sigu1, sigu2,sigv,lam1 and lam2
 FRML RL13 L13=0.001+(0.999-0.001)*CNORM(LAM1);
 FRML RL23 L23=0.001+(1-(0.001+(0.999-0.001)*CNORM(LAM1))
   -0.001)*CNORM(LAM2);
 FRML RL33 L33=1-(0.001+(0.999-0.001)*CNORM(LAM1))
   -(0.001+(1-(0.001+(0.999-0.001)*CNORM(LAM1))-0.001)
   *CNORM(LAM2));
```

```
 FRML LOGLEQ3 LOGL=LOG(L13*F13+L23*F23+L33*F33);
 FRML REGIME13 F13=(1/SQRT(SIGV**2))*NORM((Y-B)
        /SQRT(SIGV**2));
 FRML REGIME33 F33=(2/(SQRT(SIGU1**2+SIGV**2)))
        *NORM((Y-B)/SQRT(SIGU1**2+SIGV**2))
        *(1-CNORM((((Y-B)*(SQRT(SIGU1**2)/SQRT(SIGV**2)))
        /SQRT(SIGU1**2+SIGV**2)));
 FRML REGIME23 F23=(2/(SQRT(SIGU2**2+SIGV**2)))
   *NORM(((Y-B))/SQRT(SIGU2**2+SIGV**2))
   *(1-CNORM((-(Y-B)*(SQRT(SIGU2**2)/SQRT(SIGV**2)))
        /SQRT(SIGU2**2+SIGV**2)));

? Substitute constituents parts into likelihood function
 EQSUB LOGLEQ3 RL13 RL23 RL33 REGIME13 REGIME23 REGIME33;

 SET SIGU1=1;
 SET SIGU2=2;
 SET SIGV=1;
 SET LAM1=2;
 SET LAM2=0.65;
 PARAM SIGU1,SIGU2,SIGV,LAM1,LAM2;
 ML(HITER=D,HCOV=D,MAXIT=100,TOL=0.01) LOGLEQ3;
 SET N=@NOB;
 ANALYZ(NOPRINT) RL13;
 SET TPROB11=@TA;
 ANALYZ(NOPRINT) RL23;
 SET TPROB22=@TA;
 ANALYZ(NOPRINT) RL33;
 SET TPROB33=@TA;
 IF ABS(TPROB11)>1.96;
  THEN;
        PROBREG11=L13;
  ELSE;
        PROBREG11=9.999;
 IF ABS(TPROB22)>1.96;
  THEN;
         PROBREG22=L23;
  ELSE;
        PROBREG22=9.999;
 IF ABS(TPROB33)>1.96;
  THEN;
        PROBREG33=L33;
 ELSE;
        PROBREG33=9.999;
? PRINT PROBREG13 PROBREG23 PROBREG33;
```

APPENDIX B

SUPPLEMENTAL TABLES

Table A. 1. Average Estimates of the PBM Regime Probabilities for Mozambique Maize Retail Markets Using CPI as a Deflator to Project Transfer Costs.

Maize Route	PBM Regime Probabilities		
	Regime I	Regime II	Regime III
Chimoio → Xai-Xai	0.209	0.2286	0.505
Maputo → Beira	0.491	0.1E-02	0.507
Chimoio → Maputo	0.1E-02	0.943	0.055
Maputo → Mocuba	0.666 [a]	0.1E-02 [a]	0.333 [a]
Pemba → Maputo	0.015 [a]	0.1E-02 [a]	0.977 [a]
Maputo → Xai-Xai	0.1E-02	0.658	0.341
Nampula → Beira	0.1E-02 [a]	0.1E-02 [a]	0.998 [a]
Nampula → Tete	0.1E-02 [a]	0.1E-02 [a]	0.998 [a]
Chimoio → Mocuba	0.208	0.286	0.505
Tete → Maputo	0.45	0.001	0.549
Tete → Beira	0.265	0.489	0.246
Chimoio → Beira	0.832	0.2E-02	0.164
Maputo → Maxixe	0.637	0.1E-02	0.361
Nampula → Maxixe	0.094	0.012	0.893

Notes: Regime I, II, and III are defined respectively when price spreads equal, fall below, and equal transfer cost. Superscript *a* indicates that parameter estimates may not be valid since the edge of the parameter space was encountered. The figures are averages of PBM estimates with three different sets of starting values.

Table A. 2. Average Estimates of the PBM Regime Probabilities for Mozambique Maize Retail Markets Using Diesel Prices as a Deflator to Project Transfer Costs.

Maize Route	PBM Regime Probabilities		
	Regime I	Regime II	Regime III
Chimoio → Xai-Xai	0.512	0.209	0.274
Maputo → Beira	0.611	0.059	0.329
Chimoio → Maputo	0.1E-02	0.958	0.041
Maputo → Mocuba	0.006[a]	0.1E-02[a]	0.993[a]
Pemba → Maputo	0.334[a]	0.1E-02[a]	0.665[a]
Maputo → Xai-Xai	0.1E-02	0.817	0.182
Nampula → Beira	0.666[a]	0.1E-02[a]	0.333[a]
Nampula → Tete	0.1E-02[a]	0.1E-02[a]	0.998[a]
Chimoio → Mocuba	0.006	0.499	0.499
Tete → Maputo	0.500	0.309	0.189
Tete → Beira	0.607	0.281	0.111
Chimoio → Beira	0.832	0.2E-02	0.164
Maputo → Maxixe	0.263	0.467	0.27
Nampula → Maxixe	0.353	0.001	0.646

Notes: Regime I, II, and III are defined respectively when price spreads equal, fall below, and equal transfer cost. Superscript *a* indicates that parameter estimates may not be valid since the edge of the parameter space was encountered. The figures are averages of PBM estimates with three different sets of starting values.

APPENDIX C

AN OVERVIEW OF MAIZE TRADE BETWEEN MOZAMBIQUE AND SOUTH AFRICA

Most countries in the SA region have liberalized their food markets, and made regional trade agreements promoting free trade. Mozambique and South Africa are no exception. With the end of the civil war in Mozambique and the creation (or rehabilitation) of the Maputo-Witbank corridor, southern Mozambique, a deficit maize area even in the best-production years, faces a choice of importing maize either from South Africa or from surplus maize areas in northern and central Mozambique. By far, the distance and the quality of roads favor the route Maputo-South Africa.

Both formal and informal sectors are involved in maize trade between Maputo and South Africa. The informal cross-border trade between the two countries has been flourishing especially after economic reforms in Mozambique. In 1995/96, informal maize imports from South Africa to Mozambique amounted to US$1.4 million (Macamo). Recorded formal maize trade between Mozambique, South Africa, Malawi and Zimbabwe is presented in appendix table 1.

Table A.3. Recorded White Maize Imports and Exports between Mozambique and Her Neighbors from 1994 to 1999 (US$/Year)

	Exporting Country		Importing Country	
Year	South Africa	Zimbabwe	South Africa	Malawi
1994	515	117	-	-
1995	936	615	140	498
1996	1538	120	-	-
1997	-	1662	-	9523
1998	4842	200	352	5209
1999	2126	262	-	1035

Note: Author's compilation based on statistical bulletins from *Ministerio do Plano e Financas* and *Instituto Nacional de Estatistica*.

Data collected in 1995/96 indicates that literate and formally unemployed males, living predominantly on the Mozambique side of the border, dominate informal cross-border trading. Using personal capital or informal credit schemes, these experienced informal cross-border traders (ICBTs) get foreign currency in (illegal) parallel exchange markets, and use cash to buy goods that are transported in small quantities using heads, hand carts or bicycles to avoid customs charges and reduce transport costs (Macamo).

Contrary to ICBTs who do not pay taxes and operate in ambiguous legal status, formal import traders must hold an import license, a certificate of commercial registry, certification of paying taxes, and a certification from custom duties. Formal traders are subject to inspections involving the Ministries of Commerce, Health and Labor and State Administration (Coulter; Macamo). The cost to become formal traders are believed to be one of the reasons for emergence of informal trading (Macamo; Jayne et al).

The position of the GOM relative to maize imports has not been clearly understood. Jayne et al. argue that the government does not play any role in maize imports other than licensing. However, Maasdorp claims that Mozambique policy is to provide protection to the maize and grain milling industries so that they can rebuild before they are opened for free trade.

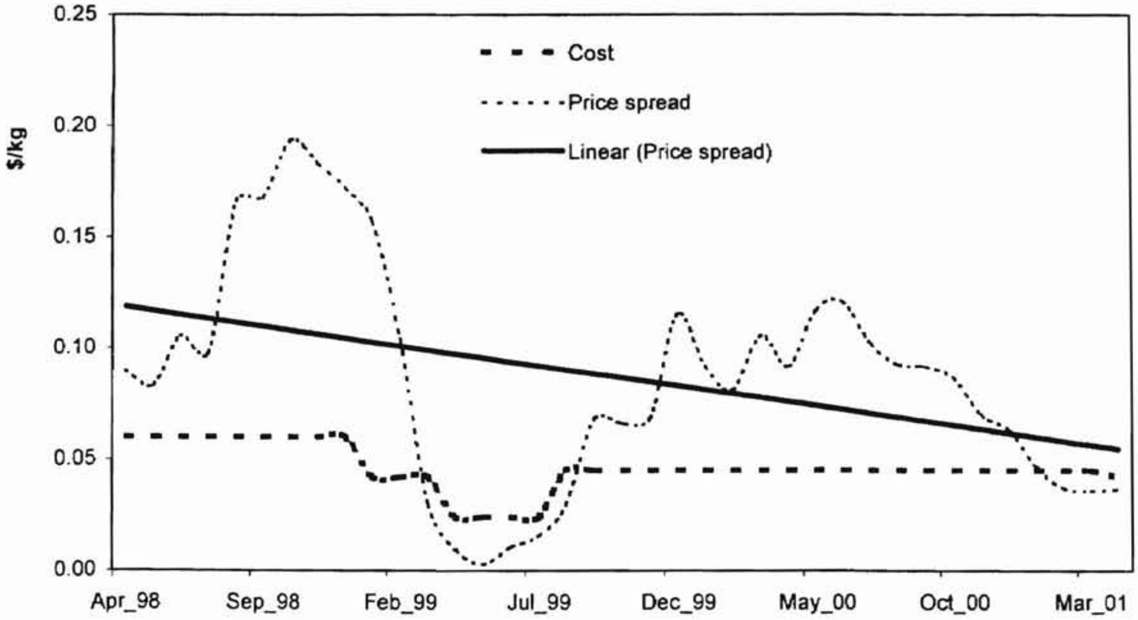
A question that has gone unanswered is how efficient spatial arbitrage between Maputo and South Africa is? Using Baulch's switching regression outlined previously, this chapter measures the efficiency of spatial arbitrage between Maputo and South Africa maize markets. Monthly maize retail prices for Maputo are from SIMA database, and spot prices from Randfontein (South Africa) are from SAFEX. Transport-cost data are comprised by actual charges by the *Transportes Lalgy*, one of the local transport companies operating in the route Maputo-South Africa. While the data from *Transportes Lalgy* and SAFEX were provided in U.S. dollars, the data from SIMA were provided in Meticais (MZM) per kilogram, and had to be converted to U.S.$ per kilogram using exchange rate (MZM/US$) provided by the *Banco de Mocambique*, the central bank of Mozambique. The conversion to US$ permitted price comparability and some control for inflation.

Transportation costs and price spreads between Maputo and Randfontein are plotted in figure A.1. As figure A.1 suggests, the difference between price spreads and transportation costs has reduced over time but some arbitrage opportunities may have gone unexploited. The PBM estimates indicate that arbitrage between Maputo and

Randfontein is efficient 90 % of the time. Hence, the Maputo maize market has greater probability of being integrated with South Africa than with maize markets within Mozambique, except Chimoio.

While the efficiency of spatial arbitrage (90%) favors the claim that the GoM does not play any role in maize imports other than licensing, there is some "room" for Maasdorp's claim that the GoM maintains some controls over maize and grain imports to allow the industry to develop before the borders are opened to free trade.

Figure A.1. Maize Transportation Cost, Price Spreads, and Trend Line from Price Spreads (US$/Kilogram) between Maputo and Randfontein from 1998 to 2001



VITA

Emilio Tostao 2

Candidate for the Degree of

Masters of Science

Thesis: SPATIAL ARBITRAGE AND MAIZE PRICE DYNAMICS IN MOZAMBIQUE

Major Field: Agricultural Economics

Education: Graduated from Francisco Manyanga Secondary School, Maputo, Mozambique, in 1989; received a Bachelor of Science with Honors in Agronomy-Rural Engineering from *Universidade Eduardo Mondlane*, Maputo, Mozambique, 1997. Completed the Requirements for the Master of Science degree with a major in Agricultural Economics at Oklahoma State University in May 2002.

Experience: Employed by the *Universidade Eduardo Mondlane*, Department of Rural Engineering as an undergraduate teaching assistant, from 1993 to 1994; Lecturer and Research Assistant, Department of Plant Production and Protection, Agricultural Economics Division, *Universidade Eduardo Mondlane*, Maputo, Mozambique, 1997 - Present.

Fellowships and Awards:

Award for Master of Sciences in the United States of America, Advanced Training For Leadership and Skills (ATLAS) program, The Africa-America Institute, 1999.