UNIVERSITY OF ALBERTA

A PRODUCTIVITY ANALYSIS OF THE GAMBIAN GROUNDNUT SECTOR

BY

JOHN EDWARD HENRY

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Dedicated to my
Mother and Father

"For always being there,
regardless of circumstance".

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ABSTRACT

The main objective of this study is to evaluate the total factor productivity (TFP) and production structure of the Gambian groundnut sector. Nonparametric indexing procedures and econometric analyses are employed.

The results indicate that groundnut TFP has declined steadily since the 1970s. The favourable terms of trade that characterized the 1980s may have aided in slowing down the erosion of TFP. However, the positive distributional effects of improved farm incomes resulted from higher producer prices rather than output increases. This reflects the importance of isolating constraints to productivity growth. The hypothesis that drought is the biggest constraint to production is not supported by the empirical evidence.

Irregularities in factor input markets and a traditional land tenure system leave farmers with little flexibility in choosing their input combinations. Low own-price elasticities suggest that input availability is more important to producers than price. Technical change is found to be land-using, draught animal-using, fertilizer-using, and Hicks-neutral regarding labour. Land-using technical change is not a viable long-run solution for increasing output. Scale effects are observed to be draught animal-using, labour-using, land-saving, and fertilizer-saving.

In order to increase TFP performance, farmers must adopt practices that improve the soil's fertility and agronomic structure. Government policies should focus on removing distortions from input markets and increasing farmers' awareness of recommended cultural practices. Ultimately, the country's research mandate must be modified and the linkage between extension services and producers strengthened. Moreover, serious consideration should be given to land reform.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Agricultural advancement in less-developed-countries (LDCs) continues to frustrate humanity. Enormous investment in a wide range of rurally-based projects throughout the world has yielded discouraging results. Over 1.1 billion people in LDCs still live in absolute poverty (WDR 1992). The Food and Agriculture Organization of the United Nations (FAO) once projected that Africa would experience food deficits if production patterns remained stagnant (Meier 1984). Truth bore witness to this prediction as population growth exceeded food consumption by 0.2 percent during 1971-84 (WDR 1986).

Most people in LDCs depend directly on the land for survival. It seems then that agriculture should play a pivotal role in the development process, rather than serving as a reservoir from which to extract production surpluses for investment in industry. Painful lessons in development drawn from a myriad of case studies over the last few decades cast doubt on the latter strategy. Surprisingly, many experts continue to dismiss the notion that the revitalization of agriculture epitomizes the driving force behind social and economic progression.

Growth in agriculture provides food and fibre for domestic consumption, enlarges the market for industrial output, earns or saves foreign exchange, releases labour for industry, and enhances domestic savings (Meier 1984; Timmer 1988). Moreover, extensive research has revealed that the contribution of agricultural growth to economic development depends on its rate of productivity growth (Hayami and Ruttan 1985). Since rising productivity forms a necessary condition for economic growth, recognizing that agricultural productivity in LDCs is less than one-tenth that of industrial countries (Thirlwall 1983) should justify concern.

The objective of this study focuses on productivity and its measurement. More specifically, the concept of total factor productivity (TFP) is applied to groundnut (peanut) production in The Gambia, a tiny country situated on the West coast of Africa.

1.2 Problem Setting

Located almost entirely in the Sahel region on Africa's West coast, The Gambia forms an enclave in the Republic of Senegal (Figure 1.1). It is one of the poorest countries on earth, with a per capita income less than U.S. $ 300 (WDR 1992). Health and sanitary conditions rank among the worst in West Africa, especially in rural areas where a large percentage of the inhabitants reside. Malnutrition is common,

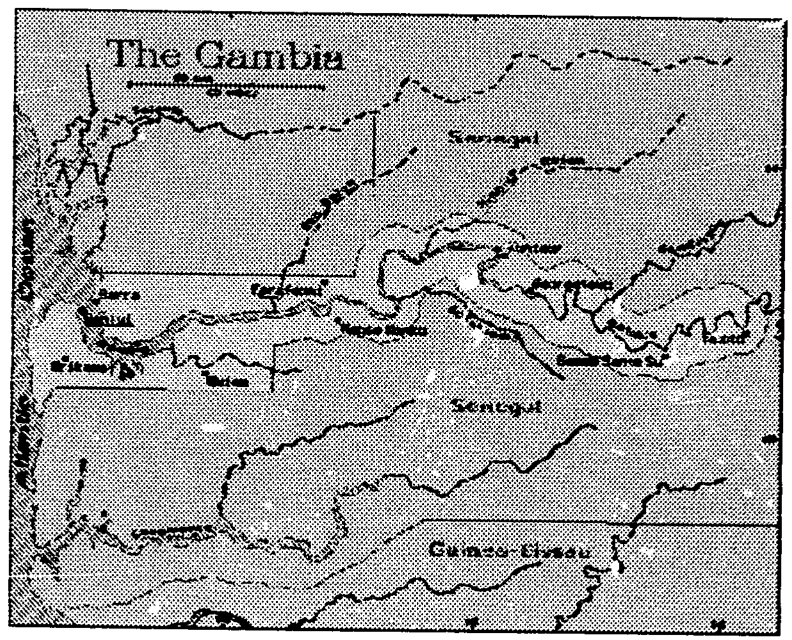

Figure 1.1: Map of The Gambia
Source: IBEA (1991)

particularly with women and young children. A positive facet of The Gambia is its civil stability. The thwarted coup d'état in 1981 highlights the only blemish on record[1].

The population, currently estimated at 1,025,867, has doubled in absolute terms since 1973 (CSD 1993). Beyond the high natural growth rate (2.9 percent annually), net immigration (0.7 percent) has contributed significantly to the increase in population (GOTG 1990; CSD 1993). With a land base of 10,690 square kilometres, the population density stands at 96 persons per square kilometre, one of the highest concentrations in Africa.

As with most LDCs, agriculture dominates the Gambian economy. This sector employs 75-80 percent of the population (Kristensen and Baldeh 1987; World Bank 1992) and accounted for 58 percent of gross domestic product (GDP) in 1981 (Sallah 1990). Recurring drought and urbanization of young people have been blamed for the fall of agriculture's proportion of GDP to 29-34 percent (GOTG 1990; Jabara 1990). These figures, however, understate the importance of agriculture because the service sector handles the bulk of agricultural marketing and trade activities.

Migration from the countryside to urban areas has led to several socioeconomic consequences, including a shortage of

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[1]On July 22, 1994, the military overthrew the democratically-elected Peoples' Progressive Party in a bloodless coup.

housing, inadequate urban services, and increased unemployment. Low productivity and output variability have created a marked disparity between urban and rural incomes. UNICEF (1985) stated that the average rural income in 1974 amounted to 26 percent of the average urban income (including subsistence production). A more recent assessment indicated that rural incomes had risen to 45 percent of urban incomes (World Bank 1981). This has more to do with rising unemployment in urban centres (migratory pressures) than from improvements in the performance of agriculture.

The arable land base has been estimated at 400,000 hectares (ha) across all six Divisions of the country (World Bank 1992)[2]. Except for approximately 1,400 ha of pump-irrigated rice, crop production relies solely on rainfall. A single annual rainy season extends from June to October.

The primary domestic crops include rice, millet, and sorghum. Maize and beans are grown on a smaller scale. In addition, donor-funded projects have established 15,000 ha of horticultural crops, such as tomatoes and onions (DOP 1990). Groundnut is the country's premier cash crop. This single commodity commands nearly 50 percent of the land under cultivation (Cockfield et al 1990; DOP 1992) and provides

[2]Estimates regarding arable land vary considerably. Posner and Jallow (1987) stated that arable land totalled 679,715 ha. This differs significantly from the 325,000 ha reported by Kristensen and Baldeh (1987). The assumptions underlying these calculations are unknown.

farmers with 80 percent of their cash incomes (McNamara 1992). Cereals and groundnut together supply rural dwellers with up to 90 percent of their food energy requirements (USAID 1989).

Generally, food supplies are adequate and the per capita intake of energy approximates recommended requirements (World Bank 1981; von Braun et al 1989). This appears as a contradiction to an earlier statement that suggested that malnutrition is common in The Gambia. However, per capita measures are average measures and can be misleading because they do not account for the distribution and variability of food supplies.

During the harvesting period (September to December) food is abundant. Toward the end of the dry season, stocks dwindle and shortages are common in July and August. This period has been appropriately labelled the "hungry season". Poorer households, those in the lowest expenditure quartile, frequently experience consumption decreases of more than 15 percent during this period; children and pregnant or lactating mothers are most susceptible to nutritional deficiencies[3] (von Braun et al 1989). The remaining quartiles enjoy sufficient

[3]Although females are responsible for subsistence farming and give higher priority to adequate nutrition than do males (UNICEF 1985), they have little control over the decision to sell or keep cash crops. This can result in irregular food consumption during the rainy season when subsistence crops run out. It could be argued, then, that some males actually aggravate the problem of poor nutrition.

and constant food reserves throughout the year (von Braun et al 1989).

Apart from small enterprises and handicrafts, narrow industrialization prevails in The Gambia. The few existing factories process mainly agricultural products, along with a limited selection of consumer goods. Industry's share of GDP averaged 9.5 percent during 1985-88 and provided employment for 17,500 people, 2,500 in factories (GOTG 1990). Steady growth has characterized the tourist trade since the early 1980s. This sector now accounts for 10 percent of GDP and employs 7,000 seasonally (GOTG 1990). The fishery resource is largely untapped, contributing just 1.5 percent to GDP while employing 3,000 (GOTG 1990). Although expansion opportunities exist in this sector, the ongoing encroachment of illegal fishing trawlers undermines future prospects (Dossett and Henry 1991).

Three broad sources comprise most of the foreign exchange required for investment, national debt-servicing, and importation. First, reexports[4] have increased in importance thanks to The Gambia's liberal customs and duties policies. Neighbouring countries have resorted to high quotas and tariffs to protect inefficient, import-substituting domestic

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[4]Reexports, as defined here, are those goods that avoid the protective barriers of neighbouring countries by whatever means. This, of course, is the differential that makes reexporting so lucrative.

industries. Of total imports, 30-35 percent is eventually reexported (IMF 1989). Most of the reexports are channelled into Senegal where the fully convertible CFA franc is the currency of trade. Profits from this activity made up 75 percent of the value of exports in 1988-89, an 18 percent increase since 1978-79 (Jabara 1990). Secondly, tourism receipts rose from 21 to 29 percent of exports during 1979-89 (Jabara 1990) and yielded U.S. $25 million in foreign exchange earnings in 1990 (GOTG 1990). However, the World Bank (1985) reported that approximately 50 percent of revenue is used to finance imported goods. The third major source of hard currency comes from groundnut sales.

Groundnut production and its derivatives accounted for 90 percent of the value of domestic exports in the 1970s and early 1980s (Kristensen and Baldeh 1987). Unfavourable weather conditions, low government-set prices, and policies directed at food self-sufficiency lowered its prominence to 73-80 percent of domestic exports (Jabara 1990; Sallan 1990). Correspondingly, its contribution to both foreign exchange earnings and GDP fell drastically. With the exceptional growth of the reexport trade, groundnut's share in foreign exchange earnings decreased from 45 percent in the early 1980s to 12 percent in 1992 (Hadjimichael et al 1992). Its proportion of GDP declined from 25 percent in 1966 to 9 percent in 1988 (McNamara 1992), but these calculations were based solely on shelled nuts. This sector generates some 29 percent of GDP when processed oil and groundnut cake are included (Sallah 1990).

The economy relies heavily on groundnut production, especially since it also forms the core of the country's major industrial operation, oil milling. Because of this dependence, production and world price variations cause erratic fluctuations in the performance of the whole Gambian economy. For example, declining groundnut harvests effected a 60 percent decrease in export earnings between 1976-77 and 1980-81 (Kargbo 1983). Strong repercussions followed. Besides economic and balance-of-payments setbacks, the country's capacity to import was weakened.

1.3 Overview of the Development Problem

The Gambia attained political independence in 1965 and with this new autonomy came a wave of pessimism (Sallah 1990). Considering its meagre endowment of natural resources, how could this minuscule "groundnut colony" expect to exist as an independent reality? Twenty-nine years later, The Gambia's enduring dependence on a single cash crop remains something of a thorn in the heel. Hopes of stimulating the economy through investment in industry resulted in a rude awakening for Gambian leaders and foreign aid agencies. The Gambia was, and still is, ill-equipped to foster sustained economic growth based on industry alone. Skilled workers and raw materials, among others, are extremely scarce. Moreover, poor agricultural productivity has not allowed a natural release of labourers from agriculture to industry[5]. Many people who migrate from rural to urban areas remain unemployed because the industrial sector does not have the support of a strong agricultural foundation. Foreign aid has played a major role in The Gambia's continued survival, despite its perpetual inefficiency in delivery.

Since independence, the government has executed five development programs with a sixth ongoing. Each campaign has leaned progressively toward economic diversification. The overall impact has proven to be insignificant and, at times, harmful.

After the close of three capital expenditure programs, the Gambian government changed its ideology and proceeded to produce the first comprehensive development plan in 1975-76. Labelled as the First Five-Year Plan, its primary focus concentrated on reducing The Gambia's dependence on groundnut through agricultural diversification and rural development. Blatantly paradoxical, the plan directed just 17.5 percent of

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[5]With sustained productivity growth, the agricultural sector necessarily shrinks due to the nature of the products it provides; agricultural goods are income inelastic. As the economy and peoples' incomes grow, the demand for primary goods is less than that for manufactured goods. This is the most general case. Countries that are rich in raw materials (e.g., oil), or possess a strong comparative advantage in producing a certain commodity, may deviate from the norm.

the plan's budget to the agricultural sector (GOTG 1975). The strategy failed to achieve its expectations. The investment was too small to achieve any notable improvements in rural areas, and agricultural diversification in the presence of low productivity affected farmers' incomes and the government's foreign exchange reserves by reducing groundnut output.

During the period 1975-80, GDP rose at an average rate of 2.9 percent, well below the 4.5 percent targeted (GOTG 1975 and 1982). Since the population grew at virtually the same rate (CSD 1993), per capita GDP remained relatively constant. The slow economic growth was attributed to falling agricultural output[6], which averaged a negative growth rate of 8 percent over the same period (GOTG 1981). Combining a sagging agricultural sector with aggressive expansion into industrial pursuits netted a 27 percent decline in the value of exports and a 229 percent increase in the value of imports (Kargbo 1983). This position placed a heavy burden on the national balance-of-payments account.

The situation continued to regress into the 1980s. A prolonged Sahelian drought confounded the problem by heightening the effect of inappropriate policies and administrative weaknesses inherent in the Second Five-Year

[6]Falling output has typically been attributed to drought and low productivity. One objective of this study is to verify or refute this reasoning, and to move from the general to the specific by separating symptoms from causes.

Plan (1981-82 to 1985-86). Though agriculture and rural development received an investment weighting of 41.2 percent from this program (GOTG 1981), the fragile economy became insolvent. By 1985, debt-service payments had risen to 25 percent of net export earnings and The Gambia fell into arrears with the International Monetary Fund (IMF) (GOTG 1990).

In response to the crisis, the government initiated the Economic Recovery Program (ERP) in June 1985. Due to the arrears and the absence of a standby agreement with the IMF, the donor community offered little financial support. Through government spending cuts and favourable groundnut harvests, the arrears were cleared and a standby agreement signed (1986). This was followed by an IMF-supported two-year extension of the ERP. Qualifying for debt rescheduling meant that the Gambian government had to abide by certain structural adjustments, as profiled by the IMF. The measures contained in the package represented a fundamental reorientation of The Gambia's approach to economic development. The government summed it up a few years later by stating:

> The cornerstone of the new philosophy was the belief that the main source of economic development in the future would be private economic agents acting within a framework of political and economic freedom, responding to price signals that as far as possible reflect genuine economic costs and benefits (GOTG 1990).

Some aspects of the structural adjustment pact were long overdue. The floating of the exchange rate, a major element of the ERP, diverted precious foreign currency away from the parallel (black) market. Outside banking had captured 48 percent of the money supply by 1986 (Ramamurthy 1986). Furthermore, the liberalization of the exchange rate system reduced the profound distortions that characterized the import/export markets. The painful side of the story included a 70 percent inflation rate (GOTG 1990), an increase of 4 percent on the duty of imported rice (Jabara 1990) that exacerbated the effects of a devalued currency (i.e., imports became more expensive), and the termination of 1840 civil servant positions (Herlehy 1988).

Those questioning the usefulness of the ERP asserted that its design did not facilitate development, rather it served to program the economy so that The Gambia could repay its debts to the international lenders (Sallah 1990). Interestingly, the IMF standby agreement committed the government to promote its reexport trade even though it is illegal in the countries taking the goods[7]. Undoubtably, the IMF viewed the lucrative reexport trade as a means for increasing the probability of The Gambia meeting its loan obligations.

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[7]The Gambia's practice of reexporting goods into Senegal has caused political tension.

The ERP ended in June 1989. According to the official view, the plan spelled success. For four years in a row GDP growth exceeded 4 percent, while the volume of domestic product climbed 20 percent (GOTG 1990). Irrespective of the pleasing statistics, ordinary people dismissed this view as rhetoric because the distribution of the economic gains was skewed toward the minority upperclass. Underclass citizens had witnessed little or no improvement in living standards and remained trapped in self-perpetuating impoverishment.

The Gambia's experiences are not unique. Put simply, alleviating destitution of the masses requires more than growth in GDP. Over one-half of the Latin American citizens continue to bear the travesties of poverty, this in spite of the surging economic growth rates recorded in several Latin countries over the past few years (WDR 1992). Similarly, frustrations intrinsic in the trickle-down approach to development have led to civil turmoil in Venezuela.

The stark reality faced by Gambians is that the available evidence precludes a short-run solution. The growth of GDP slowed to 1.9 percent in 1992 (GOTG 1993) and, with a 3.4 percent rise in population, per capita income declined. Additionally, the outstanding external public debt of U.S. $360 million (excluding IMF) for the year ending 1989-90 fell due for repayment in 1992 (GOTG 1990). The accountability of debt-servicing, projected at U.S. $58 million for 1991-92 (excluding IMF) (GOTG 1990), will linger into the next century.

A continuation of the structural adjustment that originated with the ERP moulds the plan for developing The Gambian economy through the 1990s. Establishing the Programme for Sustained Development (PSD) in 1990 reiterated the government's commitment to the ERP philosophy. The PSD aspires to consolidate the economic reforms started under the ERP. As far as possible, the government will press forward with its "hands off" attitude toward market mechanisms. To date, the government has relinquished many segments of the economy to the private sector.

As with preceding plans, the entire PSD package signifies an ambitious proposition. Only in time will the real story of its practicality unfold. Sadly, the revised 1989-90 budget projected investments in agriculture and natural resources to be 8.8 percent of total expenditures at current prices (GOTG 1990), while disbursements to service the public debt totalled 25.9 percent (GOTG 1990).

1.4 Identifying a Development Strategy

The pessimism that ushered in The Gambia's attainment of independence appears equally convincing today. Notwithstanding all of the development antidotes tested over the past three decades, this small country's lifeline continues to hang precariously with groundnut production. Economic diversification schemes, both agricultural and industrial, have floundered. Subsistence living has rooted itself deeply in all but a privileged few.

The groundnut dependency problem peaked in December 1993 when Senegal closed its borders to protect its flailing economy. This political move dampened the reexport trade considerably. Except for a small portion of the Atlantic coastline, Senegal surrounds The Gambia. The implication is that exports via ground transportation are effectively blocked. The impact is further amplified because The Gambia's reexport market includes other West African countries, such as Mali, Guinea-Bissau, and Sierra Leone. Alternative means of transportation are limited and prohibitively expensive. With reexports being the country's prime source of foreign currency, this delivers a stern blow to an already decrepit economy[8].

Bearing in mind all of the relevant facts, the task at hand entails identifying the best catalyst for initiating economic growth. Call this the seed of development. From this position, it is easier to identify those elements that have the capacity to obstruct the seed's germination. To isolate the catalyst, only agriculture and industry warrant

[8]The crisis deepened in January 1994 when Senegal's currency exchange was liberalized. The CFA franc suffered a 50 percent devaluation.

consideration. Before doing so, digressing briefly to discuss tourism should dissipate a common belief. Proponents of tourism suggest that this trade will emerge as the economic protector.

Tourism evolved dramatically in the late 1980s when the number of visitors swelled from 45,000 to 113,000 (GOTG 1990). Despite its phenomenal growth, the tourist market remains shallow. Most guests fall within the low to average income range and arrive on lowcost charters paid for at the point of origin. Articles reported in the local media hinted that little money is spent above outlays on basic expenses. Attracting the more lucrative high-income sightseer would involve substantial investment in specialized tourist facilities and on infrastructure (e.g., electricity and water supplies). Given the government's financial status and its promotion of a market-driven economy, the private sector must bear the risk. For the moment, however, it is a saver's market. Interest rates vary from 18 to 24 percent, some 10 points higher than inflation.

Tourism did not materialize without costs attached. Catering for the demands of visitors has created a cumulative negative effect on domestic food availability. In addition, the negativities of tourism in a haplessly poor country have started to filter through the glory. The tourist scene has lured a stampede of young people from the rural areas, and this has escalated the urbanization enigma and supplemented the erosion of agriculture. They quickly discover that their hopes are illusionary, and the sharp contrast in lifestyles between tourists and locals aggravates the rising frustration of the unemployed urban migrants. A distressful increase has transpired in the numbers of violent crimes, prostitutes, drug users, and the ever-annoying "beachboys"[9]. The Gambia does not possess the resources to control this epidemic and the consequence, a curtail on the growth of tourism, has commenced.

Finally, the official statistics on tourism exclude all of the intangible, but very real, costs to social welfare. Nevertheless, it remains that tourism benefits only a small segment of the population. It will continue to be an integrated component of the overall economic picture, but unquestionably it is not the focal point desired.

Returning to agriculture and industry as the means for economic development, it is worthwhile to examine the pros and cons of one versus the other. Economists have debated, endlessly it seems, the issue of whether agriculture or industry should command the highest priority by LDCs. Each side submits powerful arguments but common sense leads to the

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[9]This is a common term used to describe unemployed people who loiter around tourist centres. While many are genuinely friendly, others resort to "scamming" money from naive tourists. Intimidation and threats of violence are occasionally used.

general conclusion that both sectors contribute to sustained economic growth. The emphasis on one rather than the other hinges on a country's resources, the size of the market, the potential for growth and expansion, and the relative rates of return on investment.

Attempts to stimulate industrial activity have failed miserably in The Gambia for several reasons. Industrial ventures of any substance require large investments of capital. The high stakes inhibited the private sector's participation. Consequently, the onus was placed on government to play "businessperson". Unfortunately, the bureaucracy failed to manage its affairs efficiently. Poorly trained management and subordinates, coupled with internal power struggles and corruptive practices so common in state-run enterprises, guaranteed the demise of most ventures. The government had little choice but to begin withdrawing itself from the private arena. Moreover, with a deteriorating balance-of-payments ledger, government-owned industries operated considerably below capacity or shut down due to a lack of foreign exchange necessary to purchase inputs from abroad.

The incredible shortage of resources places another constraint on industry-based development in The Gambia. Imports comprise most of the raw materials needed for industrial activity. Given the foreign reserve deficit, this imparts further stress on a fragile national budget. Even now, The Gambia counts on foreign grants and support loans just to survive. Furthermore, the scarcity of skilled workers and poor basic services frustrate any efforts directed at industry.

Consider now that the level of investment depends on the market, or the total demand for goods and services. In turn, the total demand depends on the population and peoples' incomes. The Gambia's small, poverty-stricken domestic market defies aggressive investment in industry and foreign markets extend few opportunities. For reasons alluded to previously, viable industrial participation in the world market remains a distant possibility.

The behaviour of multinational companies lends support to the above analysis. Influential in many LDCs, these huge conglomerates seldom overlook viable investment opportunities. It is not a coincidence that, in spite of an intensive promotional campaign introduced by government, multinationals have resisted investing in The Gambia. Clearly, the business climate discourages ambitious industrial activity.

Past evidence suggests that industrially-led economic development would falter. This does not imply that government should disregard industry entirely, but it does imply that agriculture should be of primary importance. The prosperity of industry relies desperately on a healthy agricultural sector and, accordingly, a harmonious balance must be established between the two within the confines of a restricted national budget.

The decision to augment the performance of agriculture leads to defining a definite approach. Agricultural policies to date have not proven fruitful, regardless of the soundness of their underlying rationale. In the absence of productivity growth, government actions usually turn counterproductive and self-defeating. Stagnant or decreasing productivity levels constrict the options and performance of development strategies.

Enhancing export earnings through increased groundnut output means shifting resources away from domestic production. Conversely, increases in domestic output must come at the expense of groundnut production. Expanding the cultivated area, while ignoring the root problem, no longer qualifies as a realistic or competent strategy. Land availability has decreased at a drastic rate due to population pressure. Of the free land remaining, the quality ranges from poor to marginal (World Bank 1992). Enlarging the agricultural base through forest exploitation would manifest disastrous repercussions as the consequences of deforestation (e.g., soil erosion) have already inflicted The Gambia. The forested area, class one (open forest) and class two (closed forest) inclusive, decreased from 333,200 ha in 1972 to 68,500 ha in 1988, a 79 percent reduction in just 16 years (Ridder 1991).

In conclusion, improving agricultural productivity emerges as the logical starting point. This holds true especially for groundnut production. The livelihood of the rural community and the economy in general depend intimately on this crop. With the future of reexports now in doubt, and the December 1993 outcome of the final Uruguay Round of the General Agreement on Tariffs and Trade (GATT)[10], productivity growth in groundnut cropping becomes even more crucial.

1.5 Justification for the Study

Agronomists, sociologists, and anthropologists have examined in detail many aspects of groundnut production (Ashrif 1965; Conway 1973; Marenah 1975; Posner and Jallow 1987; Cockfield et al 1988; Sumberg and Gilbert 1988; Posner and Gilbert 1989[a] and 1989[b]; Posner 1990). However, despite the importance of groundnut, this crop has received scanty attention from economists.

The research literature correlates productivity growth with economic development, yet little work on this theme has surfaced in The Gambia. Although a few studies have dealt with land, labour, and fertilizer productivity (ILO 1985; Kristensen and Baldeh 1987), these partial measures grant only a crude approximation of overall crop productivity. In some

[10]The latest GATT sessions promoted increased efficiency in production through trade barrier dismantling. If the current status of Gambian agriculture remains static, primary exports will fall victim to aggressive competition.

cases, the results can be dangerously misleading. The standard for obtaining a more genuine assessment of productivity is through estimates of total factor productivity (TFP). Studies based on the TFP concept do not exist in The Gambia.

The Gambia's drive for economic growth and diversification depends on the health of agriculture. Similarly, the health of agriculture depends on the performance of the groundnut sector. Given that productivity growth is a key factor in the development process, a TFP analysis would aid in planning and policy formulation. Without such information, the aggregate effects of past policies and programs escape quantitative judgement.

Finally, Gambian farmers are pressured continually to adopt modern farming techniques as recommended by extension services and local aid agencies. Various demonstration and training programs operate to intensify the adoption rate. Technological change and input substitution, induced by changes in relative factor prices, may have altered the input mix with respect to groundnut production. A shift in input use has implications for input demand, factor substitution, and the nature of technical change. Identifying the effects of technical change on factor use could assist planners and policy-makers. This study aims to provide such information.

1.6 Objectives of the Study

The principal goal of this research project is to evaluate empirically the productivity status and production structure of the Gambian groundnut sector. The specific objectives are to:

a) quantify the growth of total factor productivity,
b) estimate the production structure in order to examine substitutability and complementary relationships between input factors,
c) measure the effect of technical change on factor use,
d) analyze the influence of weather on output,
e) evaluate alternative econometric models, and to
f) derive some policy implications.

1.7 Analytical Approach

Due to the absence of price data on land and draught animals, the Geometric indexing procedure (Solow 1957) appears to the author as the most feasible approach for measuring TFP growth and technical change. This method requires only output and input quantities. Although the process is prone to theoretical biases, a low rate of productivity growth, as found in LDCs, tends to minimize their effect (Hamal 1991).

Notwithstanding, since the theoretical advantages of the Flexible-Weight indexing procedure are so great, observations from previous studies and postulates of economic theory serve to proxy the missing variables. Also, input prices are necessary to evaluate the production structure via the share equations derived from a transcendental logarithmic cost function (Christensen et al 1971 and 1973).

1.8 Plan for the Remaining Chapters

Chapter 2 reviews the institutions and policies affecting the agricultural sector, with an emphasis on groundnut production. Chapter 3 provides a detailed discussion of the theoretical constructs of TFP measurement and the procedures related to estimating the production structure. Chapter 4 describes the source and measurement of the data used in this study. Theoretical problems and trend analyses related to the data are detailed. Chapter 5 reports the empirical results of the Geometric and Divisia indexing procedures. A brief analysis of weather influence is included. Chapter 6 presents an econometric analysis of the production structure based on the transcendental logarithmic cost function. A nonlinear transformation of the model is tested. Chapter 7 summarizes the findings and limitations of the study, and offers policy recommendations and suggestions for future research.

CHAPTER 2

AGRICULTURAL INSTITUTIONS AND POLICIES IN THE GAMBIA

2.1 Introduction

The ideologies of agricultural institutions and government policies have a direct influence on the performance of agriculture, particularly with groundnut production in The Gambia. In turn, the livelihood of a large percentage of the population depends on the effectiveness of agricultural organization. This chapter provides a review of the principal institutions and polices involved in Gambian agriculture.

2.2 Agricultural Institutions

2.2.1 Government Bureaus

Government's strategy under the Economic Recovery Program (ERP) has been to establish and maintain an environment conducive to economic growth and efficiency. Specifically, improvements in groundnut productivity, crop diversification, and food production have been targeted.

The Ministry of Agriculture (MOA), the main institution responsible for agricultural development, was reorganized and streamlined in 1987. While some services were privatized (e.g., animal health care), a central management unit and four operational departments were created. The restructuring was designed to focus on extension services, research, policy analysis, and agricultural statistics.

2.2.1.1 Central Management Unit (CMU)

This agency oversees the management of the MOA and coordinates all operational activities. It consists of a permanent secretary, two deputies responsible for programs and administration, and a director for the Department of Planning.

2.2.1.2 Department of Planning (DOP)

The DOP advises the Minister on policy matters and aids in identifying and preparing agricultural investment programs and projects. In addition to monitoring ongoing investment operations, it collects and disseminates agricultural data through its National Agricultural Data Center (NADC). A National Agricultural Sample Survey (NASS) is conducted each year and the results are reported in a statistical yearbook.

2.2.1.3 Department of Agricultural Services (DAS)

This branch provides crop extension services to farmers. It consists of a director, who reports to the permanent secretary of the MOA, an assistant director, an executive officer, two crop protection officers, two accounts clerks, and support staff. The director is in charge of six Divisional Agricultural Offices (DAOs), 25 District Extension Centers (DECs), the Crop Protection Service (CPS), the Soil and Water

Management Unit (SWMU), the Agricultural Communications Unit (ACU), and the Food and Nutrition Unit (FNU).

2.2.1.4 Department of Livestock Services (DLS)

The main obligations of the DLS are disease control, livestock extension, research, and meat inspection. Other responsibilities, such as operating the Livestock Marketing Board and veterinary services, have been privatized. Its livestock research activity was slated for transfer to the Department of Agricultural Research (DAR), or some other suitable organization.

2.2.1.5 Department of Cooperation (DOC)

The DOC deals with the promotion of cooperative societies and gives advice to its members. Additionally, it collects information on the demand for production inputs, market trends, and training needs.

2.2.1.6 Ministry of Natural Resources and Environment (MNRE)

The MNRE was created in 1990 to direct the implementation of the Gambia Environmental Plan. It is comprised of an Environment Unit and a Planning Unit.

2.2.1.7 Gambia Agricultural Research System (GARS)

The GARS is made up of several institutions, the main ones being the Department of Agricultural Research (DAR), the DLS, the DOP, and the National Agricultural Research Board

(NARB). The DAR, established in 1988 following the reorganization of the MOA, concentrates on crop-based research. The DLS specializes in animal-based research while the DOP supports studies in social sciences. Departments within the MNRE, such as the Department of Water Resources (DWR) and the Department of Forestry (DFOR), are responsible for research in their areas of specialization. The NARB, also created in 1988, gives advice on research priorities for agriculture, livestock, and natural resource management.

2.2.1.8 The Gambia College (GC)

Gambia College is the only post-secondary institution in the country. It was established in 1978 by an act of Parliament, bringing together four existing schools viz. the School of Agriculture, the Schools of Education, the Schools of Nursing and Midwifery, and the School of Public Health.

The School of Agriculture offers two-year certificate courses in general agriculture and livestock management for DAS field workers, and a three-year Higher Diploma in Agriculture (HDA) program. The HDA graduates mostly find employment with DAS/DLS or non-governmental organizations (NGOs). The school also provides short-term in-service training for the upgrading of extension workers.

2.2.1.9 The Gambia Produce Marketing Board (GPMB)

The GPMB was created as a parastatal organization with responsibility for marketing groundnut, rice, and cotton. Other duties included rice importation and the operation of paddy processing facilities. Under the ongoing Program for Sustained Development (PSD), its name was changed to the Gambia Oilseed Producing and Marketing Company (GOPMAC) and was eventually privatized. A sales agreement was signed between GPOMAC, the Gambia Cooperative Union (GCU), and the Alimanta Group on July 28, 1993. The sale included two processing factories, as well as the river fleet (two large boats and 22 barges). With the exception of its headquarters, all other assets of the GOPMAC were sold. The government retained ownership of the building housing the headquarters.

2.2.1.10 Gambia Cooperative Union (GCU)

Cooperative movement in The Gambia started in the 1950s under government control, primarily to assist groundnut producers in marketing activities. In 1970, the movement evolved into the GCU. The GCU was responsible for the existing multi-purpose primary societies that numbered 86.

Up until the privatization of the GPMB, the GCU was the major licensed buying agent for this parastatal organization. GCU purchased groundnuts from farmers through the primary Cooperative Produce Marketing Societies (CPMSs) and supplied production inputs, often on credit. During the last decade, some CPMSs were disqualified because of shortfalls in minimum tonnage or delinquencies on outstanding loans. Farmers evaded loan obligations by selling their produce to neighbouring Senegal. Approximately 36 CPMSs are still functioning today.

In the early 1990s, the GCU sold its groundnut stock to Senegal. This was in response to higher prices prevalent in Senegal and the fact that the GPMB was experiencing financial difficulties. GCU purchases for the 1993/1994 season were practically nil due to its inability to secure funding. This was a direct consequence of gross internal embezzlement, involving some GAD 75 million (CAD 10.9 million).

2.2.2 Institutional Organization

2.2.2.1 Land Tenure System

Land tenure and allocation practices are traditional in The Gambia. Land is owned by the government and is vested in and administered by the district authority. Individuals or groups that first clear a plot can claim usufructory rights, however, respect of such rights entails registering with the district authority. The distribution of land use rights is governed and regulated by local customary laws and is usually the responsibility of the *alkali*[1]. This land tenure system was

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[1]An *alkalo* is an elected male who governs a specific district within the country.

established largely by historical factors (Kargbo 1983). Increasing population pressure and the frequency of land disputes have led to a definite shift from communal tenure to privatization of rights (Sallah 1987).

The literature is satiated with arguments for and against traditional land tenure systems. A common argument against this form of land ownership is its lack of clearly defined, strictly enforceable property rights. Eicher and Baker (1980) contended that communal systems are flexible and not an immediate constraint on increasing agricultural output. The government asserts that villagers and compound heads have a clear understanding of their specific usufructory rights and the scope of such rights. Moreover, current legal arrangements allow for the flexibility needed to accommodate specific pressures, such as cropping techniques (GOTG 1979). In cases where high investment is involved, lease agreements are encouraged (GOTG 1979). Nevertheless, land disputes have been increasing in number and frequency since the proposal for a land commission was suppressed in the 1950s (Haswell 1975). One argument that has been overlooked in favour of land reform is that communal systems do not recognize the efficiency benefits of entrepreneurial activities[2].

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[2]In general, a private land market will filter out inefficient producers in the long-run because they cannot compete with those who utilize scarce resources more proficiently. Of course, certain distortions (e.g., government subsidy programs) are capable of reducing a market's effectiveness to this regard.

2.2.2.2 Agricultural Research

The DAR operates two research stations in the country and manages six research programs: cropping systems/resource management, upland cereals, rice, grain legumes/oilseeds, horticultural, and agricultural engineering/animal traction. Accomplishments are mainly in the areas of soil fertility management strategies, crop density, the introduction of higher yielding seeds and pest resistant varieties (coarse grains and groundnut), mechanization of rice production, and horticultural marketing.

A distinguishing feature of the GARS is its promotion of on-farm testing. This is usually done in collaboration with extension services and NGOs. NGOs, particularly the Catholic Relief Services (CRS), have enjoyed success with on-farm testing projects. Technology testing involving the participation of farmers is undertaken by the Farmer Innovation Testing Technology (FITT) program. The DAR also runs the Seed Technology Unit (STU). The STU produces foundation seed, performs quality control and seed certification functions, and promotes seed multiplication by farmers.

Animal production research conducted by the DLS has, in the past, concentrated on range and feed management. More recently, it has been experimenting with market-oriented sheep fattening. Research by the International Trypanotolerance Centre (ITC) has focused on its renowned trypano-resistant N'Dama cattle. The ITC agenda has been broadened to include small ruminants, livestock systems, and animal traction.

A negative aspect of the GARS is that it is virtually totally dependent on technology generated elsewhere. Poor linkages with external sources, inadequate human resources, and funding constraints restrict the propagation of new technology in The Gambia.

2.2.2.3 Agricultural Extension

Extension services for crop and livestock production fall under the DAS and the DLS, respectively. There is little cooperation or coordination of activities between the two departments.

The director of the DAS is aided by an assistant director who is charged with managing the agricultural extension and linkage with the DAR. At the divisional and district level, extension is supervised by six Divisional Agricultural Offices (DOAs) and 25 District Extension Centers (DECs). Each DAO has a coordinator, an assistant coordinator, two specialists (crop production and protection), two animal traction instructors, and a training officer. The 25 DECs are guided by District Extension Supervisors (DESs), who supervise a number of Village Extension Workers (VEWs).

The DLS is headed by a director and assistant director. The assistant director is responsible for the field operations of the department. A chief veterinary officer and a crew of livestock assistants work at the divisional level. Livestock assistants treat animal diseases and execute an annual vaccination campaign. Unless a part of a donor-financed project, no extension advice on animal husbandry practices is provided.

2.2.2.4 Agricultural Credit

The GCU is the primary source of agricultural credit for small farmers. High risks and costs dissuade commercial banks from advancing loans to farmers. To a lesser extent, private traders, NGOs, and certain development projects disburse credit. The importance of the GCU in this area is decreasing rapidly.

In the past, the GCU has received loanable funds from the Gambia Commercial Development Bank (GCDB) which, in turn, were refinanced by the Central Bank of The Gambia (CBG). The GPMB also provided seeds and fertilizer for distribution through the GCU channels. Operational difficulties experienced by the GCU in the mid-1980s were intensified by unusually low rates of repayment[3]. Although the situation improved somewhat under the second Agricultural Development Project (ADP-II), credit

[3]By 1985, the GCU owed GAD 35.2 million to the GCDB, GCB, and GPMB.

recovery fell to 50 percent in 1991/1992 (Jabara 1990). The future prospects for the GCU are grim, especially in light of the recent internal corruption.

One promising initiative is the Village Savings and Loans Association (VISACAS) scheme. Established in 1988, the VISACAS system has been remarkably successful in improving the capacity of rural people to operate their own village mini-banks, thereby mobilizing savings and increasing loan recoveries.

2.2.2.5 Supply of Agricultural Inputs

The GPMB has traditionally been the major supplier of agricultural inputs. Heavy financial losses from subsidization policies resulted in a restructuring of the fertilizer supply system in the mid-1980s. By 1986, fertilizer importation was decontrolled and the GPMB relieved of its responsibility for handling fertilizer[4]. Subsequently, a portion of the market became serviced by the private dealers network instituted by the Food and Agricultural Organization of the United Nations (FAO) Fertilizer Project. With the close of the FAO project in 1992, the Agricultural Input Office (AIO) was born.

Operating under the general supervision of the DAS, the objective of the AIO is to realize increased crop production

[4]Regardless, the private sector was extremely sluggish in responding to this newly opened market. Large left-over ADP-II fertilizer stocks and preferential financing arrangements enjoyed by the GCU discouraged private involvement (Jabara 1990).

and productivity by ensuring a reliable supply of appropriate agricultural inputs for the farming community. Essentially, the AIO coordinates the activities of the users and operators of agricultural inputs and serves as the liaison office between the DAS, DAR, DOP, NGOs, and the private sector. In addition, the AIO performs quality control functions regarding international standards, packaging, and the use of recommended nutrient contents.

2.3 Agricultural Policies

While IMF and World Bank-based economic adjustment packages have not worsened preexisting levels of poverty, policy changes in general have not advanced dramatically its alleviation (Sahn 1994). This section provides an overview of agricultural policy in The Gambia.

2.3.1 Agricultural Price Policy

Pricing policies for crops in The Gambia are generally restricted to groundnut and rice. The particulars regarding rice are discussed in Section 2.3.4 below.

2.3.1.1 Output Price Policy

Prior to the implementation of the ERP in 1985, the producer price for groundnut was set substantially below the prevailing export price. The difference represented an export tax on groundnut, the GPMB's marketing costs, and the groundnut stabilization fund. The net level of policy-induced implicit taxation ranged from 10-30 percent and caused yearly export revenue losses of 20-70 percent to the national budget (Badiane and Kinteh 1994). The fall in groundnut exports of the African Groundnut Council (AGC) member countries was about three times larger than the fall in global exports (Badiane and Kinteh 1994). This implies that domestic policies contributed more to the decline in exports than factors related to international markets.

The GPMB plunged into debt in the early 1980s when it was forced to subsidize producers for three consecutive years. Allegations of operational inefficiencies were levelled at the GPMB, but a study by the United States Agency for Development (USAID) indicated that subsidy payments, low production, and public service commitments contributed mostly to the rapid surge in liabilities (USAID 1985)[5]. However, whether or not the export tax constituted an undue burden on farmers was not addressed. High taxes are not necessarily harmful if the revenues generated are reinvested into effective agricultural research and rural improvement activities to raise production efficiency, and if the wedge between domestic and world prices is not too wide. Although Gambian policies did not satisfy these conditions, farmers were not obligated to pay income tax.

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[5]On the other hand, the GCU was found to be highly inefficient in its buying operations (Langan 1988).

In an attempt to enhance foreign exchange earnings, and to satisfy the conditions of the IMF standby agreement, the groundnut producer price was raised for the 1985/1986 and 1986/1987 seasons. Once the IMF arrears were cleared, producer prices were subsequently lowered. In the 1989/1990 trading season, further reforms empowered the GPMB with the right to set its own purchase price and to procure groundnut from any source. The price-support subsidy was discontinued, however, removal of the export tax dampened the impact on farmers.

Problems continued to surface. Despite a large producer price increase for 1989/1990, a five-ton minimum purchase requirement deterred farmers from selling directly to the GPMB and the GCU's inefficiency in marketing led to increased private and cross-border trading, even to the extent of farmers accepting lower prices.

The privatization of the GPMB in 1993 did not prove to be a welcome relief for farmers. Purchases by the Alimanta Group were far from brisk, and farmers who sold their nuts to the GCU complained bitterly about tardy payments. One must be wary in interpreting the term "privatization". The nature of the groundnut market does not necessarily protect farmers from monopsony influences[6]. The average world price for groundnut

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[6]Marketing and distribution of groundnut require substantial capital investments. This greatly restricts the number of firms entering the market.

during 1993/1994 was GAD 8909. Yet, in comparison, the producer prices offered by the GCU (GAD 1800) and Alimanta (GAD 2000) were remarkably low. This translates into a marketing margin of 77.6 to 79.8 percent.

2.3.1.2 Input Price Policy

Throughout the 1970s and early 1980s, fertilizer and certain implements were heavily subsidized, the prices being set by government. Sales were often made on credit, by that encouraging farmers to sell their harvests to GCU for loan repayments. Financial losses to the GPMB led to difficulties for the GCU. Fertilizer retailing allowances paid by the GPMB were inadequate to cover the GCU's operational costs. Farmers benefitted from the low cost of fertilizer, but suffered from untimely deliveries.

Fertilizer reforms built into the ERP were designed to suspend subsidies and to increase the efficiency in fertilizer marketing through private traders. The objectives were obstructed by the fertilizer distribution changes introduced by the ADP-II. While the idea was to establish a free market system, aid agencies became little more than market externalities because their activities often disrupted the natural forces of supply and demand. Given the market distortions, rising prices, and more stringent credit requirements, it is not shocking that fertilizer use dropped sharply during the ERP. The drive for market-determined prices continues under the current PSD plan.

2.3.2 Agricultural Credit Policy

Due to the precarious financial circumstances surrounding the GCU and inefficiencies in the credit distribution system, reforms under the ERP were introduced. Interest rates charged to farmers were raised to 24 percent per annum in 1986/87 to better reflect the GCU's cost of borrowed funds (i.e., market-determined) (Jabara 1990), and new criteria for credit eligibility became effective in 1987/88. The revised credit policy excludes defaulters from obtaining additional credit and restricts the loan amounts to those received in the previous year. Only cooperative members who received credit in the previous year are eligible for new credit. To tackle the inefficient distributional system, the number of CPMSs was reduced from 86 to 54 in 1989.

The reforms have hurt poorer rural households because they depend the most on credit. Obviously, higher interest rates and restrictions on access to credit limit the participation of poorer families in this vital market. Puetz and von Braun (1988) determined that higher-income households are more likely to pay cash for agricultural inputs even though they have greater access to credit.

2.3.3 Macroeconomic Policy

2.3.3.1 Monetary and Fiscal Policy

A prudent monetary policy formed a key element of the ERP and it continues with the ongoing PSD. A limit has been established for the expansion of the banking system's net domestic assets so that they are more compatible with the accumulation of foreign exchange reserves. The goal is to provide adequate cover for the country's import requirements. An increased reliance is placed on indirect controls by operating through the liquidity of the commercial banks. With the help of foreign consultants and aid agencies, further measures are being taken to rehabilitate the Gambia Commercial and Development Bank by improving the framework for credit supervision and loan recovery.

The government is committed to maintaining market-determined interest rates[7]. The Treasury Bill rate, which reflects the cost of investible funds both locally and in world financial markets, is the key indicator as all other rates are influenced by this rate. Unless lending at concessionary rates is an intrinsic part of an aid program, subsidized credit is avoided.

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[7]This policy applies to all sectors, including agriculture.

Despite the decline in inflation over the past several years, interest rates remain high[8]. This situation tends to discourage investment because of the difficulty in obtaining the rate of return necessary to service the borrowed funds. Also, when the nominal interest rate is well above inflation, the high real interest rate attracts savers rather than investors. By promoting an efficient and competitive commercial banking system, the government is confident that the spread between the rates charged to depositors and borrowers will narrow.

2.3.3.2 Exchange Rate and International Trade Policies

Exchange rate and trade policy changes are the most important and controversial tools for attaining economic reform in Africa. The primary reform objectives are to raise the relative price of tradables to nontradables and to improve the efficiency of resource allocation.

The distributional implications of the Dalasis devaluation under the ERP favoured the poor. The devaluation removed implicit taxes on groundnut producers, increased the prices of tradable goods (the poor are more heavily concentrated in producing tradable goods), and, because the poor rely more on home-produced foodstuffs, softened the effects of higher priced tradable staple foods (e.g., rice).

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[8]As of March 1994, interest rates ranged from 18 to 24 percent.

A smooth functioning foreign exchange market is equally vital to the Gambian economy as a whole. The availability of hard currency at market-clearing prices ensures that there is access to imported goods and services for those who can afford them. Furthermore, a foreign exchange market that is free of government-induced distortions encourages entrepreneurs and business firms to invest in export and import-substitution activities.

The value of the Dalasis (GAD) will continue to be determined by the supply and demand for foreign currency on the interbank market. The gap between official rates and those in the parallel (black) market are constantly monitored to assess the functional efficiency of the official market. The PSD proposes to adopt new regulations that will apply uniformly to all dealers in foreign exchange.

An efficient foreign exchange system is also important since The Gambia depends heavily on international trade. In addition to 50 percent of its food supplies, all fertilizers, fuel, capital goods, and most manufactured products must be imported (Jabara 1990). However, a significant amount of imported foodstuffs and manufactured goods are reexported to other West African countries[9].

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[9]As noted in Chapter 1, the IMF (1989) estimated that 30 to 35 percent of imports are eventually reexported to other West African countries.

The major foreign exchange earners for The Gambia are reexport sales, groundnut sales, and tourism. Several factors have a direct influence on the performance of these sectors. The volume and value of reexports depend on the international prices for these products and the purchasing power in neighbouring countries. Prior to the floating of the exchange rate, reexport traders enjoyed an overvalued Dalasis that allowed them to import goods at the official exchange rate and then resell them at the higher black market rate. This was detrimental to The Gambia because profits were generally held in overseas bank accounts.

The earning power of groundnut is swayed by world prices and the extent to which harvests are sold illegally to Senegal. Depending on the groundnut price differential between the two countries, cross-border trading can flow either way. Higher prices in The Gambia attracted Senegalese nuts in the early 1980s, but the flow was reversed from the mid-1980s onward as the GPMB price failed to compete. It is very difficult to quantify with any accuracy the volume of smuggled groundnut. Today, higher local prices and the devaluation of the CFA franc discourage the smuggling of groundnut to Senegal.

Considering the problems and risks associated with the reexport trade (Chapter 1, p.15), a reorientation of trade policy is undoubtably in the making. The rapid fall of this foreign currency generator adds yet another constraint to The Gambia's ability to revitalize its economy and repay foreign debts. Additionally, the potential negative effects on tourism of the recent coup raises concern.

2.3.4 Food Security Policy

Since the mid-1970s, the Gambian government has been promoting food security through agricultural diversification. While recognizing the importance of groundnut to the whole economy, the authorities were also cognizant of the per capita decrease in domestic crop production. The ongoing task is to establish a proper balance between domestic and groundnut crop production[10]. This is a formidable endeavour when overall crop productivity is low.

Rice is the staple food for Gambians. Because a large proportion of a family's income is tied to rice consumption, the pre-ERP policy was to stabilize its retail price. Importation and distribution of rice were the exclusive monopoly of the GPMB, and the rice stabilization policy placed a severe burden on its financial stability; the GPMB's selling price was often lower than its wholesale costs (which included a 23 percent rice import duty). Since the import duty was not passed on to consumers through the retail price, the

[10]Recall that groundnut production is an important foreign exchange earner. Hard currency is needed to service foreign debt (e.g., IMF loans) and to pay for imported goods.

stabilization policy amounted to nothing more than a tax on the GPMB. The retail price was eventually set to cover all GPMB costs (1985), including a 26 percent duty fee. Consumers faced an additional price hike in the same year when the flexible exchange rate policy was introduced[11]. Although the import duty rose again in 1986/87 to 30 percent, it was finally eliminated in 1988/89. The suspension of subsidized rice did not seriously affect the poor because elite members of society had greater access to official sources.

Another strategy has been to reduce the country's dependence on imported rice by investing in rice production development projects. Several programs have been implemented since the 1970s, however, Kargbo (1983) indicated that The Gambia's comparative disadvantage in rice production resulted in negative net economic returns for all ventures undertaken. Nevertheless, activities to this regard continue today.

2.4 Summary

In this chapter, the principal institutions and policies involved in Gambian agriculture have been reviewed. The main components of the Ministry of Agriculture (MOA) were discussed, along with the organizational structure of land tenure, agricultural research, extension, credit, and input

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[11]The move to a flexible exchange mechanism resulted in a devaluation of the Dalasis. This made imported goods more expensive.

supply. Agricultural policies dealing with input/output prices, international trade, interest and exchange rates, credit, and food security were detailed.

CHAPTER 3

TOTAL FACTOR PRODUCTIVITY AND PRODUCTION STRUCTURE: THEORETICAL CONSIDERATIONS

3.1 Introduction

The economic performance of an industry is influenced by general market conditions interacting with organizational and technological factors specific to its unit firms (Salem 1987). Ultimately, productivity growth plays a pivotal role in determining the vitality and commercial competitiveness of industries.

This chapter begins by defining the relationship between productivity and technical change. Following a brief discussion contrasting partial and total factor productivity (TFP) measures, the theoretical underpinnings of the growth accounting (index number) and econometric approaches to productivity analysis are presented.

3.2 Productivity Versus Technical Change

Many studies have used the terms "productivity" and "technical change" interchangeably, however, productivity usually encompasses components other than pure technical advancement. If production on a larger scale enhances the utilization of scarce resources such that inputs need not be increased by the same proportion, *ceteris paribus*, the gains should not be attributed to technical change. In production economics, this phenomenon is termed increasing returns-to-scale. Alternatively, scale effects can induce decreasing returns to production. Other extraneous influences are possible. For example, the effects of institutional change or the removal of production inefficiencies that prevent the attainment of a potential level of output may be embedded in productivity estimates.

Despite a universal acceptance of the existence of such effects, the task of decomposing productivity estimates remains an empirical difficulty. This is true particularly for input quality changes. Because most of the attributes attached to inputs are not objectively measurable, data are restricted to physical or observable quantities.

Researchers have attempted to address this problem. The work has confirmed that components other than pure technical change may have a significant impact on productivity. Fan (1991) established that the recent rapid growth in Chinese agriculture was due largely to higher levels of input usage; input growth accounted for 57.7 percent of the total production growth, while technical change and efficiency improvement contributed 42.3 percent. Capalbo (1988) decomposed the growth of productivity into segments of nonconstant returns-to-scale and technical change for the United States agricultural sector; the combined effect of scale and quality-adjusted growth of aggregate input explained 11.0 percent of the growth in aggregate output[1].

3.3 Partial Productivity Versus Total Factor Productivity

Partial productivity (PP) relates one or more outputs to a single input. This type of evaluation was popular in the 1950s and 1960s. There can be as many such measures as there are outputs and inputs. The most common PP estimates are yield per hectare and yield per unit of labour. In contrast, TFP is based upon a weighted sum of all inputs given their relative importance in the production process. The TFP indexing procedure is far more comprehensive than PP indexes.

Partial productivity measures are easy to construct and understand, but are limited because they provide only a crude indication of overall productivity. The PP framework does not take into account the effect of other factor inputs. Instead of ranking the specific contribution of individual production inputs, PP reflects the joint effect of a number of interrelated influences. Consequently, PP estimates may be deceptive. Wong (1989) examined the trends and differences in agricultural productivity growth in China and India. The

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[1]Other studies have investigated the influence of institutional change on productivity values (Lin 1987; McMillan et al 1989).

results showed strong upward trends in land and labour productivity, yet a downward trend in TFP.

The imperfections attached to PP analyses were acknowledged long ago. Experimentation with the TFP concept originated in the 1940s (Capalbo and Vo 1988). Ruttan (1957) and Fabricant (1959) concluded that a broader coverage of resources in index construction produced a superior estimate of productivity. Today, virtually all practitioners have adopted the TFP methodology. Nonetheless, TFP suffers from issues of aggregation of heterogenous inputs (outputs) and deficiencies in quantity and market information. These weaknesses restrict the construction of true TFP indexes.

3.4 Measuring Total Factor Productivity

Approaches to measuring productivity may be grouped into two categories (Yotopoulos and Nugent 1976; Capalbo 1988): a) analyses for which a change in TFP is interpreted as the ratio of the rate of change of an index of aggregate output to an index of aggregate input (growth accounting), and b) econometric analyses which describe technological change as shifts in a production (cost) function.

To compare the two techniques, one needs to understand the assumptions and methodology underlying each approach. Growth accounting is derived from the neoclassical theory of production and distribution which contends that payments to input factors exhaust total output under the assumptions of competitive markets and constant returns-to-scale. If technological advance is evident, however, payments to factor inputs do not exhaust total output and there remains a residual output unexplained by total factor input. This residual forms the foundation for measuring TFP under the growth accounting framework. Much research has been devoted to measuring and explaining this residual (Domar 1961; Kendrick 1961; Jorgensen and Griliches 1967; Denison 1979).

Opponents of neoclassical theory claim that it fails to answer what technological progress is and how it comes to exist. Applications of the theory ordinarily result in poor fits, consequently new theories outside of mainstream economics have emerged (Romer 1990 and Scott 1991 in Solow 1991). These new ideas on economic growth yield powerful conclusions, but caution should be exercised since the assumptions underlying these theories are difficult to test (Solow 1991).

The parametric approach to productivity measurement is based on econometric estimation of the production (cost) technology. It requires specifying a production (cost) function, or a theoretical derivative thereof, that represents the technology. If scale and efficiency effects are assumed to be constant, it follows that a shift in the production (cost) function can be interpreted as a change in the state of technology or productivity.

A close conceptual relationship exists between the growth accounting and econometric procedures. In fact, Diewert (1976) has shown that many index number formulas exactly represent a specific production function. A primary distinction separates the two. Index number measurement is deterministic whereas econometric estimation is statistical. Given that the theory is developed deterministically, it is vague whether the theoretical mathematical conditions are met in a stochastic framework (Conway 1990). Wide differences may be evident because of the properties of the error term (Harper and Gullickson 1986). Some economists advocate that econometric estimates of production structures are more desirable than index number estimates, at least for comparative purposes. Caves et al (1982) argued that this view is erroneous when dealing with very general structures of production[2].

Each technique has advantages and disadvantages. Growth accounting requires data only on the two periods being compared, although this convenience comes at a cost in assumptions about the underlying technology (Hazledine 1991;

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[2]The structures of production considered by Caves et al (1982) were so general, the authors stated that they would be difficult to analyze econometrically. Regardless, econometric estimation is necessary to extract information on the parameters of the production structure and the implied substitution and scale properties.

Rosegrant and Evenson 1992). The standard assumptions are Hicks-neutral technical change, constant returns-to-scale, and long-run competitive equilibrium. These conditions may not hold in reality, hence the conclusions drawn may be false. The assumptions implicit in growth accounting can be relaxed with econometric measurement, but only under the restriction of input-output separability; outputs must be aggregated into a single index when estimating an aggregate production function. Furthermore, since the econometric methodology uses data on a number of periods to empirically test the relevant hypotheses, the process is data-intensive. If the production system under scrutiny has a large number of inputs and a small sample size, econometric estimation may not be feasible due to insufficient degrees-of-freedom.

Growth accounting can accommodate disaggregation of inputs when disaggregation would create both data and statistical difficulties for econometric procedures[3] (Hazledine 1991). Jorgensen (1988) provided evidence that disaggregation may aid in reducing the residual, or unexplained portion. On the other hand, econometric estimation enables testing for scale effects, technical change biases, and the validity of neoclassical optimization assumptions. It

[3]Disaggregation increases the number of parameters to be estimated, thereby resulting in a loss of degrees-of-freedom. Furthermore, disaggregation may cause problems with collinearity.

is acknowledged that using a time trend to econometrically measure technical change biases and structural change presumes that the data are non-stationary[4] (Clark and Klein 1993).

3.5 Implementing the Growth Accounting Framework

With growth accounting, indexes of total input and total output must be computed to obtain a ratio of aggregate output to aggregate input. There is little controversy among economists with respect to the overall framework, but considerable debate has focused on the choice of procedure for aggregating the inputs and outputs.

There are three methods that have been used most frequently in the literature for constructing productivity indexes. They are the arithmetic (Abramovitz 1956; Kendrick 1961), Geometric (Solow 1957), and Flexible-Weight (Christensen et al 1971 and 1973) indexing procedures. Each one represents a specific production function (Diewert 1976); respectively, the preceding indexes depict a linear, a Cobb-Douglas, and a transcendental logarithmic production function. The following sub-sections discuss these indexes in detail.

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[4]Stationarity of a univariate stochastic process is defined as a property that ensures constancy of the means, variances, and autocovariances through time (Judge et al 1988). Because technical change is assumed to follow a linear trend, this implies that the system is non-stationary. If this is true, estimates derived from regressions on level data may be inconsistent (Phillips and Durlauf 1986). There is a growing body of literature dealing with this issue (Engle and Granger 1987; Park 1990; Park and Ogaki 1991; Clark and Youngblood 1992; Clark and Klein 1993).

3.5.1 The Arithmetic Productivity Index

The arithmetic index expresses all variables of the underlying linear production function as index numbers with a common base and factor prices as weights. Considering a simple model with two inputs, the arithmetic index, I, is defined as (Yotopoulos and Nugent 1976)

$$I = \frac{\frac{Q}{Q_o}}{\left(\frac{P_{ko}K_o}{Q_o}\right)\left(\frac{K}{K_o}\right) + \left(\frac{P_{lo}L_o}{Q_o}\right)\left(\frac{L}{L_o}\right)} = \frac{Q}{P_{ko}K + P_{lo}L}, \tag{3.1}$$

where Q/Q_o, K/K_o, and L/L_o are, respectively, indexes of output, capital, and labour, and P_{ko} and P_{lo} are the base prices of capital and labour. The weights used for capital and labour are their respective base-year shares in output. Equation (3.1) can be rearranged as

$$Q = I(P_{ko}K + P_{lo}L). \tag{3.2}$$

This shows explicitly that output is a linear combination of the factor inputs.

Two well known indexing formulas that are based on the arithmetic methodology are Laspeyres and Paasche. The difference between them concerns the weighting mechanism.

Laspeyres uses base-year weights whereas Paasche employs end-year weights. Comparatively, the Paasche formula has been less popular in applied work due to bias sensitivities (Ruttan 1954). The conventional Laspeyres quantity index can be expressed as (Christensen 1975)

$$I_t = \frac{Q_t}{Q_o} = \frac{\sum_i P_{io}Q_{it}}{\sum_i P_{io}Q_{io}}, \tag{3.3}$$

where I_t is the aggregate input (output) quantity index in period t, P_i and Q_i are the prices and quantities of the inputs (outputs), and the subscripts, o and t, signify the base and comparison periods, respectively. Equation (3.3) can be re-written as

$$I_t = \frac{\sum_i \left(\frac{Q_{it}}{Q_{io}}\right) P_{io}Q_{io}}{\sum_i P_{io}Q_{io}} = \sum_i W_{io}\left(\frac{Q_{it}}{Q_{io}}\right), \quad \text{where} \quad W_{io} = \frac{P_{io}Q_{io}}{\sum_i P_{io}Q_{io}}. \tag{3.4}$$

Observe that fixed base-period factor prices are used as weights. Since prices are held constant at their base-period levels, only input (output) quantities are necessary to construct the index. If the base-period factor prices and quantities are allowed to change in each successive indexing period such that

$$I_t = \frac{Q_t}{Q_{t-1}} = \frac{\sum_i P_{i,t-1} Q_{it}}{\sum_i P_{i,t-1} Q_{t-1}}, \tag{3.5}$$

then both quantity and price data are required. Equation (3.5) is called the Laspeyres chained quantity index.

Due to its simplicity, the Laspeyres index was used extensively in applied work throughout the 1960s and early 1970s (Hamal 1991). With the recent advancements in index number theory, it has become somewhat of an "antique". Few economists would advocate the use of a linear production function. Nevertheless, users of the Laspeyres index (e.g. Lapierre et al 1987; Narayanan and Kizito 1992) are taking that position implicitly[5].

A linear production function implies that there is perfect substitutability between input factors. In other words, an increase in the relative price of any one input would result in the discontinuation of its use. If a perfect substitute is available at a lower price, there is no economic rationale for purchasing the higher priced input. Moreover,

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[5]Narayanan and Kizito have recently updated their work using a Flexible-Weight indexing procedure.

the marginal productivities of factor inputs in a linear production function such as (3.2) deviate only through changes in the productivity constant, I. This means that the marginal rate of technical substitution (MRTS) remains the same regardless of how fast one input is growing in relation to the other (Yotopoulos and Nugent 1976). Put another way, under the assumption of perfect competition, the marginal productivities of inputs become equal to their respective market prices. When prices are fixed at their base-period levels, the Laspeyres index does not affiliate changes in marginal productivities with changes in factor proportions. Clearly, the theoretical restrictions built into the Laspeyres indexing procedure are undesirable.

3.5.2 The Geometric Productivity Index

The Geometric indexing procedure was an ingenious breakthrough for students of productivity analysis. The greatest advantage it has over the arithmetic index is that it permits input prices to vary. Accordingly, so do the corresponding marginal productivities. The Geometric index can be derived by specifying an aggregate production function of the form

$$Q = A(t)f(K,L), \qquad \textbf{(3.6)}$$

where Q is output, A(t) is technology as a function of time, and f(K,L) represents a functional relationship involving capital (K) and labour (L). The production specification can be expanded to include any number of factor inputs. Given that technology is independent of capital and labour, it is disembodied and Hicks-neutral. This implies that technical change does not alter the MRTS, rather it simply shifts the production frontier.

The change in output when all factor inputs are allowed to vary can be evaluated by totally differentiating (3.6) such that

$$dQ = f(K,L)\left(\frac{\partial A(t)}{\partial t}\right)dt + A(t)\left[\left(\frac{\partial f}{\partial K}\right)dK + \left(\frac{\partial f}{\partial L}\right)dL\right]. \tag{3.7}$$

If time is introduced as an element, a change in output with respect to a change in time can be discerned. It follows that (3.7) is transformed as

$$\begin{aligned}\frac{dQ}{dt} &= f(K,L)\left(\frac{\partial A(t)}{\partial t}\right) + A(t)\left[\left(\frac{\partial f}{\partial K}\right)\left(\frac{dK}{dt}\right) + \left(\frac{\partial f}{\partial L}\right)\left(\frac{dL}{dt}\right)\right] \\ &= f(K,L)\left(\frac{\partial A(t)}{\partial t}\right) + A(t)\left[f_1\left(\frac{dK}{dt}\right) + f_2\left(\frac{dL}{dt}\right)\right],\end{aligned} \tag{3.8}$$

where f_1 and f_2 are the marginal productivities of capital and labour, respectively. Close inspection reveals that a change in output over time can be broken down into three components, viz. changes due to technology, capital input, and labour input. Technology, A(t), may be a constant or a more complicated function (e.g., exponential) so that its effect increases through time.

By letting $A = A(t)$, $dQ/dt = \dot{Q}$, $dA(t)/dt = \dot{A}$, $dK/dt = \dot{K}$, and $dL/dt = \dot{L}$, (3.8) simplifies to

$$\dot{Q} = \dot{A}f(K,L) + Af_1\dot{K} + Af_2\dot{L}. \tag{3.9}$$

Dividing through by Q, where $Q = Af(K,L)$, gives

$$\left(\frac{\dot{Q}}{Q}\right) = \left(\frac{\dot{A}}{A}\right) + Af_1\left(\frac{\dot{K}}{Q}\right) + Af_2\left(\frac{\dot{L}}{Q}\right). \tag{3.10}$$

Assuming that each input factor is paid the amount of its marginal product, the shares of capital and labour in a linear homogeneous production function are defined as

$$S_k = \frac{(KAf_1)}{Q} \quad \text{and} \quad S_l = \frac{(LAf_2)}{Q}, \tag{3.11}$$

where S_k and S_l are the respective shares of capital and labour in total output. Substituting (3.11) into (3.10) yields

$$\left(\frac{\dot{Q}}{Q}\right) = \left(\frac{\dot{A}}{A}\right) + S_k\left(\frac{\dot{K}}{K}\right) + S_l\left(\frac{\dot{L}}{L}\right), \qquad \textbf{(3.12)}$$

which is the standard Solow growth accounting equation. The residual contribution to growth, an estimate of productivity growth, is isolated by rearranging (3.12) as

$$\left(\frac{\dot{A}}{A}\right) = \left(\frac{\dot{Q}}{Q}\right) - S_k\left(\frac{\dot{K}}{K}\right) - S_l\left(\frac{\dot{L}}{L}\right). \qquad \textbf{(3.13)}$$

In words, (3.13) states that the percentage change in productivity growth is defined as the percentage change in output minus the proportionate changes in capital and labour. In estimating a Cobb-Douglas (CD) production function, $Q = Ae^{rt}K^{\alpha}L^{\beta}u^{\gamma}$, the coefficients α and β are the respective shares of capital and labour. Subsequently, (3.13) becomes

$$\left(\frac{\dot{A}}{A}\right) = \left(\frac{\dot{Q}}{Q}\right) - \alpha\left(\frac{\dot{K}}{K}\right) - \beta\left(\frac{\dot{L}}{L}\right) - \gamma\left(\frac{\dot{u}}{u}\right), \qquad \textbf{(3.14)}$$

where u is an error term. The contribution of the error term (u) to TFP is $\dot{A}/A$, since $\gamma(\dot{u}/u) = (\dot{A}/A)$ under the neoclassical assumptions.

The Geometric index can be used further to decompose the growth in output per unit labour. Assuming constant returns-to-scale, $(\alpha + \beta) = 1$, dividing (3.14) by L returns

$$\left(\frac{\dot{q}}{q}\right) = \left(\frac{\dot{A}}{A}\right) + \alpha\left(\frac{\dot{k}}{k}\right), \qquad \textbf{(3.15)}$$

where $q = (Q/L)$ and $k = (K/L)$. It follows that (3.15) isolates the proportional contributions of productivity growth and capital per unit labour growth to the increase in output per unit labour.

Three possible sources of bias coincide with the Geometric index (Yotopoulos and Nugent 1976; Judge et al 1988). Biases may result from misspecification of the functional form of the production technology, measurement errors in the data used to estimate the model, and the omission of pertinent explanatory variables. Additionally, the assumption that technical change is disembodied and Hicks-neutral may not reflect the real world.

It has been argued that changes in aggregate income (the income approach) provide a better reflection of changes in economic welfare than deviations in gross product (Chandler 1962). Gross product measures are deficient because they include capital consumption allowances that are designed to maintain the capital stock carried over from the past (Ruggles and Ruggles 1956). Chandler (1962) asserted that capital consumption is not a part of the income-value of output. Consequently, the output needed to preserve the previously existing capital stock is not included in the output whose changes are being analyzed.

Despite its negative aspects, the Geometric indexing procedure has persisted in applied research (Chandler 1962; Lave 1964; Evenson and Jha 1973; Krueger and Tuncer 1980; Hayami and Ruttan 1985; Wong 1989; Lin 1990; Hamal 1991; Si 1991). For case studies involving LDCs, it is usually the most feasible method available to the researcher. Quality market data are not readily available in LDCs. The Geometric approach eases the difficulty by relying more on theory than on data. Since estimation biases tend to be small when dealing with low rates of productivity growth, as found in LDCs, the Geometric methodology can provide TFP estimates comparable to those procured through more sophisticated techniques (Hamal 1991).

3.5.3 The Flexible-Weight Productivity Index

An alternative approach for measuring changes in TFP is based on the concept of cost and revenue shares. The Tornqvist-Theil superlative[6] index is a discrete approximation to the continuous time Divisia index. The cost function

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[6]An index that is exact for a linear homogeneous flexible functional form for the aggregator function is defined as being superlative (Diewert 1976).

underlying this index is the flexible form transcendental logarithmic (translog) cost function. It is "flexible" in the sense that it does not place *a priori* restrictions on the value of the elasticity of substitution (EOS) between any two inputs. If the relative price of an input increases, its use will decrease until all marginal productivities are proportional to the new prices. Because the EOS between input pairs can assume any value, substitutability and complementarity relationships can be examined. This is in sharp contrast to the linear and CD production functions. A linear production function implies that the EOS between input pairs is infinity (perfect substitutability), whereas the CD form restricts the EOS value to unity (constancy of factor shares).

The use of the Tornqvist-Theil index also represented efforts to adjust conventional inputs for quality differences (Capalbo and Vo 1988). Conceptually, quality improvements in factor inputs are reflected in higher prices. Since this indexing procedure relies on current factor prices in constructing the weights, quality adjustments are accounted for implicitly.

Other flexible forms followed the development of the translog function: the Generalized Leontief (Diewert 1971), Generalized Cobb-Douglas (Diewert 1973), Quadratic (Lau 1974), and Generalized Concave (McFadden 1978) functional forms. A mathematical property that is common to all flexible forms is that each can provide a (local) second-order approximation to an arbitrary twice-continuously differentiable production or cost function. The selection of one over another is based more on personal choice than on theory.

Research by Berndt et al (1977) suggested that the translog function outperformed the Generalized Leontief and Generalized Cobb-Douglas functional forms, whereas Appelbaum (1979) found the Generalized Leontief to be more appropriate for analyzing U.S. manufacturing data. In a study of Canadian agriculture, Lopez (1980) concluded that relative factor prices played an important role in the determination of the demands for inputs; thus, the Leontief production function was rejected. Regardless, the translog function has become one of the most widely used forms in empirical work (Binswanger 1974[a]; Binswanger 1974[b]; Berndt and Christensen 1974; Berndt et al 1977; Brown 1978; Kako 1978; Applebaum 1979; Islam and Veeman 1980; Hazilla and Kopp 1984; Adamowicz 1986; Capalbo and Denny 1986; Rahuma 1989; Hamal 1991; Rosegrant and Evenson 1992; Dehaan and Clark 1993).

The Divisia index is defined in continuous time as (Christensen 1975)

$$\frac{Q_t}{Q_o} = \exp\left[\int \sum_i W_{it}\left(\frac{\dot{Q}_{it}}{Q_{it}}\right)\right], \quad \text{where} \quad W_{it} = \frac{P_{it}Q_{it}}{\sum_j P_{jt}Q_{jt}}. \qquad \textbf{(3.16)}$$

W_{it} is the share of the i^{th} factor input (output) in total cost (total value product) in period t, and P and Q are the input (output) prices and quantities.

As the time unit becomes infinitely small between observations, a discrete approximation converges to the continuous Divisia index. The weighted log-change index, defined as

$$\ln\left(\frac{Q_t}{Q_o}\right) = \sum_i \overline{W}_i \ln\left(\frac{Q_{it}}{Q_{io}}\right), \quad \text{where} \quad \overline{W}_i = \frac{(W_{it} + W_{io})}{2}, \qquad \textbf{(3.17)}$$

illustrates a fixed-base Divisia approximation (Christensen 1975); the base-weights (W_{io}) and quantities (Q_{io}) remain fixed during the construction of the index series. Equation (3.17) becomes a chained index if the base-period changes in each successive period such that

$$\ln\left(\frac{Q_t}{Q_{t-1}}\right) = \sum_i \overline{W}_i \ln\left(\frac{Q_{it}}{Q_{i,t-1}}\right), \quad \text{where} \quad \overline{W}_i = \frac{(W_{it} + W_{i,t-1})}{2}. \qquad \textbf{(3.18)}$$

The chained index is commonly employed in empirical work (White 1993).

The indexes obtained from (3.18) are used to calculate a ratio of aggregate output to aggregate input for each year in the sample. The residual difference between the changes in aggregate output and aggregate input defines the change in TFP over time.

3.6 Choice of Productivity Index

From a theoretical position, the Flexible-Weight indexing procedure is superior to both the arithmetic and Geometric methodologies. However, a model must be judged also on the basis of its practicality. In this respect, the Geometric approach is the most practical. It represents an improvement over the arithmetic index and, unlike the Flexible-Weight ind x, does not require price data. For this study, price data are not available for land and draught animals.

Since The Gambia does not have a strong time-series database, the Geometric approach has been selected as the model of choice. Other LDC-based productivity studies have employed the Geometric index for the same reason, therefore a direct comparison of the results is possible. Bearing in mind the theoretical advantages of the Flexible-Weight index, an attempt is made to proxy the missing price variables. Moreover, input prices are necessary for estimating the production structure of the Gambian groundnut sector. What must be ascertained is the reliability of the proxied variables. Given that only minor estimation differences separate the two methods in the presence of low productivity growth (Hamal 1991), the results of the two procedures should be similar if, in fact, the assumptions are plausible.

3.7 Estimation of Factor Shares

Factor shares in the Flexible-Weight index are calculated using equation (3.18). The Geometric index requires estimating an aggregate production function for groundnut. Equation (3.6) is extended to four factor inputs so that

$$Q = A(t)f(R,L,F,K), \qquad \textbf{(3.19)}$$

where Q is groundnut output, A(t) is technology as a function of time, and f(R,L,K,F) represents a functional relationship involving land (R), labour (L), draught animals (K) and fertilizer (F).

As is customary, the functional form is assumed to be a linearly (degree one) homogeneous CD specification. Further assuming that technical change is disembodied, Hicks-neutral, and an exponential function of time, (3.19) can be re-written as

$$Q = Ae^{rt}K^{\alpha}L^{\beta}F^{\gamma}R^{\delta}, \qquad \textbf{(3.20)}$$

where e is an exponential operator. The linear homogeneity assumption, which implies that the production function exhibits constant returns-to-scale, can be tested by formulating the null hypothesis as H_o: $\alpha+\beta+\gamma+\delta=0$.

The factor inputs are treated as variable, therefore equation (3.20) represents a long-run production function. If the levels of certain inputs are truly fixed, then the functional form is misspecified. Issues relating to variable versus fixed inputs in production analyses are well documented (Debertin 1986; Chambers 1988), but no less confusing.

The difficulty lies in establishing a concrete definition of short-run and long-run with respect to time. Conceptually, if the time period is sufficiently long, all production inputs become variable. On the other hand, if the time period considered is relatively short, some of the inputs may be fixed. For example, farms operating expensive and highly specialized capital equipment are usually unable to fully adapt to changes in economic conditions in the short-run. But what is the exact length of time that coincides with the term "short-run"? It is clear that any precise classification of short-run or long-run is arbitrary.

The short-run/long-run identity problem is not as serious when dealing with primitive production systems, as found in the Gambian groundnut sector. Groundnut farmers, in general, are able to make input decisions prior to planting. In this setting, all of the factor inputs are variable and the production function given in equation (3.20) is judged to be properly specified.

3.8 Estimation of the Production Structure

With the necessary theoretical restrictions in place, profit maximization and cost minimization are dual problems. Instead of evaluating the production function directly, estimates of the parameters can be derived through the cost-minimizing demand equations obtained from the total cost function. This approach may reduce the problem of severe collinearity normally encountered when estimating production functions directly (Islam 1982). Hence, the parameter estimates may be more precise. A translog cost function that considers technical change can be expressed as (Binswanger 1974[b]):

$$\begin{aligned} \ln TC &= \alpha_0 + \alpha_Y \ln Y + (1/2)\gamma_{YY}(\ln Y)^2 + \sum_i \beta_i \ln P_i \\ &+ (1/2)\sum_i \sum_j \gamma_{ij} \ln P_i \ln P_j + \sum_i \alpha_i \ln Y \ln P_i + \theta_T T \\ &+ (1/2)\theta_{TT} T^2 + \theta_{TY} T \ln Y + \sum_i \theta_i T \ln P_i + \epsilon_i, \end{aligned} \tag{3.21}$$

where TC is the total cost of production, Y is aggregate output, the P's are input prices, T is a time variable, and ϵ_i is the regression error.

Through Shephard's lemma (1953), the cost-minimizing input demand equations are obtained by differentiating the total cost function in (3.21) with respect to the input prices. The resulting system of demand equations can be evaluated using time series data. The parameter estimates characterize the underlying production function. The system of share equations takes the form

$$\frac{\partial \ln TC}{\partial \ln P_{it}} = S_{it} = \beta_i + \sum_j \gamma_{ij} \ln P_{jt} + \alpha_i \ln Y_t + \theta_i T_t + e_i, \qquad \textbf{(3.22)}$$

where $S_{it} = [(P_{it}X_{it})/\Sigma P_{it}X_{it}]$ is the total cost share of the i^{th} input in period t.

The procedure described above is valid only if five theoretical properties are satisfied. Specifically, duality theory requires that restrictions of adding-up, symmetry, monotonicity, homogeneity of degree zero in input prices, and concavity in input prices hold. If these conditions are not met, the parameter estimates are meaningless with respect to theory. It is important to recognize that, unlike the CD production function, the translog functional form is not self-dual. Generally, the adding-up, symmetry, and homogeneity restrictions are imposed on the system in (3.22), whereas the properties of monotonicity and concavity are tested after the model has been estimated (Antle and Capalbo 1988).

Mathematically, the theoretical restrictions to be imposed are stated as

$$\sum_i \beta_i = 1; \quad \sum_i \alpha_i = 0; \quad \sum_i \theta_i = 0 \quad \text{(adding-up)}, \qquad \textbf{(3.23)}$$

$$\gamma_{ij} = \gamma_{ji} \quad \text{(symmetry)}, \qquad \textbf{(3.24)}$$

$$\text{and} \quad \sum_j \gamma_{ij} = 0 \quad \text{(homogeneity of degree 0)}. \qquad \textbf{(3.25)}$$

To illustrate the flexibility of the translog function, the set of equations in (3.22) can take on different forms given a change in the restrictions imposed. Islam (1980) noted three examples. If the restrictions in (3.23), (3.24), and (3.25) are placed on (3.22), a nonhomothetic structure with augmented technical change is generated. Alternatively, if the time coefficients are set equal to zero, a nonhomothetic structure without augmented technical change results. Finally, if scale effects are ignored (i.e., the output coefficients equal zero), a homothetic structure with augmented technical change is produced.

3.8.1 Elasticities of Substitution and Factor Demand

When analyzing the production structure of a given system, researchers are interested particularly in elasticities of substitution, price elasticities of factor demand, technical change biases, and scale effects. The γ_{ij} coefficients in (3.22) can be converted into point estimates of Allen partial elasticities of substitution (σ_{ij}) and price elasticities of factor demand (η_{ij}).

A specific σ_{ij} describes the ease with which one element of an input pair can be substituted for the other in the production process. Binger and Hoffman (1988) defined σ_{ij} as a measure of the proportionate change in the input ratio relative to a proportionate change in the MRTS. If σ_{ij} is positive, the two inputs are substitutes. Conversely, if the sign of σ_{ij} is negative, the two inputs are complements. The magnitude of σ_{ij} indicates the degree of flexibility that firms have in adjusting their input mix in response to relative changes in prices (Debertin 1986). If σ_{ij} is a large value, this means the firm has a high level of flexibility in substituting one input for another given changes in prices. The value of σ_{ij} can range from 0 to $+\infty$. When $\sigma_{ij} = 0$, the corresponding isoquant is "L-shaped", implying that the firm must use inputs in fixed proportions (Leontief technology). At the other extreme, $\sigma_{ij} = +\infty$, the two inputs are perfect substitutes and the cost-minimizing combination is indeterminate (the slopes of the isoquant and isocost line are equal).

The own-price elasticity of demand (η_{ii}) measures the responsiveness of the quantity demanded for an input with respect to a change in its own price, *ceteris paribus*. If η_{ii} has an absolute value such that $0 < \eta_{ii} < 1$, the input is inelastic (low responsiveness) to changes in its own price. A value of $\eta_{ii} > 1$ indicates that the input is elastic (high responsiveness) to changes in its own price. If $\eta_{ii} = 1$, the elasticity is unitary; a 1% increase in price results in a 1% decrease in the quantity demanded. The cross-price elasticity of demand (η_{ij}) measures the responsiveness of the quantity demanded for the i^{th} input with respect to a change in the price of the j^{th} input, *ceteris paribus*. A negative value for η_{ij} identifies a complementary relationship between the two inputs. A positive sign demonstrates that the two inputs are substitutes.

The equations used by Binswanger (1974[b]) to calculate the elasticities are expressed as

$$\sigma_{ii} = \frac{1}{s_i^2}(Y_{ii} + s_i^2 - s_i) \quad \text{(for all i)}, \qquad \textbf{(3.26)}$$

$$\sigma_{ij} = \frac{Y_{ij}}{s_i s_j} + 1 \quad \text{(for all } i \neq j\text{)}, \qquad \textbf{(3.27)}$$

$$\eta_{ii} = \frac{\gamma_{ii}}{s_i} + s_i \quad \text{(for all i),} \qquad \textbf{(3.28)}$$

$$\text{and} \quad \eta_{ij} = \frac{\gamma_{ij}}{S_i} + S_j \quad \text{(for all } i \neq j\text{).} \qquad \textbf{(3.29)}$$

3.8.2 Embodied Technical Change Biases and Scale Effects

Technical change in methodologies such as the Geometric indexing procedure is assumed to be Hicks-neutral and disembodied. In the real world, such an assumption is not plausible. To the contrary, it is highly probable that technical change is embodied and biased toward a specific input. The flexibility of the translog function permits examining the nature of technical change via the cost function or share equations. From the share equations in (3.22), the estimated coefficients on the time variable, θ_i, reveal information about the characteristics of technical change. Technical change can be i^{th} input-using ($\theta_i > 0$), i^{th} input-saving ($\theta_i < 0$), or Hicks-neutral ($\theta_i = 0$).

Scale effects measure the change in output with respect to a change in the demand for factor inputs. These effects can be evaluated by examining the signs of the estimated coefficients (α_i) corresponding to the aggregate output variable (Y). When $\alpha_i > 0$, $\alpha_i < 0$, and $\alpha_i = 0$, the scale effect is i^{th} input-using, i^{th} input-saving, and neutral, respectively.

3.9 Summary

In Chapter 3, the relationship between productivity and technical change was defined and an explanation was provided as to why estimates of total factor productivity (TFP) are preferred to partial productivity (PP) measures. Having established the superiority of TFP-based productivity analyses, theoretical issues pertinent to implementing the TFP methodology were discussed in detail. Furthermore, the growth accounting (indexing procedure) and econometric approaches to productivity analysis were compared and contrasted. Once the theoretical considerations and practicality constraints were weighed, an appropriate empirical strategy was devised for achieving the objectives of this study.

CHAPTER 4

GROUNDNUT PRODUCTION AND RAINFALL DATA: THEIR MEASUREMENT AND ANALYSIS

4.1 Introduction

In order to analyze the total factor productivity (TFP) and production structure of the Gambian groundnut sector, time series data on quantities and prices of crop outputs and inputs are required. After briefly considering the topic of data aggregation, this chapter outlines the sources and assumptions used for assembling the database. Additionally, national rainfall data are used to study the influence of weather on groundnut production. A trend analysis is conducted for each series.

4.2 Data Aggregation Issues

With complex production systems, as evident in industrial countries, a factor input such as labour is comprised of many categories. Classes range from unskilled workers to management personnel. In essence, a production process may be viewed as a two-stage operation whereby, in this example, the labour input is actually manufactured out of several labour sub-components (stage 1), and then this substance is combined with other inputs to produce the final product (stage 2) (Solow

1955). As such, the labour data must be transformed in some way to produce a proxy for aggregate labour.

A traditional method for aggregating two or more data series is to simply sum them if they are expressed in the same units. If the units are not the same, aggregation is possible by measuring one type in terms of the other. In the case of labour, wage rates equal marginal productivities under the assumption of competitive markets. It follows that this assumption allows one to convert quantities of one type of labour into another to obtain a sum of the two types.

This convenience comes with theoretical costs. It has been well documented that such a method of aggregation reflects an underlying production technology for which the labour types being aggregated are perfect substitutes. Clearly, this condition does not conform well with reality. It is far from reasonable to assume that an unskilled labourer would be a perfect substitute for a professional manager.

The challenge in empirical work is to formulate data aggregates that obey optimality conditions while, at the same time, are not subjected to unduly restrictive assumptions. In this study, the production system is primitive and consists of only one output and four simple factor inputs. Nevertheless, the same issues apply when aggregating the individual factor inputs to form a composite input index for use in the TFP analysis.

Another form of aggregation relates to the summation of divisional or county data to derive national quantities. Research evidence submitted by Domar (1961) and Lave (1964) suggested that little bias is involved with this type of aggregation. This is an important point because the Gambian production data are based on divisional estimates.

4.3 Groundnut Output and Input Quantity Data

4.3.1 Groundnut Output

The groundnut output quantity data (Table A.1, Appendix A) are measured in metric tons (MT). The series was constructed from FAO and DOP estimates. Output figures were available through the Gambian Co-operative Union (GCU) purchase records, however, these data were considered to be distorted due to cross-border trading. In the early 1980s, 10-20 thousand metric tons of groundnuts were attracted from Senegal annually, this in response to higher purchase prices prevalent in The Gambia (USAID 1986). The trade flow was reversed in 1985 when the Gambian price failed to match the Senegalese offering (Jabara 1990).

4.3.2 Land Input

The land input quantity data (DOP; FAO) presented in Table A.1 of Appendix A are measured in hectares (ha) and represent the stock of land available for groundnut production in each year[1]. Generally, the flow of services emanating from a factor input is preferable to a simple measure of total stock when estimating TFP (Capalbo and Antle 1988; Rahuma 1989; Hamal 1991). If services such as summer fallow and minor crops do exist and are excluded, TFP measurement is biased. In this case, the stock of land is deemed acceptable because groundnut output provides the only service in any one cropping season (Swindell 1978; Kargbo 1983; Posner and Jallow 1987).

4.3.3 Labour Input

A definition for labour is somewhat arbitrary. The economics literature offers little guidance as to how to measure this factor input. Ultimately, it must somehow depend on who is included in the labour force and how many hours they are able and willing to work. Despite the fact that peasant labour dominates traditional agricultural societies[2], the task of quantifying labour inputs remains an empirical difficulty.

The annual hours available for farm work per person depend on the number of hours individuals are prepared to work, given their other commitments. This means that the labour force and the hours devoted to agriculture are tied to

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[1]The author is well aware of the inconsistencies in the land input series. Data from other sources were tested, however, the results were far from satisfactory.

[2]For the most part, agriculture in developing countries consists of one labour class. This is in contrast to industrial countries where agriculture involves many labour categories (e.g., management, technicians, labourers).

customs and traditions, and attitudes toward leisure and income. Furthermore, it is reasonable to conclude that the quality of labour is not homogeneous. Byerlee et al (1977) contended that conventional measures of labour for rural Africa were of limited value because most of the population is self-employed in producing commodities mainly for home consumption. This is a valid point for domestic crops, but it is less applicable for a cash crop such as groundnut. Whereas domestic crop consumption may approach 100 percent (Kargbo 1983), home use for groundnut is in the 10-15 percent range (Jabara 1990).

The use of labour hours or labour days has been found to be satisfactory (Brown 1978; Hamal 1991). A working day is usually assumed to equal eight work hours, regardless of actual quality. This system is used by the FAO Data Collection System. Moreover, the Gambian government adopts this method in establishing its minimum daily wage rates. Regardless, the limitations are readily apparent. Workers vary in skill, strength, and versatility.

Another practise is to measure labour in manday equivalents by applying specific conversion factors[3]. There is no consensus on what the conversion factors should be. Norman

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[3]For example, children under 6 years of age may equal zero man-equivalents while children between 7 and 14 years may equal 0.5 man-equivalents.

(1973), Spencer et al (1976), and Tang and Stone (1980) applied different conversion factors. Brown (1979) argued that conversion factors are unnecessary; jobs on farms are highly specialized, therefore it is a fallacy to assume that a child's output is less effective than a man's.

In any event, the final decision rests on what information is accessible to the researcher. For this study, the labour input quantity data (Table A.1, Appendix A) are measured in person days. A national agricultural labour stock series (DOP; FAO) was adjusted according to groundnut land use and then converted into person days by multiplying the adjusted labour stock by 119. Kargbo (1983) stated that groundnut production entailed 119 working days per labourer annually. It is acknowledged that this figure is a single point estimate. Notwithstanding, it is used for the entire series due to the unavailability of additional observations. Given the primitive production practices found in The Gambia, such an assumption should not stray too far from reality.

The agricultural labour stock series was originally calculated from periodic census data (CSD[a]) by estimating an exponential function of the form $Y = Ae^{bT}$. The results proved to be unsatisfactory. Although this method is practical for filling in sporadic gaps in a data series, its unidirectional estimating structure makes it impractical for creating a continuous series from a few observations.

4.3.4 Draught Animals Input

Draught animals represent a proxy for capital goods in the traditional production system. Many of the issues involved with measuring labour are relevant to the assessment of draught animals. Donkeys, oxen, and horses serve as draught animals in The Gambia. Donkey power is the most common, followed by oxen and horses. Periodic draught animal population censuses were available (DOP), but again a series estimation via an exponential function proved inadequate.

FAO estimates of animal stocks were adjusted according to groundnut land use. No conversion factors were used to obtain animal-equivalents. The stock series was multiplied by a factor of 27 to convert it to a flow of services, measured in animal days. Kargbo (1983) indicated that a draught animal involved with groundnut production worked an average of 27 days per annum. As with labour, it is assumed that this figure has remained fairly constant over time. The resulting draught animal series is presented in Table A.1, Appendix A.

4.3.5 Fertilizer Input

Estimating fertilizer use is confounded by cross-border trading and other distortions (Kristensen and Baldeh 1987; Jabara 1990). In fact, the inconsistency of fertilizer availability and the overall mismanagement of the GCU[4], the

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[4]The fertilizer market has since been privatized.

country's major supplier, led to increased cross-border selling in the 1980s (Jabara 1990). Studies have revealed that fertilizer is applied to just 15 percent of the area sown to groundnut, and that the average application rate is 75 percent below the recommended level (Sumberg and Gilbert 1988). Regardless, estimates of national fertilizer consumption are employed as a proxy for actual use. Considering that fertilizer plays such an insignificant role in Gambian production, biases should be minimal.

The fertilizer input series (Table A.1, Appendix A) is measured in metric tons (MT) of nutrient phosphorus (P_2O_5) (AIO 1992; FAO). The series was converted into phosphorous nutrient units based on the composition of single super phosphate (SSP), which is approximately 18 percent P_2O_5. Compound fertilizer is not generally used because groundnut is a legume[5].

4.4 Trend Analysis of Output and Input Quantity Data

A trend analysis involves evaluating an exponential function of the form $Y = Ae^{bT}$, where Y is the variable of interest, e is an exponential operator, T is time, and A and b are the parameters to be estimated. The function is converted into an equivalent linear function by taking logs on both sides to yield $\ln Y = \ln A + bT$.

[5]A legume is a plant species that can fix its own nitrogen.

The annual compound growth rates for the production variables are determined by estimating the individual linear functions by ordinary least squares (i.e., regressing time on the log of each index series), and then subtracting 1 from the antilog of the estimated time coefficients (b). It is important to realize that longer time intervals usually give a clearer, more accurate representation of the general trend. This is due to the fact that shorter intervals are susceptible to the presence of outliers[6]. It is possible to have sub-sample periods (encompassing the entire series) that show negative trends while the complete sample displays an overall positive trend, or vice-versa. Moreover, longer intervals grant additional degrees-of-freedom for the statistical model.

For expository purposes, the output index and linear growth trend for groundnut are illustrated in Figure 4.1. The estimated time coefficient (b) equals the slope of the linear trend line. Using the data in Table A.1 (Appendix A), a simple quantity index was constructed for output and each of the factor inputs (Table 4.1). Additionally, growth trends for selected time periods were estimated[7] (Table 4.2).

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[6]Longer periods allow for the "smoothing out" of large deviations that may occur in the data in a given year.

[7]Unless noted otherwise, percentage growth statements refer to average annual growth rates.

FIGURE 4.1
GROUNDNUT OUTPUT INDEX AND TREND, 1964-1991

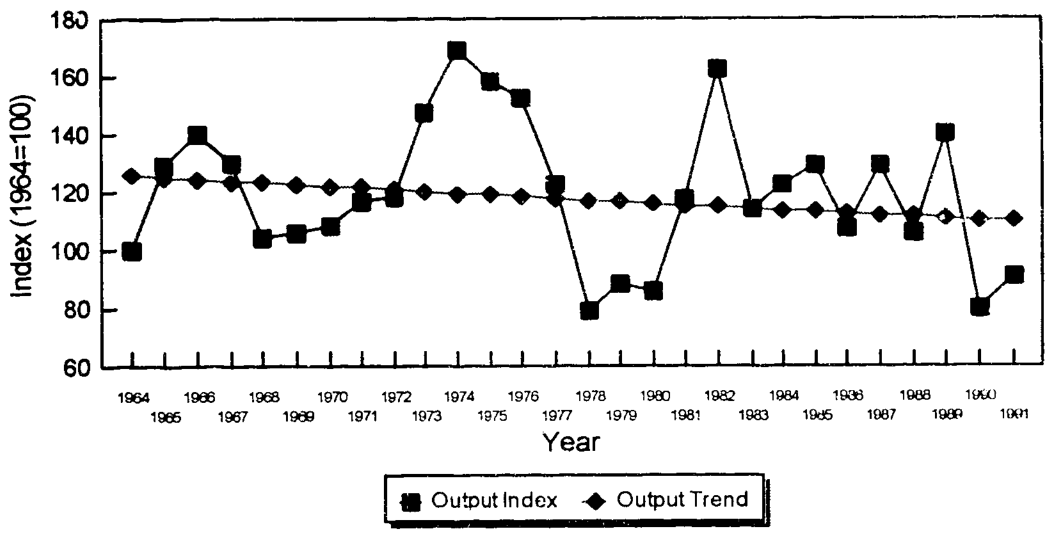

Table 4.2 shows that output and land declined at an average annual rate of 0.5 and 2.9 percent, respectively. Labour (0.6 percent), draught animals (0.4 percent), and fertilizer (7.6 percent) yielded positive growth trends. The estimates associated with output, labour, and draught animals are not statistically different from zero. Although output decreased at a slower rate than land, this does not necessarily constitute an increase in productivity. A proper evaluation must consider the use of all resources combined.

Observe that while fertilizer use is insignificant in The Gambia, its consumption shows a dramatic increase throughout the 1960s and 1970s. This should be expected since the

TABLE 4.1
GROUNDNUT OUTPUT AND INPUT QUANTITY INDEXES, 1964-1991
(1964=100)

Year	Output	Land	Labour	Draught Animals	Fert.
1964	100.0	100.0	100.0	100.0	100.0
1965	129.1	101.3	113.7	122.2	140.2
1966	140.1	111.3	127.4	145.2	462.2
1967	129.9	122.0	136.4	133.3	673.2
1968	103.9	93.3	91.1	125.9	557.3
1969	105.4	94.0	91.6	123.7	370.7
1970	108.4	95.3	93.2	131.9	268.3
1971	116.5	111.3	102.5	133.3	357.3
1972	118.3	115.3	100.9	136.3	487.8
1973	147.3	116.7	102.7	148.1	1036.6
1974	168.8	122.7	100.4	168.9	863.4
1975	158.1	126.7	99.9	170.4	880.5
1976	152.6	126.7	119.1	164.4	1495.1
1977	122.2	70.0	88.4	148.9	1878.0
1978	78.9	66.7	80.2	147.4	1353.7
1979	88.0	66.7	82.7	150.4	2448.8
1980	86.0	66.7	74.2	148.9	1990.2
1981	117.2	66.7	86.7	160.7	1500.0
1982	162.4	66.7	97.5	163.0	1102.4
1983	114.0	66.7	92.5	146.7	1701.2
1984	122.6	66.7	115.8	148.1	3073.2
1985	129.0	63.3	127.1	138.5	1587.8
1986	107.5	61.3	123.4	137.8	1997.6
1987	128.9	63.3	126.1	140.0	858.5
1988	106.0	63.3	128.9	130.4	858.5
1989	139.7	57.6	130.3	140.7	1707.3
1990	80.1	61.4	128.1	138.5	1341.5
1991	90.5	54.6	127.0	131.9	975.6

TABLE 4.2
GROUNDNUT OUTPUT AND INPUT QUANTITY
ANNUAL COMPOUND GROWTH RATES (%)

Period	Output	Land	Labour	Draught Animals	Fert.
1964-69	-1.3	-1.3	-2.9	3.1	37.2*
1970-79	-2.6	-5.3*	-1.8	1.6	25.2*
1980-91	-1.5	-1.5*	4.8*	-1.6**	-4.4
1964-91	-0.5	-2.9*	0.6	0.4	7.6*

* significant at the 0.01 level
** significant at the 0.05 level

application of chemical fertilizer in the mid-1960s was virtually zero from a national perspective. As such, any moderate fertilizer increase would appear to be striking in relation to the base year (1964). In accordance with the observations of Jabara (1990), fertilizer use declined in the 1980s.

4.5 Groundnut Output and Input Price Data

As alluded to previously, implementation of the Divisia indexing procedure requires price data. An attempt has been made to establish suitable proxies for land and draught animal prices. Under a traditional land tenure system, formal land prices do not exist. Similarly, there is no market information available for draught animal prices.

4.5.1 Groundnut Output Price

The producer price series for groundnut (CSD[a]), presented in Table A.2, Appendix A, is measured in Gambian Dalasis units (GAD). As of April 1994, one Canadian dollar (CDN 1.00) equalled approximately GAD 6.85.

4.5.2 Land Price

In the absence of market-determined land prices, a method must be devised for establishing an acceptable proxy. This is a problem that is characteristic of studies involved with developing countries. Researchers have approximated land prices by relating them to the rents earned on land and to other crop prices. In economic terms, land rent is defined as the surplus paid to that unit of land after all other production costs have been netted out (Hartwick and Olewiler 1986). That is, the rent attached to a unit of land is the difference between total revenue and total cost, excluding land itself. Ignoring discounting (time value of money), the algebraic expression for land rent is defined as

$$P_{Rt} = \sum_{i} R_{it} - \sum_{i} C_{it}, \quad \text{where} \quad \sum_{i} R_{it} = \sum_{i} P_{it} Y_{it}. \qquad \textbf{(4.1)}$$

P_{Rt} is the land rent in GAD per hectare in period t, R_{it} is the revenue from the i^{th} crop in GAD per hectare in period t, C_{it}

is the cost in GAD per hectare of all inputs other than land for the i^{th} crop in period t, P_{it} is the price of the i^{th} crop in GAD per metric ton in period t, Y_{it} is the yield of the i^{th} crop in metric tons per hectare in period t, and t is the time period.

The formula in (4.1) cannot be used in this study because adequate price and costs of production data on the other major crops in The Gambia are not available. Hamal (1991) simplified the problem by assuming constant production costs and employing crop shares as weights. The price data requirement precludes its application here.

Given the chronic lack of data, generating land prices necessarily entails some heroic assumptions. The decision was made to equate the price of land with an approximation of its net income per hectare, lagged one time period. Suppose a hectare of groundnut produced a net income of GAD 500.00 last year. Should the farmer decide to lease the land for the next growing season, he or she would expect to receive a rental fee of GAD 500.00, minus the value of any personal labour[a]. Conceptually, it is also plausible that the operator would be willing to discount the rental fee since production risks would be passed on to the lessee; Gambian farmers are

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[a]The value of personal labour will be ignored here because there is no information indicating what the proportion of owner's labour in total labour should be.

generally risk-averse (Kargbo 1983). Of course, there is a probability that the land would generate more than the previous year's income. For simplicity, it is assumed that the farmer's decision is based solely on last year's price, adjusted for the absence of risk. An attempt has been made to account for costs not included in this study. It follows that the land price is determined by

$$P_t = \left(R^{*}_{t-1}\right)(1 - \delta), \quad \text{where } R^{*}_{t-1} = R_{t-1} - C_{t-1}. \qquad \textbf{(4.2)}$$

P_t represents the price of land per hectare in time t, R_{t-1} is the gross revenue per hectare in time t-1, δ is a constant factor of proportionality (vc + r) composed of unaccounted variable costs (v) and production risks (r), and C_{t-1} is the total costs accounted for (i.e., labour, draught animals, and fertilizer).

According to a financial analysis by Kargbo (1983), costs excluded in this study (e.g., seeds, bags, depreciation) amounted to 7.5 percent of gross revenue in 1983. This figure is assumed to hold for all time periods. The production risk factor (r) is completely arbitrary. In this case, the value of r was set at 12.5 percent to yield a total adjustment of 20 percent ($\delta = 0.2$). Since δ is constant, its presence will have no effect on the parameter estimates of the econometric analysis forthcoming. The modification simply produces a monotonic transformation of the variable. It will, however, affect the nonparametric Flexible-Weight indexing estimates. In light of this fact, an analysis will be conducted to test the sensitivity of the TFP estimates to changes in δ. The proxied land prices in GAD per hectare are found in Table A.2 of Appendix A.

4.5.3 Labour Price

Labour prices are based on the minimum wage rates established by government for unskilled personnel (CSD). It is recognized that an informal labour market exists in rural areas and that the rates set by government do not always hold (Kargbo 1983; Sallah 1987). Furthermore, strange farmers'[9] play a crucial role in the production process. The value of payment-in-kind goods received by strange farmers in exchange for labour services (Sallah 1987) closely approximates the official minimum wage rate for unskilled labour. It is unknown whether or not the FAO agricultural population estimates include strange farmers. The labour series, in GAD, is presented in Table A.2 of Appendix A.

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[9]Strange farmers are migrant labourers (including those from neighbouring countries) who usually exchange their services for food, shelter, and sometimes user-rights to a small plot of land.

4.5.4. Draught Animals Price

There are no formal market prices available for draught animals in The Gambia. As in the case of land, a feasible proxy must be determined. Kargbo (1983) noted that draught animal costs averaged GAD 1.00 per hour. Assuming that animal days are the same as person days (eight hours), the cost of a draught animal for a day in 1983 was GAD 8.00. Given the 1983 unskilled labour wage of GAD 5.20 per day, a draught animal was about 1.54 times as much. This is almost identical to the 1983 skilled labour wage (GAD 8.30) in the capital city of Banjul (CSD[a]). Moreover, this observation deviates very little throughout the complete time series. Thus, the skilled labourer's daily minimum wage is used as a proxy for the price of a draught animal day (Table A.2, Appendix A).

4.5.5 Fertilizer Price

The fertilizer price series is derived from the official producer cost per metric ton of SSP (FAO 1987; AIO 1992). For the years that government offered a fertilizer subsidy, the subsidized price was recorded. All other observations relate to the retail market price. The fertilizer price series is found in Table A.2 of Appendix A.

4.6 Trend Analysis of Output and Input Price Data

Following the procedure described in Section 4.3, simple indexes and their corresponding growth trends were calculated

(Table 4.3). With the exception of fertilizer during 1974-79, all of the estimated price trends were found to be statistically significant. The price of groundnut rose sharply during the 1980s, resulting in an overall average annual increase of 12.0 percent. The price of land followed suit (15.0 percent) as groundnut production became more profitable. Labour and draught animal prices increased by a moderate 5.7 and 5.9 percent, respectively. The removal of government subsidies in 1987 led to a 23.4 percent rise in the price of fertilizer.

4.7 National Rainfall Data

Table A.3 (Appendix A) contains the average annual rainfall in millimetres for the period 1974-1991 (CSD[b]). The total is further disaggregated into the individual rainy season months (May to October). These data will be used to analyze the influence of weather on groundnut production.

4.8 Trend Analysis of National Rainfall Data

The national rainfall indexes and growth trends are shown in Table 4.4. As illustrated, national rainfall trended downward by an average of 0.7 percent per annum during the period 1974-1991.

TABLE 4.3
GROUNDNUT OUTPUT AND INPUT PRICE INDEXES, 1974-1991
(1974=100)

Year	Output Price	Land Price	Labour Price	Draught Animals Price	Fert. Price
1974	100.0	100.0	100.0	100.0	100.0
1975	119.3	147.0	100.0	100.0	100.0
1976	131.4	159.2	133.3	151.2	100.0
1977	131.4	169.2	133.3	151.2	100.0
1978	135.7	244.1	133.3	151.2	100.0
1979	135.7	171.1	166.7	174.4	98.1
1980	135.7	190.4	166.7	174.4	101.9
1981	161.1	185.9	166.7	176.7	132.1
1982	167.5	299.9	166.7	176.7	150.9
1983	145.0	434.9	173.3	193.5	254.7
1984	199.7	261.5	173.3	193.5	490.6
1985	355.3	384.0	183.7	200.2	660.4
1986	575.1	763.0	183.7	200.2	792.5
1987	483.2	1064.3	183.7	200.2	792.5
1988	354.4	1040.4	183.7	200.2	792.5
1989	531.6	624.7	300.0	326.3	1698.1
1990	628.2	1357.6	300.0	326.3	1910.4
1991	547.7	834.4	300.0	326.3	2221.7
Period	**Annual Compound Growth Rates (%)**				
1974-79	5.6*	13.0*	10.3*	12.2*	-0.3
1980-91	16.3*	18.5*	5.9*	6.1*	33.3*
1974-91	12.0*	15.0*	5.7*	[illegible].6*	23.4*

* significant at the 0.01 level

TABLE 4.4
NATIONAL RAINFALL INDEXES, 1974-1991
(1974=100)

Year	Total	May	Jun	Jul	Aug	Sep	Oct
1974	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1975	152.1	144.0	46.4	182.1	93.9	262.1	138.5
1976	107.7	3460.0	123.6	130.0	63.5	123.1	205.0
1977	92.7	0.0	79.2	133.4	36.3	161.1	87.0
1978	138.4	950.0	246.2	167.3	101.6	130.5	184.1
1979	120.8	3132.0	370.3	152.9	81.8	62.9	181.8
1980	93.1	0.0	124.0	76.0	69.1	165.1	23.8
1981	105.2	6108.0	77.4	109.3	94.0	87.3	186.5
1982	96.3	1000.0	105.1	124.5	87.2	71.3	127.2
1983	69.6	1076.0	116.3	100.2	45.4	69.2	63.5
1984	93.2	3240.0	353.8	65.5	52.9	112.5	85.4
1985	102.9	0.0	86.4	130.5	82.8	132.1	52.7
1986	119.6	340.0	111.7	93.8	103.3	165.8	154.1
1987	120.5	1576.0	273.8	121.1	82.5	143.7	110.9
1988	143.3	4328.0	128.5	147.5	159.5	114.2	98.7
1989	123.6	2224.0	298.6	130.6	88.2	108.3	181.2
1990	95.7	0.0	36.5	122.7	99.8	82.9	82.0
1991	89.0	0.0	41.3	123.1	58.2	100.8	172.4
Period	**Annual Compound Growth Rates (%)**						
74-79	1.5	77.2	37.4*	5.6	-3.7	-11.2	8.9
80-91	1.3	-6.7	-4.0	3.6**	2.3	0.17	7.6
74-91	-0.7	3.4	-0.7	-0.7	1.1	-1.6	-0.37

* significant at the 0.01 level
** significant at the 0.05 level

Categorically, May and August experienced increases in rainfall while June, July, September, and October decreased slightly. From a statistical standpoint, most of the estimated trends are not significant.

4.9 Summary

Chapter 4 provided an overview of the data to be used in this study and detailed the problems associated with data collation and aggregation. Measurements and trend analyses of groundnut output-input quantities and price data, as well as national rainfall statistics, were presented. The absence of market-based prices required for the Flexible-Weight indexing procedure led to the development of surrogate variables for land and draught animals. The assumptions underlying these instruments were discussed in detail.

CHAPTER 5

ESTIMATION OF TOTAL FACTOR PRODUCTIVITY: THE GROWTH ACCOUNTING APPROACH

5.1 Introduction

Chapter 5 features total factor productivity (TFP) estimates of the Gambian groundnut sector. The calculations are derived from the Geometric and Flexible-Weight indexing procedures (Sections 3.5.2 and 3.5.3, Chapter 3). The TFP results are compared with each other and with partial productivity (PP) estimates. Additionally, annual growth trends of groundnut output, aggregate input, TFP, terms of trade, and returns to cost are quantified. A brief analysis of the influence of weather on groundnut output is included.

5.2 Estimation of Total Factor Productivity

5.2.1 Estimation of TFP Using the Geometric Indexing Procedure

To estimate TFP using the Geometric approach, equation (3.13) in Chapter 3 is extended to four factor inputs such that

$$\left(\frac{\dot{A}}{A}\right) = \left(\frac{\dot{Q}}{Q}\right) - \left(\frac{\dot{X}}{X}\right), \quad \text{where} \quad \left(\frac{\dot{X}}{X}\right) = \sum_i s_i \left(\frac{\dot{X}_i}{X_i}\right). \qquad \textbf{(5.1)}$$

X_i represents the quantity of the i^{th} input and s_i is the share of the i^{th} input in total output. The i subscript denotes the inputs: land (R), labour (L), draught animals (K), and fertilizer (F). The input shares are obtained by estimating a Cobb-Douglas (CD) production function for groundnut. The estimation procedure, results, and statistical information are outlined in Appendix B. The shares for R, L, K, and F were calculated to be 0.304, 0.232, 0.475, and -0.011, respectively. The results indicate that draught animals and land have the greatest influence on groundnut production. Table 5.1 compares the findings above with three other studies.

TABLE 5.1
COMPARISON OF FACTOR SHARE ESTIMATES

Input	Gambia	China[1]	Nepal[2]	Cross-Country[3]
Land	0.304	0.042	0.281	0.090
Labour	0.232	0.155	0.651	0.550
Draught Animals[4]	0.475	0.564	0.042	0.160
Fertilizer	-0.011	0.239	0.014	0.140

1. Wong (1989)
2. Hamal (1991)
3. Hayami and Ruttan (1985); comprised of 21 DCs and 22 LDCs
4. Hayami and Ruttan (1985) aggregated machinery and draught power in value terms; high-yielding seeds were used as a fifth input

The factor share estimates for grain production in China disclose the importance of land-saving technologies (draught animals and fertilizer). On the other hand, land and labour represent the core inputs for Nepal's crop sector. The cross-country analysis suggests that labour is by far the most dominant factor of agricultural production[1].

Using equation (5.1) and input quantity data collected in The Gambia (Table A.1, Appendix A), an aggregate input quantity index was constructed under the Geometric approach. A TFP index was derived by dividing the groundnut output index by the aggregate input index. Table 5.2 contains the output, aggregate input, and TFP indexes. Table 5.3 tabulates their growth trends.

Over the period 1964-69, TFP decreased at an average rate of 1.1 percent per annum[2]; the decline in groundnut output (1.3 percent) outweighed the decrease in aggregate input (0.3 percent). During 1970-79, output and aggregate input fell 2.6 and 3.0 percent, respectively. This effected a 0.4 percent net gain in TFP. For the entire sampling range (1964-91), both output (0.5 percent) and aggregate input (0.9 percent) decreased. Since the loss in output was less than the decline in aggregate input, TFP increased 0.4 percent. Figure 5.1 illustrates the changes in these indexes over time.

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[1]Caution should be exercised in interpreting the Hayami and Ruttan (1985) results. The authors indicated that their estimates were hampered by collinearity problems.

[2]Unless noted otherwise, statements involving percentage values refer to annual rates.

TABLE 5.2
GROUNDNUT TOTAL FACTOR PRODUCTIVITY INDEX USING THE GEOMETRIC PROCEDURE, 1964-1991

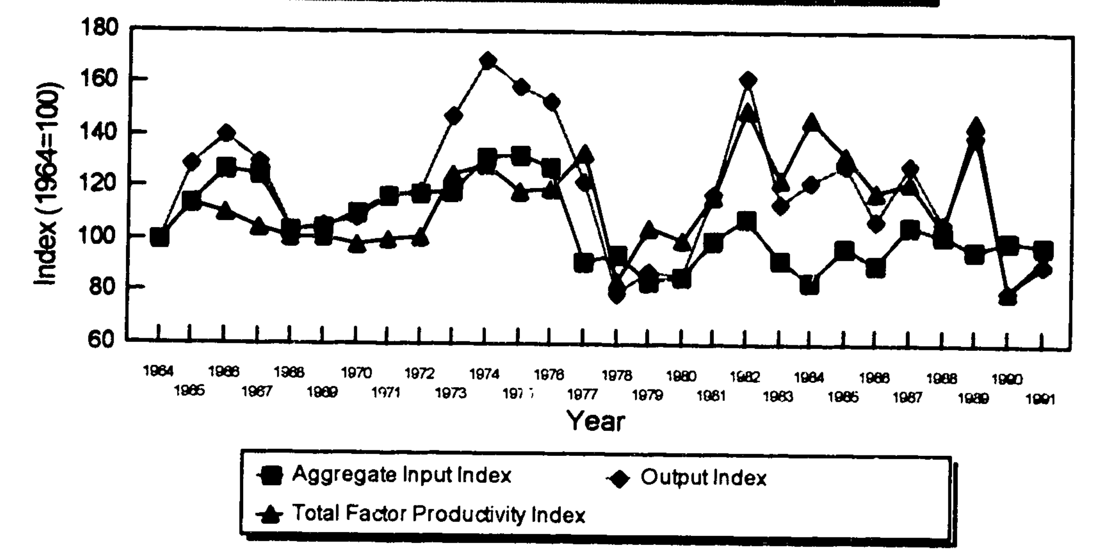
Year	Output (Y)	Input (X)	TFP (Y/X)
1964	100.0	100.0	100.0
1965	129.0	113.7	113.6
1966	140.1	127.3	110.0
1967	129.9	124.7	104.2
1968	103.9	103.2	100.7
1969	105.4	104.5	100.8
1970	108.4	110.3	98.3
1971	116.5	117.0	99.6
1972	118.3	117.8	100.4
1973	147.3	118.3	124.6
1974	168.8	131.3	128.5
1975	158.1	132.9	119.0
1976	152.6	127.8	119.4
1977	122.2	91.9	133.0
1978	78.9	94.0	84.0
1979	88.0	83.9	104.8
1980	86.0	86.3	99.7
1981	117.2	100.2	116.9
1982	162.4	108.2	150.1
1983	114.0	92.7	123.0
1984	122.6	83.7	146.5
1985	129.0	97.1	132.9
1986	107.5	90.7	118.5
1987	128.9	105.6	122.1
1988	106.0	101.6	104.3
1989	139.7	95.8	145.8
1990	80.1	99.4	80.6
1991	90.5	98.0	92.4

TABLE 5.3
ANNUAL GROWTH RATES OF GROUNDNUT OUTPUT, INPUT, AND GEOMETRIC TFP INDEXES, 1964-1991

Period	Output	Input	TFP
1964-1969	-1.32	-0.26	-1.07
1970-1979	-2.64	-2.98*	0.35
1980-1991	-1.50	0.55	-2.03
1964-1991	-0.50	-0.86*	0.36

* significant at the 0.01 level

FIGURE 5.1
GROUNDNUT GEOMETRIC INDEXES, 1964-1991



TFP in Nepal's crop sector decreased 0.5 percent during 1961-1987 (Hamal 1991). China experienced negative TFP growth in its grain sector from the 1960s up until the mid-1970s (Li 1989; Wong 1989). From the late 1970s onward, TFP increased rapidly. Si (1991) confirmed the fast growth in the late 1970s, but further concluded that TFP was positive throughout the 1960s and 1970s.

5.2.2 Estimation of TFP Using the Divisia Indexing Procedure

A Divisia aggregate input quantity index was constructed using equation (3.18) and the input quantity/price data from Appendix A (Tables A.1 and A.2)[3]. The Shazam econometric computer package (White 1993) provided the algorithm. The Flexible-Weight TFP index was calculated by dividing the simple groundnut output index by the Divisia input index. Table 5.4 summarizes the results.

As illustrated, TFP declined in all three time periods. The largest decreases in output (14.7 percent), aggregate input (10.5 percent), and TFP (4.8 percent) occurred during 1974-1979. The negative growth trends associated with longer time spans are less striking. TFP fell 2.5 percent during 1980-1991 and 0.5 percent overall (1974-1991). The recovery of TFP during the 1980s mirrors the findings of Block (1994) for Sub-Saharan Africa. Excluding the increase in aggregate input for 1980-1991, all of the trends are negative. Six of the nine

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[3]Because the time series on prices are shorter than their quantity complements, only quantities for the period 1974-1991 are used in the Divisia analysis.

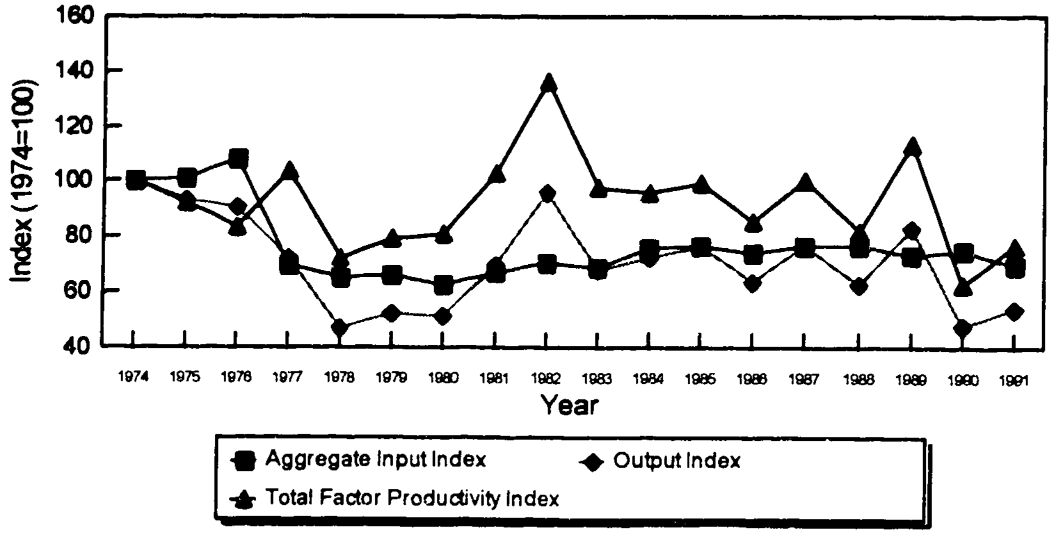
TABLE 5.4
GROUNDNUT TOTAL FACTOR PRODUCTIVITY INDEX
USING THE DIVISIA PROCEDURE, 1974-1991

Year	Output (Y)	Input (X)	TFP (Y/X)
1974	100.0	100.0	100.0
1975	93.7	101.4	92.4
1976	90.4	108.6	83.3
1977	72.4	69.6	104.1
1978	46.8	65.0	71.9
1979	52.1	65.9	79.1
1980	51.0	62.9	81.0
1981	69.4	67.3	103.2
1982	96.2	70.7	136.1
1983	67.5	69.2	97.6
1984	72.6	75.8	95.8
1985	76.4	76.6	99.8
1986	63.7	74.4	85.7
1987	76.4	76.4	100.0
1988	62.8	76.8	81.8
1989	82.8	73.1	113.3
1990	47.5	75.3	63.1
1991	53.6	69.7	77.0
Period	**Annual Compound Growth Rates (%)**		
1974-1979	- 14.7*	-10.5*	-4.8**
1980-1991	- 1.5	1.0*	-2.5**
1974-1991	-1.6	-1.1	-0.5

* significant at the 0.01 level; ** significant at the 0.10 level

estimates are statistically significant. Figure 5.2 provides a graphical picture of these indexes.

FIGURE 5.2
GROUNDNUT DIVISIA INDEXES, 1974-1991



Hamal (1991) stated that the Flexible-Weight TFP index for grain production in Nepal decreased 0.19 percent over the interval 1961-1987. A positive growth rate characterized the 1980s (1.0 percent). The validity of these results, however, is uncertain. The figures were not supplemented with statistical information.

Regarding the Flexible-Weight TFP estimates obtained in this study, the reader is reminded that the risk adjustment factor (δ) attached to the land price proxy affects the Divisia results and, in turn, influences the TFP index. To test the robustness of the TFP calculations obtained under the assumption that $\delta = 0.2$, a sensitivity analysis was performed (Table 5.5).

TABLE 5.5 DIVISIA TFP SENSITIVITY ANALYSIS			
Period	TFP (δ=0)	TFP (δ=0.2)	TFP (δ=0.4)
1974-1979	-4.2	-4.8**	-5.4*
1980-1991	-2.2	-2.5**	-2.9*
1974-1991	-0.2	-0.5	-0.9

* significant at the 0.05 level
** significant at the 0.10 level

In comparing Tables 5.4 and 5.5, it is apparent that large changes in δ induce only minor deviations in the TFP growth estimates. When $\delta = 0$, the periodic trend estimates are very close to the original model ($\delta = 0.2$), with no directional changes. The same holds true for $\delta = 0.4$, except that two of the trends (1974-1979 and 1980-1991) are now significant at the 0.05 level. This represents a modest statistical improvement over the original estimates.

Another observation is that TFP decreases faster as the value of δ gets larger. Intuitively, this makes sense. Larger values of δ result in lower land prices. Falling land prices, *ceteris paribus*, have a negative impact on TFP. Given that land quantities remain fixed at their original levels in the presence of lower prices, the groundnut sector moves farther away from its optimal combination of inputs.

5.3 Comparative Analysis of TFP Results

A direct comparison of all time intervals is not possible. The Divisia index covers a shorter time span (1974-1991) than does the Geometric index (1964-1991).

During the 1970s, the Geometric TFP index (GPI) increased 0.4 percent whereas the Divisia TFP index (DPI) decreased 4.8 percent. Note that the DPI considers only the last half of the 1970s and, unlike the GPI estimate, is statistically significant.

The two indexing procedures showed similar TFP decreases in the 1980s. The GPI and DPI fell 2.0 and 2.5 percent, respectively. For the complete samples, the GPI (1964-1991) rose 0.4 percent while the DPI (1974-1991) dropped 0.5 percent. Neither growth rate is statistically different from zero. As such, the directional discrepancy of the two estimates is irrelevant. Interestingly, the GPI decreased 0.6 percent during 1974-1991[4]. This is almost identical to the DPI figure for the same period.

In view of the GPI and DPI results, the findings of Hamal (1991) are substantiated; that is, empirical biases between

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[4]This calculation is not formally reported. It too was found to be statistically insignificant.

the two indexing procedures tend to be small when dealing with low rates of productivity growth[5]. Also, since two of the DPI trends have some statistical justification, it lends support to the similar GPI estimates.

5.4 Comparative Analysis of TFP and Partial Productivity Results

The partial productivity growth trend (PPGT) estimates for the factor inputs are presented in Table 5.6. Land displays a significant and positive PPGT for all intervals except 1964-1969 and 1980-1991, which are both zero. This result conflicts with the GPI and DPI figures which are, for the most part, negative. A time period that does stand out is 1980-1991. Only one of the PPGT estimates is negative in this time frame. In contrast, the GPI and DPI are clearly negative. It follows that partial productivity measures must be treated with caution when evaluating production performance.

5.5 Estimation of Terms of Trade and Returns to Cost

The terms of trade (TOT) and returns to cost (RTC) ratios (Islam 1982; Hamal 1991) give a crude assessment of the welfare position of Gambian groundnut farmers. The TOT is

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[5]The Hamal (1991) conclusion was not exactly authentic because he used the Divisia indexing procedure to aggregate the crop outputs (his study involved ten crops) for use in the Geometric TFP calculations. To justify his statement regarding measurement biases, he should have tested his hypothesis by employing an index that did not include prices (i.e., a theoretically inferior index).

TABLE 5.6
PARTIAL PRODUCTIVITY ANNUAL COMPOUND GROWTH RATES (%), 1964-1991

Period	Land	Labour	Draught Animals	Fertilizer
1964-1969	0.0	1.6	-4.3*	-29.2*
1970-1979	2.8**	-0.8	-4.2*	-21.6*
1980-1991	0.0	-6.0*	0.0	9.6*
1974-1991	2.2*	-4.0*	-0.3	2.7
1964-1991	2.4*	-1.1*	-0.9*	-6.5*

* significant at the 0.01 level
** significant at the 0.05 level

defined as the ratio of output prices received by farmers to input prices paid by farmers. The TOT is calculated by dividing the output price index by the aggregate input price index. The RTC is defined as the ratio of output value to factor input value. The RTC is calculated by dividing the output value (output price index times output quantity index (Table 5.3)) by the input value (aggregate input price index times aggregate input quantity index (Table 5.3)). Alternatively, the RTC can be derived simply by multiplying the TFP index by the TOT index. As with the aggregate input quantity index, the aggregate input price index is constructed using the Divisia indexing procedure. Table 5.7 summarizes the results.

The TOT and RTC growth rates are negative for the period 1974-1979 and positive thereafter. The TOT improvement in the

TABLE 5.7
DIVISIA INDEXES: OUTPUT PRICE, INPUT PRICE, TERMS OF TRADE, AND RETURNS TO COST, 1974-1991

Year	Output Price (P_Y)	Input Price (P_X)	Terms of Trade (P_Y/P_X)	Returns to Cost (P_YY/P_XX)
1974	100.0	100.0	100.0	100.0
1975	119.3	168.7	70.8	65.4
1976	131.4	193.7	67.9	60.3
1977	131.4	221.4	59.4	68.3
1978	135.7	267.3	50.8	50.4
1979	135.7	266.8	50.9	86.0
1980	135.7	297.1	45.7	71.0
1981	161.1	285.6	56.4	114.2
1982	167.5	334.2	50.1	98.2
1983	145.0	391.0	37.1	37.6
1984	199.7	341.7	58.4	82.9
1985	355.3	408.9	86.9	119.4
1986	575.1	530.6	108.4	121.4
1987	483.2	606.4	79.7	125.1
1988	354.4	599.2	59.1	63.3
1989	531.6	625.3	85.0	153.3
1990	628.2	925.8	67.9	51.7
1991	547.7	784.0	69.9	113.2
Period	**Annual Compound Growth Rates**			
1974-1979	5.6*	20.1*	-12.1*	-16.3*
1980-1991	16.3*	11.0*	4.8*	2.24
1974-1991	12.0*	11.0*	0.9	0.4

* significant at the 0.01 level

1980s enhanced the financial position of groundnut farmers, as evident by the positive RTC ratio. A substantial progression in TFP performance (Table 5.3) accompanied the betterment in the TOT and RTC. However, the positive distributional effects resulted from higher producer prices rather than output increases. This emphasizes the need to focus on productivity constraints such as stagnant technology and information asymmetries.

5.6 Interpreting the TFP Results

Given the scarceness of pertinent data, explanations of the results are limited to qualitative judgements. It is clear that the government's First Five-Year Plan (implemented in 1975-76) did little to boost productivity in groundnut production. In fact, productivity growth may have been hindered in all agricultural sectors. The small percentage of the plan's total budget allocated to agriculture (17.5 percent) doomed the drive for effective production diversification from the start. Moreover, inflation and high export taxes levied by government induced production disincentives by handicapping the growth of producers' real incomes.

The government attempted to reverse the situation by modifying its development programs for the 1980s. Agriculture received a budgetary allocation of 41.2 percent in the Second

Five-Year Plan (1981-82 to 1985-86). This investment, along with extensive technical assistance from development agencies, may have assisted in slowing down the erosion of TFP growth. Still, it remains that TFP decreased substantially throughout the 1980s.

Other culprits are at least partially responsible for the losses in TFP. Explosive population growth has escalated the demands on the country's land base. This pressure has greatly reduced the fallowing period for groundnut fields (Posner and Jallow 1987; Mills et al 1988; Posner and Gilbert 1989[a]). Continuous cropping has manifested a cumulative negative effect on the land's nutritional status (i.e., nutrients are being removed from the soil faster than they are being replenished).

This study has observed that national fertilizer use decreased 4.4 percent during the 1980s (Table 4.2, Chapter 4). Puetz and von Braun (1988) indicated that fertilizer use in the McCarthy Island Division (MID) declined more than 50 percent from 1984 to 1987. Sumberg and Gilbert (1988) concluded that fertilizer is applied to just 15 percent of the area sown to groundnut, and that the average application rate is 75 percent below recommended levels. Adoption of recommended fertilizer rates has been estimated as low as 10 percent (Sonko and Jabang 1992). Mills et al (1988) noted that many farmers do not perceive chemical fertilizer applications to be an effective strategy for declining soil fertility. This is somewhat surprising[6].

Soil analyses have confirmed the loss in soil fertility. The median value of phosphorus, an important macronutrient for groundnut, is below the acceptable level for all Divisions of the country (Peters and Schulte 1987). It was further determined that soil organic matter is low in groundnut fields country-wide. Organic matter aids in retaining moisture and reducing soil erosion. Traditional cultural practices, such as "slash and burn", have exacerbated the problem.

There is evidence that farmers have a low awareness on a variety of recommended practices (Sonko and Jabang 1992). For example, most farmers do not know the correct seeding and spacing rates (73-88 percent). Together with poor seed vitality (Cockfield et al 1990), this has serious consequences for production performance. Both the aid agencies and the farmers themselves share responsibility for the low awareness of approved practices. On average, only 13 percent of Gambian farmers have attended agricultural demonstrations (Sonko and Jabang 1992). Of the farmers sampled, 59 percent stated that they had insufficient knowledge of demonstration sites. Attendance records for extension training were moderately

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[6]Since 1981, the FAO Fertilizer Project conducted hundreds of fertilizer trials and demonstrations on farmers' fields throughout the country. In addition, the project established a private dealers network and trained numerous village extension workers to assist farmers.

better, ranging from 20 to 38 percent. Part of the problem may be related to the skewed distribution of farm assets toward richer farmers (Haydu et al 1986).

Finally, it appears that adjustments to the agricultural research agenda are warranted. Millions of dollars have been poured into production-based research with very little to show in terms of productivity growth. Fertilizer use is desperately low, and the situation will not improve until farmers are convinced of its merits and a properly functioning trade market is established. Farmers are keenly aware that availability and timeliness of delivery are highly irregular. At times, the fertilizer has arrived too late or not at all. Higher prices (up 23.4 percent since 1974), coupled with supply shortages, worsen distributional imbalances as the upperclass minority outbids poorer households.

One aspect that has been neglected thus far is the influence of weather on production. Farmers the world over face climatic conditions that affect their production. The next section explores this area, albeit in a rather unsophisticated manner.

5.7 Analyzing the Influence of Weather on Output

Meterological variables, especially in rain-fed agricultural systems, can determine whether or not farmers experience a bumper-crop season or total failure. Poor groundnut harvests in The Gambia are usually attributed to drought (Jabara 1990).

The relationship between weather variables and crop production has been studied in detail (Fisher 1924; Stallings 1960; Shaw 1964; Ezekiel and Fox 1965; Doll 1967; Thompson 1969 and 1970; Kellogg and Severin 1990). The methods used by researchers range from simple correlation analyses (Ezekiel and Fox 1965) to sophisticated econometric models of high-ordered functional forms (Ezekiel and Fox 1965; Thompson 1969). Weather indexing techniques are also common in the literature (Stallings 1960; Shaw 1964; Doll 1967; Kellogg and Severin 1990).

The weather data available for analysis in this study are limited to national rainfall figures for the period 1974-1991 (Table A.3, Appendix A). Advanced analytic techniques require additional variables (e.g., temperature) and a longer series of observations. The hypothesis to be tested is that decreasing rainfall has had a detrimental effect on groundnut production.

Although theoretically limited, a simple correlation analysis provides a preliminary assessment of the hypothesis. Correlation estimates for annual rainfall and three production measures (output, Geometric TFP, and Divisia TFP) are presented in Table 5.8. There is no indication of strong positive correlations between annual rainfall and the selected production indicators. To the contrary, the correlation is negative in many instances. Further analyses must be conducted.

TABLE 5.8
RAINFALL CORRELATION ANALYSIS, 1974-1991

Month	Output (000'MT)	Geometric TFP Index	Divisia TFP Index
May	-0.01	-0.26	0.08
June	0.01	-0.02	0.04
July	-0.36	-0.29	-0.13
August	-0.06	-0.36	-0.17
September	0.23	-0.14	-0.09
October	-0.16	-0.19	-0.05
Annual Total	-0.34	-0.26	-0.17

Four regression models are estimated to test for the influence of rainfall on groundnut output. With the exception of Model II, all models are run seven times; once with annual rainfall as an explanatory variable, and once for each month of the rainy season (May through October). Model I considers a linear specification of the form

$$Q = \beta_o + \beta_1 W + \beta_2 T + \epsilon, \qquad \textbf{(5.2)}$$

where Q is output, W is rainfall, T is time, and ϵ is an error term. The time trend allows for technological progress[7].

Model II is an expanded form of Model I. A dummy variable is added to assess the impact of rainfall >= 5 mm (millimetres) during the month of May. Having the rains begin in May[8] is regarded by Gambian farmers as being important because it allows for timely planting. Boote et al (1982) contended that water deficit in the early stage of the groundnut's life cycle reduces only vegetative growth. The effect on final yield is minimal. Groundnut plants are most sensitive to water deficit during the pod formation stage. Perhaps the dependence on an early rain is related to the fact that farmers seed mainly by hand (Posner and Gilbert 1989[a]). If rainfall is >= 5 mm, the dummy variable takes on a value of one; it is zero otherwise. The 5 mm value is selected to ensure sufficient variation in the dummy variable. Model II is specified as

$$Q = \beta_o + \beta_1 W + \beta_2 T + \beta_3 D + \epsilon, \qquad \textbf{(5.3)}$$

where D denotes the dummy variable.

Model III adds rainfall to the CD production function described earlier. Fertilizer is discarded because of its

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[7]The time trend considers only a constant rate of change. Therefore, nonlinear movements in technology are not captured.

[8]The first rains usually come in late May or early June.

insignificance. Model III is formulated as

$$\ln Q = \ln A + bT + \alpha \ln R + \beta \ln L + \gamma \ln K + \delta \ln W + e. \qquad (5.4)$$

Model IV tests the CD functional form with only rainfall and a time trend. Given the small sample size, a larger number of degrees-of-freedom may be helpful. Model IV takes the form

$$\ln Q = \ln A + bT + \delta W + e. \qquad (5.5)$$

The regression results indicated that rainfall had no effect whatsoever on the variation in output[9]. The R^2-adjusted statistic was actually negative on numerous occasions. There are two possible explanations. Either the findings are justifiable, or the data are corrupt.

Data mismeasurement is inevitable to a certain degree. Although the output data have been used in former analyses with some success, the rainfall estimates have not been adequately scrutinized. More evidence must be compiled before a rational judgement can be made as to their validity.

A general observation is that rainfall in The Gambia has diminished over the years. The data support this conviction. The quantity of total annual rainfall decreased, on average,

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[9]Due to the highly insignificant results, the regression estimates are not reported.

0.7 percent per year during 1974-1991 (Table 4.4, Chapter 4). Has this decrease actually harmed groundnut production? To answer this question, it is necessary to examine the rainfall data in more detail. Table 5.9 presents some descriptive statistics of the data.

TABLE 5.9
DESCRIPTIVE STATISTICS OF RAINFALL DATA*, 1974-1991

Variable	N	Mean	Std Dev	Var	Min	Max
May	18	7.7	9.1	82.9	0.0	30.5
June	18	69.9	49.6	2459.3	16.9	171.3
July	18	196.5	47.3	2232.9	104.9	291.4
August	18	247.7	82.7	6835.6	107.8	474.0
September	18	199.8	78.0	6082.7	103.1	429.9
October	18	59.5	25.7	660.6	11.4	98.2
Total	18	799.0	157.5	24802.0	538.2	1111.5

* rainfall is measured in millimetres

With respect to volume, there is no evidence to support the assertion that water is in short supply. Groundnut plants (120-day variety) require approximately 440 mm of water in a growing season (Kassam and Harkness 1973). The mean rainfall for The Gambia during 1974-1991 was almost 800 mm. Furthermore, the minimum (538.2 mm) was well above the critical level. In the context of random variables and dispersion, Chebyshev's theorem says that 80.8 percent of the rainfall observations fall between 440.0 and 1158.0 mm. This implies that rainfall variability is not a major constraint to groundnut production for this sample. In reference to the mean and standard deviation for May and June, rainfall variability appears as a potential threat from a qualitative position. Empirically, this hazard has not been vindicated.

Other studies have examined the rainfall question. Research conducted in the North Bank and Western Divisions established that the downward trend in rainfall has not placed a serious limitation on groundnut harvests (Posner and Gilbert 1989[a] and 1989[b]). Block (1994) reached a similar conclusion for Sub-Saharan Africa as a whole. It must be reemphasized that only the volume of water is at issue here. Other prominent factors, such as the distribution of rainfall **within** each month, are neglected due to data constraints. Rainfall variability has been increasing over time (Posner and Gilbert 1989[a] and 1989[b]).

The evidence leans heavily toward rejecting the notion of insufficient rainfall. Indeed, the facts validate the concerns raised by other studies. The complete picture indicates that the poor agronomic structure of soils in The Gambia gives the illusion of rainfall deficit. Rather than insufficient water, it is the soil's inability to absorb and retain moisture in the root zone that is the malefactor. Excessive runoff and evaporation make crops susceptible to water deficiencies by lessening their ability to withstand periods of drought. The low level of organic matter advances the evaporation process and encourages erosion.

It seems clear that farmers must begin to adopt cultural practices that aid in reversing the structural maladies of their soils. This is especially critical given that annual rainfall is decreasing while its variability is increasing.

5.8 Summary

In this chapter, the total factor productivity (TFP) of the Gambian groundnut sector was estimated using the Geometric and Flexible-Weight indexing procedures. The analysis indicated that the Geometric TFP index (GPI) increased 0.4 percent annually (1964-1991), whereas the Divisia TFP index (DPI) decreased 0.5 percent (1974-1991). The directional discrepancy is irrelevant because the trend estimates are not statistically different from zero. However, the DPI is negative and significant for the intervals 1974-1979 (4.8 percent) and 1980-1991 (2.5 percent). As a direct comparison, the GPI decreased 0.6 percent during 1974-1991. Since the GPI and DPI are virtually identical for this time period, it implies that the GPI biases are small when productivity growth is low. This finding also lends support to the assumptions that were used to construct proxies for land and draught animal prices.

Partial productivity (PP) evaluations are prone to misinterpretations. Land returned a positive PP in situations where TFP was negative. Furthermore, during 1980-1991, only one PP estimate was negative. This conflicts with both the GPI and DPI estimates.

Changes in TFP are positively correlated with changes in the terms of trade (TOT) ratio. The favourable TOT during 1980-1991 was influential in improving the farmers' returns to cost (RTC) and may have aided in minimizing TFP losses. However, the positive distributional effects resulted from increases in producer prices rather than output increases. This reflects the importance of non-price productivity constraints.

The two methodologies concede that TFP decreased during the 1980s. In attempting to explain these results, qualitative evidence suggests that declining soil fertility and imprudent cultural practices are major reasons for the erosion in TFP. It is unclear whether the benefits of production-based research outweigh the costs at the present time. Therefore, a restructuring of the research agenda may be in order.

Finally, there is no proof to substantiate the hypothesis that declining rainfall has seriously affected groundnut yields. The collective evidence points a stern finger at the government and the farmers themselves. It is imperative that government policies and programs persuade and **permit**[10] farmers to adopt cultural practices that limit soil destruction and enhance water conservation.

[10]Even though a farmer may clearly understand the importance of certain cultural practices (e.g., adequate fallowing), adoption of such practices may not always be possible due to survival constraints; land is extremely scarce and there are many mouths to feed.

CHAPTER 6

ESTIMATION OF PRODUCTION STRUCTURE: THE ECONOMETRIC APPROACH

6.1 Introduction

Chapter 6 involves estimating the production structure for groundnut via the share equations obtained from a transcendental logarithmic (translog) cost function. Pertinent statistical tests and estimates of Allen partial elasticities of substitution, own and cross-price elasticities, scale effects, and technical change biases are reported. Additionally, an alternative econometric model is tested. The results of the two models are compared.

6.2 Estimation of Production Structure

Due to insufficient degrees-of-freedom, the production structure of the Gambian groundnut sector cannot be assessed using the translog cost function (equation (3.21), Chapter 3). However, some specific properties of the cost function can be obtained from the set of share equations given in equation (3.22). The expanded form of (3.22) is expressed as

$$S_i = \beta_1 + \gamma_{11}\ln P_1 + \gamma_{12}\ln P_2 + \gamma_{13}\ln P_3 + \gamma_{14}\ln P_4 + \alpha_1 Y + \theta_1 T + e_1 \qquad \textbf{(6.1)}$$

$$S_2 = \beta_2 + \gamma_{21}\ln P_1 + \gamma_{22}\ln P_2 + \gamma_{23}\ln P_3 + \gamma_{24}\ln P_4 + \alpha_2 Y + \theta_2 T + e_2 \qquad (6.2)$$

$$S_3 = \beta_3 + \gamma_{31}\ln P_1 + \gamma_{32}\ln P_2 + \gamma_{33}\ln P_3 + \gamma_{34}\ln P_4 + \alpha_3 Y + \theta_3 T + e_3 \qquad (6.3)$$

$$S_4 = \beta_4 + \gamma_{41}\ln P_1 + \gamma_{42}\ln P_2 + \gamma_{43}\ln P_3 + \gamma_{44}\ln P_4 + \alpha_4 Y + \theta_4 T + e_4, \qquad (6.4)$$

where 1, 2, 3, and 4 represent the factor demands for land, draught animals, fertilizer, and labour, respectively.

By imposing the adding-up condition (equation (3.23), Chapter 3), the cost shares must sum to one. Consequently, one of the equations must be dropped from the estimation process to avoid over-identification. It makes no difference which equation is deleted. The system is then estimated with the GAUSS econometric computer package (Aptech Systems 1991) using the Seemingly Unrelated Regression (SUR) methodology (Zellner 1962)[1]. The parameters of the discarded equation are recovered through the equalities defined by equation (3.21). The standard errors for these coefficients are derived from the variance-covariance matrix, or by injecting the discarded equation into the system (i.e., drop one of the other equations).

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[1]All programs written for use in GAUSS are presented in Appendix D. Many thanks are extended to Dr. J. Stephen Clark (Associate Professor, Nova Scotia Agricultural College) for converting the author's linear SUR programs to nonlinear specifications using the Gauss-Newton algorithm reported in Gallant (1987).

6.2.1 Statistical Tests

As with the Cobb-Douglas model (Appendix B), statistical tests related to theoretical restrictions, autocorrelation, heteroskedasticity, and collinearity are applied[2].

6.2.1.1 Test of Theoretical Restrictions

Recall that the share equation estimates are meaningful only if certain theoretical restrictions hold (Section 3.8, Chapter 3). The adding-up condition is imposed on the system. The homogeneity and symmetry restrictions are tested during the estimation process.

The homogeneity and symmetry conditions are tested using the likelihood ratio statistic (LRS)[3]. The LRS, which is distributed chi-square with p degrees-of-freedom, is calculated as

$$LRS = 2\left[\ln L\left(\hat{\theta}_1\right) - \ln L\left(\hat{\theta}_o\right)\right] \sim \chi^2_p, \qquad \textbf{(6.5)}$$

where p is the number of restrictions imposed in the model. The log likelihood values for the unrestricted and restricted models are denoted by $\ln L(\hat{\theta}_1)$ and $\ln L(\hat{\theta}_o)$, respectively.

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[2]Descriptions of the autocorrelation, heteroskedasticity, and collinearity tests are found in Appendix B.

[3]Since one of the equations must be dropped in order to estimate the system, it is impossible to test the symmetry restriction across all equations.

The LRS is also suitable for testing the conditions of homotheticity and Hicks-neutrality. Homotheticity implies that a change in output does not affect the derived demand for factor inputs. Hicks-neutrality suggests that the ratios of marginal products of the factor inputs remain constant given changes in technology. The concavity and monotonicity restrictions are tested after the model has been estimated. Concavity is checked by examining the Hessian matrix of second partials of the cost function with respect to input prices (Antle and Capalbo 1988). If the matrix is negative semidefinite, the cost function is concave in input prices. This requirement is often verified by examining the signs of the estimated own-Allen partial elasticities of substitution for all inputs (Rahuma 1989); these elasticities must be negative. A necessary and sufficient condition for monotonicity in prices is the existence of positive cost shares (Antle and Capalbo 1988)[4].

To test the restrictions, equation (6.4) (fertilizer) is dropped during the estimation process[5]. The results are summarized in Table 6.1. Homogeneity and homotheticity are accepted, whereas symmetry, symmetry and homogeneity jointly,

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[4]Hamal (1991) used the shares obtained from the price and quantity data to check for monotonicity. This is tautological because the data necessarily yield positive cost shares. A proper test must involve the cost shares predicted by the model.

[5]The SHAZAM econometric program (White 1993) is used to test the restrictions.

and Hicks-neutrality are rejected at the 0.01 level. As a result, the symmetry and homogeneity restrictions must be imposed on the system to satisfy the theoretical properties of the neoclassical cost function.

TABLE 6.1
LIKELIHOOD RATIO TESTS OF RESTRICTIONS

Restriction	Calculated LR Value	Degrees of Freedom	Critical Chi-square*	H_o:
Homogeneity (H)	2.538	3	11.345	Accept
Symmetry (S)	22.876	3	11.345	Reject
H and S	20.398	6	16.812	Reject
Homotheticity	7.606	3	11.345	Accept
Hicks-neutrality	14.052	3	11.345	Reject

* 0.01 level of significance

The failure of theoretical curvature conditions implied by economic theory when estimating flexible functional forms is a common problem. Even after the necessary restrictions are imposed on the system, global satisfaction is rare[6]. Needless to say, a heated debate has developed with respect to the practicality of neoclassical production theory. It is not intended to explore this issue in great detail here, but it is sufficiently important to at least cover the basics.

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[6]Diewert and Wales (1987) developed two methods for imposing the appropriate conditions globally.

Fox and Kivanda (1994) argued that agricultural and natural resource economists do not take the falsificationist methodology seriously, and that the track record is poor when the falsifiable hypotheses of cost minimization and profit maximization are tested; therefore, neoclassical-based production analyses should be viewed with scepticism. The reader is referred to Clark and Coyle (1994) and Paris (1994) for strong discussions which refute many of the claims made by Fox and Kivanda (1994) and lend support to the neoclassical theory of production, despite the general failure of theoretical curvature conditions.

Although it is possible to test many of the assumptions underlying the neoclassical model, it is not possible to conclude that a failure of restrictions is a failure of the theory. Dynamics precludes any hope of collecting perfect data; all data sets are inflicted with theoretical, measurement, and randomized errors.

There is no argument that restriction testing should be conducted. However, in the final analysis, imposing restrictions even when they have been rejected may produce additional insights into the problem at hand and yield estimates that are closer to reality (Clark and Coyle 1994).

6.2.1.2 Autocorrelation Test

Tables 6.2 and 6.3 present the findings of the Durbin-Watson (DW) and Breusch-Godfrey (BG) tests. The DW results are inconclusive while the BG analysis indicates no autocorrelation. Because the BG procedure is based on asymptotic theory, it may not be an accurate guide in finite samples; the sample size (18 observations) in this study is very small. Conversely, the DW is a finite sample test and is generally more powerful than its asymptotic alternative (Judge et al 1988). The fact that the DW test does not yield a statistical conclusion leaves room for suspicion regarding the BG test results.

Another method to check for autocorrelation involves estimating the system of share equations to obtain the regression residuals. Lagged forms of the original errors are then treated as explanatory variables in a subsequent regression which takes the form

$$e_t = \rho_1 e_{t-1} + \rho_2 e_{t-2} + \ldots + \rho_n e_{t-n} + v_t, \qquad (6.6)$$

where e_t denotes the original errors in time t, $e_{t-1}, \ldots, e_{t-n}$ are lagged versions of e_t, and ρ is the coefficient of autocovariance, and v_t is the regression error. In this case, equation (6.6) was estimated with two lags (i.e., with e_{t-}

TABLE 6.2
DURBIN-WATSON AUTOCORRELATION TEST

Dependent Variable	Estimated d	d_L*	d_U*	$4-d_L$	$4-d_U$	Auto[1]
Land	1.989	0.435	2.015	3.565	1.985	?
Labour	1.988	0.435	2.015	3.565	1.985	?
Draught	2.511	0.435	2.015	3.565	1.985	?
Fertilizer	2.402	0.435	2.015	3.565	1.985	?

* 0.01 level of significance
1. reject the null hypothesis of no autocorrelation if $0<d<d_L$ or $(4-d_L)<d<4$; do not reject if $d_U<d<(4-d_U)$; inconclusive (?) if $d_L<=d<=d_U$ or $(4-d_U)<=d<=(4-d_L)$

TABLE 6.3
BREUSCH-GODFREY AUTOCORRELATION TEST (FIRST-ORDER)

Share Equation	Test Statistic	Degrees of Freedom	Critical Chi-square*	Presence of Auto.
Land	0.010	1	6.635	No
Labour	0.002	1	6.635	No
Draught	2.029	1	6.635	No
Fertilizer	2.886	1	6.635	No

* 0.01 level of significance

and e_{t-2} on the right-hand side) using ordinary least squares. The findings revealed the presence of first-order autocorrelation[7]. As such, the data will have to be transformed to correct for serial correlation[8].

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[7]The ρ values and their corresponding t-ratios were found to be $\rho_1 = 0.837$ (10.502) and $\rho_2 = 0.020$ (0.256).

[8]Judge et al (1988) provides an indepth review of the Cochrane-Orcutt correction procedure.

6.2.1.3 Heteroskedasticity Test

The results of the Breusch-Pagan test (Table 6.4) indicate that the null hypothesis of no heteroskedasticity cannot be rejected at the 0.01 level of significance.

TABLE 6.4
BREUSCH-PAGAN HETEROSKEDASTICITY TEST

Share Equation	BP1 Statistic	Degrees of Freedom	Critical Chi-square*	Presence of Hetero.
Land	5.897	6	16.812	No
Labour	3.612	6	16.812	No
Draught	10.270	6	16.812	No
Fertilizer	10.518	6	16.812	No

* significant at the 0.01 level

6.2.1.4 Collinearity Tests

The simple correlation, auxiliary regression, and principal components analyses (Tables 6.5 to 6.7) reveal that collinearity between the prices of labour and draught animals may be a problem. Given that the wage for skilled labour is used as a proxy for the price of draught animals, the presence of collinearity is not surprising. Without additional information, the only recourse is to impose a further restriction on the data, if indeed it turns out that the estimates are severely hindered by collinearity (i.e., make draught animal prices a constant multiple of labour prices).

TABLE 6.5
CORRELATION COEFFICIENT ESTIMATES

Variables	Correlation	Collinearity
Land-Labour	0.791	No
Land-Draught	0.797	No
Land-Fertilizer	-0.898	No
Draught-Labour	0.994	Yes
Fertilizer-Labour	0.858	No
Fertilizer-Draught	0.851	No

TABLE 6.6
AUXILIARY REGRESSION EQUATION RESULTS

Dependent	R^2-Adjusted	F-Statistic	Collinearity
Land	0.792	17.223*	No
Labour	0.986	306.972*	Yes
Draught	0.986	303.174*	Yes
Fertilizer	0.865	28.195*	No

* significant at the 0.01 level

TABLE 6.7
PRINCIPAL COMPONENTS RESULTS*

Condition Number	Land	Labour	Draught Animals	Fert.	Output
1.0	0.000	0.000	0.000	0.000	0.591
19.4	0.014	0.000	0.000	0.152	0.068
90.8	0.843	0.001	0.001	0.278	0.025
141.0	0.103	0.011	0.014	0.632	0.309
1119.7	0.040	0.985	0.985	0.039	0.007

* columns show the proportion of total variation of the variable coefficients associated with each condition number

6.2.2 Estimation Results of Translog Model

The model can be estimated using either the unrestricted or the theoretically restricted variance-covariance matrix (VCM). Asymptotically the two methods are equivalent, therefore there is no theoretical justification for preferring one over the other. Judge et al (1988) suggested that estimating with the unrestricted VCM is more logical since it is based on the assumption that the null hypothesis (i.e., the restrictions hold) is true. Furthermore, in making use of the fact that OLS and SUR return the same parameter estimates when the explanatory variables are identical across all equations, a step is saved in the estimation process by initially calculating the unrestricted VCM.

The parameter estimates of the translog model, corrected for serial correlation, are presented in Table 6.8. The R^2-statistics for the land, draught animals, fertilizer, and labour equations were calculated to be 0.57, 0.53, 0.85, and 0.87, respectively. Based on the estimation statistics, it does not appear that collinearity is a major problem.

One issue that should be addressed is the exogeneity of output in a system of share equations. LaFrance (1991) concluded that output is more likely to be endogenous when estimating such a system. As a test, output was first estimated as a function of input prices and then the predicted

TABLE 6.8
PARAMETER ESTIMATES OF THE TRANSLOG MODEL, 1974-1991

Parameter[1]	Estimate[2]	T-Ratio[3]
β_1	0.7464*	5.706
γ_{11}	0.0453*	4.252
$\gamma_{12} = \gamma_{21}$	-0.0181**	-2.005
$\gamma_{13} = \gamma_{31}$	-0.0706*	-5.310
$\gamma_{14} = \gamma_{41}$	0.0434*	3.317
α_1	-0.0793*	-4.037
θ_1	-0.0130*	-3.722
β_2	-0.1473	-0.811
γ_{22}	0.0847*	4.478
$\gamma_{23} = \gamma_{32}$	-0.0119	-0.871
$\gamma_{24} = \gamma_{42}$	-0.0547*	-3.515
α_2	0.0448***	1.679
θ_2	0.0095	1.155
β_3	0.2140	0.892
γ_{33}	0.1083*	4.155
$\gamma_{34} = \gamma_{43}$	-0.0259	-1.003
α_3	-0.0074	-0.203
θ_3	0.0090***	1.677
$\beta_4 = (1-\beta_1-\beta_2-\beta_3)$	0.1869	0.740
$\gamma_{44} = (-\gamma_{41}-\gamma_{42}-\gamma_{43})$	0.0371	1.213
$\alpha_4 = (-\alpha_1-\alpha_2-\alpha_3)$	0.0419	1.105
$\theta_4 = (-\theta_1-\theta_2-\theta_3)$	-0.0054	-0.954

1. The numbers 1, 2, 3, and 4 denote land, draught animals, fertilizer, and labour, respectively.
2. * significant at the 0.01 level; ** significant at the 0.05 level; *** significant at the 0.10 level
3. The degrees-of-freedom for this model are calculated as df=(m*n)-K, where m is the number of share equations, n is the number of observations, and K is the total number of variables in the system (Johnston 1984). As such, df=(3*18)-18 = 36.

values were used in a second stage estimation. This procedure mitigates the endogeneity problem asymptotically (Gallant 1987). The parameters differed very little from the original estimates found in Table 6.8, therefore the results are not reported.

6.3 Estimates of Elasticities

6.3.1 Allen Partial Elasticities of Substitution

The Allen partial elasticities of substitution (σ_{ij}) are calculated by inserting the mean value of the predicted cost shares (Table A.5, Appendix A) and the γ_{ij} coefficients (Table 6.8) into equations (3.26) and (3.27) of Chapter 3. The negative own-Allen partial elasticities of substitution (Table 6.9) verify that the concavity restriction holds at the mean for the time periods considered[9].

TABLE 6.9
OWN-ALLEN PARTIAL ELASTICITIES OF SUBSTITUTION

Input	1974-1979	1980-1991	1974-1991
Land (σ_{11})	-2.86*	-4.07*	-4.29*
Draught (σ_{22})	-1.94*	-1.24*	-1.52*
Fertilizer (σ_{33})	-1.25*	-1.11*	-1.16*
Labour (σ_{44})	-1.36	-2.01	-1.76

* significant at the 0.01 level

[9]On an annual basis, however, the Allen-own partial elasticities of substitution and the predicted shares show that concavity and monotonicity hold for only one and five years, respectively.

To examine the ease with which one element of an input pair can be substituted for the other in the production process, Allen partial elasticities of substitution (EOS) are estimated (Table 6.10). All but one of the estimates are statistically significant.

TABLE 6.10
ALLEN PARTIAL ELASTICITIES OF SUBSTITUTION

Input	1974-1979	1980-1991	1974-1991
Land-Draught (σ_{12})	0.43**	0.23**	0.42**
Land-Fertilizer (σ_{13})	-0.37*	-2.26*	-1.13*
Land-Labour (σ_{14})	1.56*	3.13*	2.19*
Draught-Fertilizer (σ_{23})	0.71*	0.88*	0.85*
Draught-Labour (σ_{24})	0.10*	0.43*	0.38*
Fertilizer-Labour (σ_{34})	0.74	0.71	0.72

1. $\sigma_{ij} > 0$ ($\sigma_{ij} < 0$) implies that the i^{th} and j^{th} inputs are substitutes (complements)
* significant at the 0.01 level
** significant at the 0.05 level

With the exception of land and fertilizer, all input pairs are substitutes. The complementarity of land and fertilizer increased during the 1980s. Rising fertilizer prices and supply uncertainties may have caused advocates to reduce the amount of land devoted to groundnut production; soil fertility tends to be higher for millet than groundnut (Peters and Schulte 1987).

The substitutability of the land-labour, draught animal-fertilizer, and draught animal-labour input pairs have increased over time. This is in line with *a priori* expectations. Conversely, the land-draught animal and fertilizer-labour input pairs have decreased in substitutability, albeit only marginally. This may be due to the fact that fertilizer availability is sporadic and the distribution of farm assets such as draught animals is skewed toward higher-income households. This was found to be the case in Burkina Faso (Savadogo 1994). Land and labour display the highest substitutability while draught animals and labour have the lowest. The scarcity of land in relation to labour leads to higher inputs of labour to intensify the use of cropped land, and low incomes limit the substitution of draught animals for labour.

Overall, the EOS estimates are low. This means that farmers do not enjoy a high degree of substitutability between factor inputs. This has important ramifications for total factor productivity (TFP). TFP growth may be improved when farmers have a greater flexibility in choosing their input combinations.

6.3.2 Elasticities of Factor Demand

Elasticities of factor demand (η_{ij}) are estimated by inserting the mean value of the predicted cost shares (Table A.5, Appendix A) and the γ_{ij} coefficients into equations (3.28) and (3.29). Periodic estimates of own and cross-price elasticities are presented in Table 6.11.

TABLE 6.11
OWN AND CROSS-PRICE ELASTICITIES OF INPUT DEMAND

Period	Input	Land	Draught	Fert.	Labour
1974-79	Land	-0.57*	0.07**	-0.09*	0.60*
	Draught	0.09**	-0.31*	0.18*	0.04*
	Fert.	-0.07*	0.11*	-0.31*	0.28
	Labour	0.31*	0.02*	0.19	-0.52
1980-91	Land	-0.29*	0.08**	-0.69*	0.91*
	Draught	0.02**	-0.41*	0.27*	0.13*
	Fert.	-0.16*	0.29*	-0.24*	0.21
	Labour	0.22*	0.14*	0.22	-0.58
1974-91	Land	-0.49*	0.12**	-0.33*	0.70*
	Draught	0.05**	-0.42*	0.25*	0.12*
	Fert.	-0.13*	0.23*	-0.26*	0.23
	Labour	0.25*	0.10*	0.21	-0.56

1. A cross-price elasticity (η_{ij}) > 0 implies that the i^{th} and j^{th} inputs are substitutes.
* significant at the 0.01 level
** significant at the 0.05 level

As predicted by economic theory, the own-price elasticities are negative for all time periods evaluated. Since the demand for these inputs is relatively unresponsive to price changes (inelastic), it implies that input accessability, rather than input prices, is most important to farmers. Land and fertilizer have become more inelastic over time. This is a direct consequence of the increasing scarcity of land and fertilizer. Labour, while generally overabundant, can actually be in short supply during the peak period of a harvesting season (Sallah 1987). This may partially explain why it is not more responsive to price changes.

The cross-price elasticities (CPE) also reveal that all input pairs except for land and fertilizer exhibit substitutability relationships. Moreover, as with the Allen EOS, the CPE are relatively inelastic.

6.4 Scale Effects and Technical Change Biases

Scale effects measure the influences of changes in output on the demand for factor inputs. Technical change biases relate changes in input use to changes in technology[10]. The estimated parameters pertaining to scale effects and technical change biases are found in Table 6.12. The scale effect estimates suggest that increases in groundnut output lower the demand for land and increase the demand for draught animals. The scarcity of land has led to more intensive cropping through draught animal power. The labour and fertilizer scale estimates are not statistically different from zero, which imply neutral scale effects. Technical change biases are found to be embodied and non-neutral regarding land (saving) and

[10]Technical change in the Geometric TFP analysis was assumed to be disembodied and Hicks-neutral. In reality, technical change is more likely to be embodied and factor-biased.

fertilizer (using), and Hicks-neutral for draught animals and labour[11].

TABLE 6.12
TECHNICAL CHANGE AND SCALE EFFECTS, 1974-1991

Input	Technical Effect (θ_i)	Scale Effect (α_i)
Land	-0.013*	-0.079*
Draught Animals	0.009	0.045**
Fertilizer	0.009**	-0.007
Labour	-0.005	0.042

1. $\theta_i > 0$, $\theta_i < 0$, and $\theta_i = 0$, imply that technical change is i^{th} input-using, i^{th} input-saving, and Hicks-neutral; $\alpha_i > 0$, $\alpha_i < 0$, and $\alpha_i = 0$, imply that the scale effect is i^{th} input-using, i^{th} input-saving, and neutral, respectively
* significant at the 0.01 level
** significant at the 0.10 level

6.5 An Alternative Econometric Model

6.5.1 A Log-Normal Transformation

Share equation estimation, as presented in Section 3.8 (Chapter 3), is common in the economic literature. Its popularity stems from the fact that, through some appropriate theoretical model, several functional forms give rise to linear share equations. The estimating procedure, however, violates one of the assumptions of traditional regression techniques.

Consider again the system of share equations obtained from a translog cost function. By design, the factor input

[11]Although the technical change effects for labour and draught animals are not recorded as zero in Table 6.12, from a statistical position they are not significantly different from zero; hence, these effects are Hicks-neutral.

cost shares and the regression error terms must lie within the interval [0,1]. This is in conflict with the standard econometric assumption that the dependent variable and error term can assume any real value.

There are two methods that could be used to estimate the system of share equations under more realistic assumptions (Dehann and Clark 1993). The first alternative is to formulate the log likelihood function under the restriction that the error term must lie within the interval [0,1], and then maximize the likelihood function with respect to the parameters of the distribution. A second approach is to transform the model so that the dependent variable is consistent with the assumptions concerning the error term. The second method is considered here.

Using a transformation model proposed by Rossi (1983), the system of share equations above (equations (6.1) to (6.4)) is assumed to follow a log-normal distribution. An arbitrary share is selected as the base-share and the system is estimated as

$$\ln\left(\frac{S_{it}}{S_{nt}}\right) = \ln\left(\frac{\beta_i + \sum_j \gamma_{ij}\ln P_{jt} + \alpha_i \ln Y_t + \theta_i T_t}{\beta_n + \sum_j \gamma_{nj}\ln P_{jt} + \alpha_n \ln Y_t + \theta_n T_t}\right) + u_{it}, \tag{6.5}$$

where S_{nt} is the base-share and u_{it} is the error of the regression. The log ratio of the shares transformation allows the independent variable to take on any value. This is consistent with traditional regression assumptions.

The biggest disadvantage in estimating the transformed model is that each equation is nonlinear in parameters. As such, nonlinear regression techniques must be used and there is no guarantee that the system will converge. The trade-off then is how good is the linear approximation versus how easy is it to estimate the nonlinear model. This is an empirical matter.

6.5.2 Estimation Results of Nonlinear Model

The parameter, elasticity, technical change and scale effect estimates are presented in Appendix C[12]. As with the linear model, the nonlinear system was corrected for serial correlation using the Cochrane-Orcutt procedure (Judge et al 1988). It was necessary to program GAUSS in such a way that the Gauss-Newton iterative step became progressively smaller, until the system settled on a positive portion of the function. The system could not be solved with a full Gauss-Newton step because negative shares were encountered and the log of a negative number is undefined. Unfortunately, since

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[12]The predicted cost shares used to estimate the elasticities are found in Table A.6, Appendix A.

the unrestricted model did not converge, it was not possible to test the theoretical restrictions. The homogeneity and symmetry restrictions were imposed on the system.

6.6 Comparative Analysis of Linear and Nonlinear Results

The nonlinear model (NLM) clearly outperforms its linear (LM) counterpart in terms of significant parameter estimates. Twenty of 22 coefficients are statistically significant with the NLM, most at the 0.01 level. In contrast, only 12 parameters are significant in the LM. Regarding concavity and monotonicity, both models satisfied these conditions for the time intervals considered. However, with respect to individual years of the sample, the NLM is again superior; the monotonicity and concavity restrictions hold in the NLM (LM) in 18 (5) and 8 (1) years, respectively. The R^2-statistics (not reported) are difficult to interpret with the NLM and are not comparable to those estimated from the LM.

The elasticity estimates are remarkably similar, both in direction and magnitude. With the LM, all inputs except for land and fertilizer are substitutes; the NLM treats all inputs as substitutes. The major difference between the two models lies with the scale and technical change parameter estimates. The NLM shows that scale effects are land-saving, fertilizer-saving, draught animal-using, and labour-using, while technical change is land-using, draught animal-using, fertilizer-using, and Hicks-neutral for labour. In considering the overall performance of the two models, it is justifiable to place more confidence on the NLM results where differences occur. Indeed, from a national perspective, a land-using technical change effect conforms more with reality because technology in The Gambia is primitive and population growth is high.

In conclusion, while the statistical performance of the NLM is superior in this case, the LM does a good job in approximating the NLM results. It follows that the LM may be a reasonable alternative in situations where the NLM is difficult or impossible to estimate.

6.7 Summary

In Chapter 6, an empirical analysis of the production structure of the Gambian groundnut sector was presented. The estimation process was based on a system of share equations derived from a transcendental logarithmic (translog) cost function.

Although the groundnut production inputs (land, labour, draught animals, and fertilizer) display substitutability relationships, the results further indicate that farmers in The Gambia have little flexibility in choosing their input combinations. This may have a negative impact on the growth of total factor productivity (TFP). Furthermore, the inelastic own-price elasticity estimates suggest that the availability of inputs may be more important to farmers than their prices. These observations have important ramifications for agricultural policy.

Finally, a log-normal transformation of the linear translog model (LM) produced statistically superior results. However, for this sample, the LM performed admirably in approximating the estimates of its nonlinear counterpart. Therefore, the linear specification may prove useful in situations where the nonlinear transformation model is difficult or impossible to estimate.

CHAPTER 7

SUMMARY AND CONCLUSIONS

7.1 Introduction

Despite enormous investment in rurally-based projects throughout the world, agricultural development in less-developed-countries (LDCs) has been disappointing. Over a billion people still face a life of absolute poverty.

Most people in LDCs depend directly on the fruits of the land to survive. Yet, many experts dismiss the notion that the revitalization of agriculture epitomizes the driving force behind economic and social progression. Many projects still focus on industrially-led development, treating agriculture as nothing more than a reservoir from which to extract production surpluses for investment in nonagricultural pursuits. It seems as though the painful lessons drawn from past failures have gone unheeded.

A healthy agricultural sector is vitally important. It provides food and fibre for domestic consumption, enlarges the market for industrial output, earns or saves precious foreign currency, releases labour for industry, and enhances domestic savings. Moreover, agricultural productivity is recognized as a critical determinant of both rural and economic welfare in Africa.

The objective of the present study is to conduct a productivity analysis of the groundnut sector in The Gambia, a small country on Africa's West coast. Groundnut not only represents a key source of protein for local consumers, it is also the principal source of income for farmers and for generating foreign exchange. Surprisingly, research in The Gambia has been limited to a few rudimentary analyses of groundnut productivity.

Nonparametric indexing procedures are used to assess the total factor productivity (TFP) of groundnut production. Econometric analyses serve in estimating the specific production structure. Information obtained from this enquiry will assist planners and policy-makers in making more informed decisions regarding development.

7.2 Agricultural Institutions and Policies in The Gambia

Agricultural institutions and government policies have a direct influence on the performance of Gambian agriculture. The Ministry of Agriculture (MOA), whose main responsibility is agricultural development, was reorganized and streamlined in 1987. The restructuring resulted in the privatization of some services and the creation of others. The overall objective was to increase the operational efficiency of the MOA and to enhance its effectiveness through extension services, research, and policy analysis. Although the restructuring program has yielded a solid foundation from which to work, inefficiencies and corruptive practices, as found in the Gambia Cooperative Union (GCU), have greatly diminished its potential for assisting farmers.

The land tenure system is traditional. Land is owned by the government and is vested in and administered by the district authority. Individuals or groups gain usufructory rights by registering with the district authority, usually an *alkalo*. A rapidly expanding population and the increase in the number and frequency of land disputes have caused a shift from communal to quasi-private ownership. Proponents of the traditional system argue that land users are fully aware of the nature and scope of their usufructory rights. While this may be true, it remains that private systems generally operate more efficiently through entrepreneurial activities.

In-country research focuses on crop production and, to a lessor extent, livestock production. A distinguishing feature is that most of the studies are conducted through on-farm testing. On the down side, the research system is almost totally dependent on technologies developed elsewhere. Extension services for crop and livestock production fall under the Departments of Agricultural Services and Livestock Services, respectively. However, unless a part of a donor-financed project, no extension advice on animal husbandry practices is provided.

Historically, the GCU has been the primary source of agricultural credit. Corruption and credit recovery problems have reduced the GCU's prominence in this regard. One promising initiative is the Village Savings and Loans Association (VISACAS) program. Since its establishment in 1988, the VISACAS has been successful in improving the capacity of rural people to operate their own village mini-banks, thereby mobilizing savings and increasing loan recoveries.

Regarding agricultural inputs, the traditional supplier has been the Gambia Produce Marketing Board (GPMB). Heavy financial losses brought about by inappropriate subsidization policies eventually led to the privatization of this parastatal organization. However, lingering market distortions have discouraged the participation of private dealers. At present, the government-controlled Agricultural Input Office (AIO) is a major supplier.

After the introduction of the Economic Recovery Program (ERP) in 1985, agricultural policies have been oriented toward self-sufficiency in food production and achieving market-based economic solutions. For example, interest rates in the economy are now determined largely by market forces, including the agricultural sector. The exchange rate was liberalized in 1986 in an effort to raise the relative price of tradables to nontradables and to improve the efficiency of resource allocation in the economy. Furthermore, output (groundnut), and input (fertilizer) subsidies have been dismantled, as well as the price stabilization program for imported rice, a staple food in the Gambian diet. The government continues to invest in rice production projects to reduce the country's dependence on foreign rice.

7.3 Total Factor Productivity and Production Structure: Theoretical Considerations

The terms "productivity" and "technical change" are often used synonymously in the economics literature. This notion of equivalence overlooks the fact that productivity is composed of elements other than pure technical advancement. For example, scale or institutional change effects may be embedded in productivity estimates.

Total factor productivity (TFP) analysis has become the standard indicator for gauging the efficiency in which production systems transform factor inputs into outputs. TFP measurement is based upon a weighted sum of all inputs given their relative importance in the production process. In contrast, partial productivity (PP) analyses relate one or more outputs to a single input. PP measures have limited value because they reflect only the joint effect of a number of interrelated influences. As such, PP measures can be very misleading.

Approaches to quantifying productivity may be grouped into two categories. The growth accounting (indexing) procedure interprets TFP changes as the ratio of the rate of change of an index of aggregate output to an index of aggregate input. The econometric approach describes technological change as shifts in a production or cost function.

A close conceptual relationship exists between the growth accounting and econometric procedures. Research has shown that many index number formulas exactly represent a specific production function. However, a primary distinction separates the two. Index number measurement is deterministic whereas econometric estimation is statistical. Furthermore, the econometric approach allows a detailed parametric assessment of the production structure.

Each technique is a progeny of the neoclassical theory of economic optimization and implementation of either requires a well defined set of theoretical assumptions. A fundamental assumption of this theory is that producers minimize costs of production by using all inputs in proportions such that their marginal productivities are equal to their purchase prices.

As with any applied research project, there are many theoretical and execution-based issues that must be addressed. Having carefully weighed the advantages and disadvantages associated with each method, an analytical strategy that would best meet the objectives of this research was designed. Specifically, this study proposes to estimate the TFP of the Gambian groundnut sector through the Geometric indexing procedure. In addition, using proxied variables for land and draught animal prices, the results obtained are compared to those generated from the theoretically superior Flexible-Weight (Divisia) indexing procedure. A system of share equations derived from a transcendental logarithmic cost function provides the framework for econometrically evaluating the production structure.

7.4 Groundnut Production and Rainfall Data: Their Measurement and Analysis

In order to implement the growth accounting and econometric procedures, groundnut output/input data (quantities and prices) are required. The variables included in this study are groundnut output (metric tons), land (hectares), labour (person days), draught animals (animal days), and fertilizer (metric tons of nutrient phosphorous). National rainfall figures (millimetres) are used to evaluate the influence of weather on groundnut production.

The Geometric indexing approach, which needs only quantity data, measures the productivity status of the Gambian groundnut sector for the period 1964-1991. The Divisia indexing procedure and the econometric analysis consider a shorter time span (1974-1991) due to insufficient price data.

A major difficulty in implementing the methodologies that require price data is that land and draught animal prices do not exist. As a result, it is necessary to identify realistic proxies for the missing variables. Based on economic rationale and information from other studies, a risk-adjusted net profit formula derives the land price proxy while the official minimum daily wage rate for skilled labour serves as the price for a draught animal day.

Trend analyses of the data show that the quantities of labour, draught animals, and fertilizer increased at an average annual rate of 0.6, 0.4, and 7.6 percent, respectively (1964-1991). The large growth in fertilizer is somewhat misleading because the trend estimate uses 1964 as the base year, and fertilizer consumption in that year was basically nil. Conversely, output and land decreased 0.5 and 2.9 percent, respectively. Regarding the price data (1974-1991), the prices for groundnut, land, labour, draught animals, and fertilizer rose 12.0, 15.0, 5.7, 0.6, and 23.4 percent, respectively. Finally, although rainfall increased in May (3.4 percent) and August (1.1 percent) during 1974-1991, the national volume fell 0.7 percent annually.

7.5 Estimation of Total Factor Productivity: The Growth Accounting Approach

The growth accounting analysis indicates that the Geometric TFP index (GPI) increased 0.4 percent per year during the 1970s, whereas the Divisia TFP index (DPI) decreased 4.8 percent. The DPI considers only the last half of the 1970s and, unlike the GPI estimate, is statistically significant.

Both methods generated similar TFP decreases in the 1980s; the GPI and DPI fell 2.0 and 2.5 percent, respectively. Again, only the DPI estimate is significantly different from zero. For the complete samples, the GPI (1964-1991) rose 0.4 percent while the DPI (1974-1991) dropped 0.5 percent. Since neither growth rate is significant, the directional discrepancy is irrelevant. Interestingly, the GPI declined 0.6 percent during 1974-1991. This is almost identical to the DPI figure for the same period. Therefore, the findings coincide with other studies that have found only minor discrepancies between the two methods in cases where productivity growth is low. Also, the results lend some support to the assumptions that were used to proxy the prices for land and draught animals.

The terms of trade (TOT) and returns to cost (RTC) ratios are calculated to assess the welfare position of groundnut farmers. The TOT and RTC growth rates are negative for the period 1974-1979, but positive for 1980-1991. The improvement in the TOT that occurred in the 1980s enhanced the financial position of farmers and may have aided in slowing down the erosion of TFP. However, the positive distributional effects of improved farm incomes resulted from higher producer prices rather than output increases. This emphasizes the need to focus on productivity constraints such as stagnant technology.

From a qualitative position, there are several factors that have influenced the overall decline in TFP. Studies have shown that fallowing periods for groundnut fields have decreased substantially, induced partially by population pressure. Continuous cropping and falling fertilizer use have manifested a cumulative negative effect on the land's nutritional status. Fertilizer is applied to only a small percentage of the area sown to groundnut and most applications are well below recommended levels. Even more disturbing is the realization that many farmers do not perceive chemical fertilizer as being an effective strategy for declining soil fertility, nor do they possess a high awareness of recommended cultural practices. Thus, the current proliferation of production-based research in the country is called into question.

With respect to the hypothesis that declining rainfall has negatively affected groundnut production, there is no empirical evidence to support such a statement. The fact that rainfall is clearly insignificant in the statistical analyses, and that the volume of water is well above the critical level for groundnut, suggests that structural maladies prevent the soil from absorbing and retaining moisture in the root zone.

Obviously, this diminishes the crop's ability to withstand periods of drought. Farmers must begin to adopt cultural practices that promote soil conservation.

7.6 Estimation of Production Structure: The Econometric Approach

The production structure of the Gambian groundnut sector is evaluated by econometrically estimating a system of share equations derived from a transcendental logarithmic (translog) cost function. The parameter estimates reveal information about input price and substitution elasticities, as well as scale and technical change biases.

The results indicate that, except for land and fertilizer, all input pairs are substitutes in the production process. The complementarity of land and fertilizer increased throughout the 1980s. Rising fertilizer prices and supply uncertainties may have encouraged advocates to reduce the amount of land devoted to groundnut. While the substitutability of the land-labour, draught animal-fertilizer, and draught animal-labour input pairs increased over time, the land-draught animal and fertilizer-labour combinations decreased in substitutability, although only marginally. This may be due to the fact that fertilizer availability is sporadic and the distribution of farm assets such as draught animals is skewed toward higher-income families.

Over the entire sample, land and labour display the highest substitutability while draught animals and labour have the lowest. The scarcity of land in relation to labour leads to higher inputs of labour to intensify the use of cropped land, and low incomes limit the substitution of draught animals for labour. Overall, the elasticity of substitution estimates are inelastic. This means that farmers do not enjoy a high degree of substitutability between factor inputs. This has important ramifications for TFP. It is highly probable that TFP performance would improve if farmers enjoyed a greater flexibility in choosing input combinations.

As predicted by economic theory, the own-price elasticities are negative for all time periods considered. Moreover, the estimates show that the demand for inputs is relatively unresponsive to price changes (inelastic). This implies that input availability is more important to farmers than price. Land and fertilizer have become more inelastic through time. This is a direct consequence of the increasing scarcity of land and fertilizer. Labour, while generally overabundant, can be in short supply during the peak period of a harvesting season. This may partially explain why it is not more sensitive to price changes. The cross-price elasticities confirm the input substitution relationships described above.

The scale coefficient estimates demonstrate that increases in groundnut output lower the demand for land and increase the demand for draught animals. The labour and fertilizer scale estimates are not statistically different from zero, which imply neutral scale effects. Technical change biases are embodied and non-neutral regarding land (saving) and fertilizer (using), and Hicks-neutral for draught animals and labour.

A log-normal transformation of the translog model is tested. Although more difficult to estimate, this nonlinear specification conforms better with traditional regression techniques. The transformed system clearly outperforms its linear counterpart in terms of statistical performance. Nevertheless, the elasticity estimates of the models are remarkably similar. The major difference lies with the scale and technical change estimates. Most notably, the nonlinear model describes technical change as land-using rather than land-saving. Such a finding is justified because technology in The Gambia is primitive and population growth is high. Notwithstanding, the original specification performed admirably in approximating the estimates of the transformed share system. Therefore, the linear model may prove to be useful in situations where its nonlinear derivative is difficult or impossible to estimate.

7.7 Conclusions and Policy Implications

Judging by the structural adjustments and development initiatives that are ongoing in The Gambia, economic modernization surfaces as the principal goal. This paper has argued that sustained productivity growth in agriculture is absolutely critical for The Gambia to have any hope of realizing its economic potential. To this regard, the groundnut sector inevitably plays a crucial, multi-faceted role. Thus, the main objective of this research was to assess the productivity status of the Gambian groundnut sector.

The results of the analyses conducted in this study indicate that total factor productivity (TFP) in groundnut production has been declining. The erosion of TFP slowed somewhat during the 1980s, due possibly to the favourable terms of trade (TOT) evident in that period. Unfortunately, the improvement in farmers' incomes evolved from higher groundnut prices instead of output increases. The task then is to identify the constraints to TFP growth.

In the absence of quantifiable data, it is impossible to identify which factors have the greatest impact on TFP growth. However, a subjective assessment can be made using qualitative information. Other studies have shown that soil productivity in The Gambia is depleting rapidly. Significant decreases in fallowing periods and fertilizer use have greatly reduced the soil's fertility. Furthermore, a disturbing percentage of farmers do not view chemical fertilizer as being an effective remedy for declining soil fertility, nor do they possess a high awareness of recommended cultural practices. For those farmers who do apply fertilizer, the own-price elasticity reveals that availability is more important than price.

The hypothesis that drought has been the most limiting factor of productivity growth is not supported by the findings of this study. Rather than insufficient rainfall, it is more likely to be the soil's inability to absorb and retain moisture that defines the problem. Inappropriate production methods have hastened the destruction of the soil's structure and composition, both of which are crucial for water conservation and erosion reduction.

The policy implications are clear. The government must design policies that ensure stable and timely fertilizer deliveries, and that effectively promote its usage. This would involve removing market distortions (e.g., government and aid agency externalities) that inhibit the participation of private dealers. The Agricultural Input Office (AIO) should concentrate solely on input testing, promotional activities, and disseminating information to farmers. It is imperative that the linkage between extension services and farmers be strengthened.

An adjustment to the country's research mandate is also warranted. While production-based research is influential in spurring agricultural advancement, it has little value when the knowledge obtained does not filter down to the field level. The research agenda should incorporate studies that are designed specifically for isolating the causes of non-adoption of new technologies. This information must be acted on by the appropriate agricultural institution(s).

Another productivity constraint is that farmers have very little flexibility in choosing their input combinations. The low substitutability between inputs is due to supply bottlenecks, cultural constraints (e.g., land tenure), and insufficient income/credit. As such, distributional imbalances occur as the upperclass minority outbids poorer households for scarce supplies. Policies must provide support for community-based credit schemes. If credit is accessible only to higher-income groups, technological change is more likely to succeed in areas where yields are already good, thereby widening the social gap. Subsidized credit should be avoided because it distorts the money market and typically flows to those who need it the least. Instead, the focus should be on programs such as the Village Savings and Loans Association (VISACAS). These operations tend to be more viable and efficient because they are scrutinized by the farmers themselves; the integrity of village-based organizations is guarded by peer pressure and community values.

The most controversial aspect of the drive toward modernization pertains to The Gambia's traditional land tenure system. Although land struggles have persisted, the traditional system remains firmly entrenched. A critical component of a modern economy is its dependence on entrepreneurial activities. This attribute is severely restricted in traditional societies, especially with respect to agriculture. Thus, there is little opportunity available for natural correction of production inefficiencies, or for releasing the power of entrepreneurial spirit. This is one reason why technical change was found to be land-using. Obviously, this is not a viable long-term solution for increasing output.

The removal of agricultural production inefficiencies is a prerequisite for expanding the economy. Most industrialized nations were once dominated by agriculture. Through a more efficient allocation of scarce resources, agricultural productivity increased dramatically and paved the way for industrial expansion and increased employment. Today, developed countries in general have only a very small percentage of their populations involved in primary agriculture. In contrast, the Gambian economy is locked in economic stagnancy, with 75 percent of its people tied to low-productivity, subsistence agriculture. With an exploding population, the situation can only deteriorate over time if the system remains static. Serious consideration must be given to land reform if The Gambia is to modernize its economy.

Finally, there is a concern regarding the monopsony position of the Gambia Cooperative Union (GCU) and the Alimanta Group. Unfortunately, the particulars of the agreement involving the privatization of the Gambia Produce Marketing Board (GPMB) were not available at the time of writing. The government must assume some regulatory control to ensure that farmers receive fair prices and timely payments for their groundnut harvests. This would aid significantly in reducing productivity disincentives and cross-border smuggling.

7.8 Limitations and Suggestions for Future Research

There are two major limitations affecting the results of this research. As with most studies involving developing countries, the data assembled for analysis are unrefined. Furthermore, the nonexistence of land and draught animal prices necessitated the formulation of proxy variables that were based on relatively heroic assumptions. Although collection methods in The Gambia have improved tremendously in recent times, stronger time-series data will not be available for years to come. Until then, the results of quantitative analyses that rely solely on secondary data must be treated with caution. In this case, the findings conform with those from other studies and subjective observations.

Another concern pertains to the assumptions underlying optimization theory. Due to the dynamics of risk minimization, survival strategies, and religious overtones, farmers' decisions in traditional societies do not always follow the strict axioms that define production optimality. Consequently, the results of this study are distorted in unknown ways.

Regarding future research, a productivity analysis at the primary level would aid in identifying regions of the country that are most susceptible to TFP declines. Moreover, it would permit the collection of data necessary for quantifying sources of TFP growth and for establishing linkages between crop productivity and resource degradation (e.g., soil erosion). Finally, to assess the magnitude of biases that inflict optimality-based analyses, it would be useful to employ a procedure that relaxes some of the neoclassical assumptions. For example, Fare et al (1991) developed a Malmquist output productivity index that does not assume firms are cost minimizers.

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APPENDIX A

GROUNDNUT PRODUCTION DATA

TABLE A.1
GROUNDNUT OUTPUT AND INPUT QUANTITY DATA, 1964-1991

Year	Output (000'MT)	Land (000'ha)	Labour (000'person days)	Draught Animals (000'animal days)	Fert. (000'MT P_2O_5)
1964	93.0	150.0	14042.0	378.0	0.082
1965	120.1	152.0	15962.7	462.0	0.115
1966	130.3	167.0	17892.8	548.8	0.379
1967	120.8	183.0	19159.0	504.0	0.552
1968	96.6	140.0	12796.1	476.0	0.457
1969	98.0	141.0	12855.6	467.6	0.304
1970	100.8	143.0	13090.0	498.4	0.220
1971	108.4	167.0	14394.2	504.0	0.293
1972	110.0	173.0	14170.5	515.2	0.400
1973	137.0	175.0	14415.7	560.0	0.850
1974	157.0	184.0	14099.1	638.4	0.708
1975	147.1	190.0	14028.9	644.0	0.722
1976	141.9	190.0	16723.1	621.6	1.226
1977	113.6	105.0	12411.7	562.8	1.540
1978	73.4	100.0	11259.8	557.2	1.110
1979	81.8	100.0	11609.6	568.4	2.008
1980	80.0	100.0	10412.5	562.8	1.632
1981	109.0	100.0	12172.5	607.6	1.230
1982	151.0	100.0	13685.0	616.0	0.904
1983	106.As	100.0	12988.9	554.4	1.395
1984	114.0	100.0	16259.0	560.0	2.520
1985	120.0	95.0	17850.0	523.6	1.302
1986	100.0	92.0	17321.6	520.8	1.638

... TABLE A.1 CONTINUED					
1987	119.9	95.1	17707.2	529.2	0.704
1988	98.6	95.1	18099.9	492.8	0.704
1989	129.9	86.4	18290.3	532.1	1.4
1990	74.5	92.1	17992.8	523.6	1.1
1991	84.2	81.9	17838.1	498.4	0.8

Adapted from AIO (1992), DOP, FAO, and Kargbo (1983)

TABLE A.2
GROUNDNUT OUTPUT AND INPUT PRICE DATA, 1974-1991

Year	Fert. GAD*/MT	Labour GAD/day	Draught Animals GAD/day	Land GAD/ha	Output GAD/MT
1974	106.0	3.00	4.30	143.7	310.4
1975	106.0	3.00	4.30	211.2	370.4
1976	106.0	4.00	6.50	228.7	408.0
1977	106.0	4.00	6.50	243.2	408.0
1978	106.0	4.00	6.50	350.7	421.2
1979	104.0	5.00	7.50	245.9	421.3
1980	108.0	5.00	7.50	273.6	421.2
1981	140.0	5.00	7.60	267.1	500.0
1982	160.0	5.00	7.60	431.0	520.0
1983	270.0	5.20	8.32	624.9	450.0
1984	520.0	5.20	8.32	375.8	620.0
1985	700.0	5.51	8.61	551.8	1103.0
1986	840.0	5.51	8.61	1096.5	1785.0
1987	840.0	5.51	8.61	1529.4	1500.0
1988	840.0	5.51	8.61	1495.1	1100.0
1989	1800.0	9.00	14.03	897.7	1650.0
1990	2025.0	9.00	14.03	1950.8	1950.0
1991	2355.0	9.00	14.03	1199.1	1700.0

Adapted from AIO (1992), CSD[a], FAO (1987), Kargbo (1987), Sallah (1987), and Swindell (1978)
* Gambian Dalasis (CAD 1.00 = GAD 6.85)

TABLE A.3
NATIONAL RAINFALL IN MILLIMETRES, 1974-1991

Year	Annual Total (mm)	May (mm)	Jun (mm)	Jul (mm)	Aug (mm)	Sep (mm)	Oct (mm)
1974	715.9	0.5	46.3	160.0	297.3	164.0	47.9
1975	1088.8	0.7	21.4	291.4	279.1	429.9	66.3
1976	771.1	17.3	57.2	207.9	188.6	201.9	98.2
1977	663.8	0.0	36.6	213.5	107.8	264.3	41.7
1978	990.7	4.8	113.9	267.6	302.1	214.1	88.2
1979	864.8	15.7	171.3	244.7	243.0	103.1	87.1
1980	666.6	0.0	57.3	121.6	205.5	270.8	11.4
1981	753.2	30.5	35.8	174.9	279.3	143.3	89.3
1982	689.6	5.0	48.6	199.1	259.1	116.9	60.9
1983	498.5	5.4	53.8	160.3	135.0	113.6	30.4
1984	667.5	16.2	163.6	104.9	157.3	184.6	40.9
1985	736.7	0.0	40.0	208.8	246.0	216.7	25.2
1986	856.2	1.7	51.7	150.0	307.2	271.9	73.8
1987	862.4	7.9	126.6	193.8	245.3	235.7	53.1
1988	1025.6	21.6	59.4	236.0	474.0	187.4	47.3
1989	884.7	11.1	138.1	208.9	262.2	177.6	86.8
1990	685.1	0.0	16.9	196.4	296.7	135.9	39.3
1991	636.9	0.0	19.1	197.0	173.0	165.3	82.6

Source: CSD[b]

TABLE A.4
COST SHARES OF INPUTS*, 1974-1991

Land	Labour	Draught Animals	Fertilizer
0.369	0.591	0.038	0.001
0.472	0.495	0.033	0.001
0.379	0.584	0.035	0.001
0.323	0.628	0.046	0.002
0.418	0.537	0.043	0.001
0.282	0.666	0.049	0.002
0.326	0.621	0.050	0.002
0.289	0.659	0.050	0.002
0.370	0.588	0.040	0.001
0.463	0.500	0.034	0.003
0.293	0.660	0.036	0.010
0.336	0.630	0.029	0.006
0.499	0.472	0.022	0.007
0.586	0.393	0.018	0.002
0.576	0.404	0.017	0.002
0.307	0.653	0.030	0.010
0.512	0.461	0.021	0.006
0.367	0.600	0.026	0.007

* figures are rounded; calculated from Tables A.1 and A.2

TABLE A.5
PREDICTED COST SHARES FROM LINEAR TRANSLOG MODEL*, 1974-1991

Land	Labour	Draught Animals	Fertilizer
0.261	0.453	0.009	0.277
0.174	0.616	0.317	-0.106
0.007	0.307	0.734	-0.047
0.255	0.052	-0.426	1.120
0.323	0.382	0.022	0.272
0.186	0.490	0.296	0.028
0.106	0.056	0.762	0.076
0.143	0.042	-0.323	1.137
0.150	0.355	0.110	0.384
0.096	0.717	0.389	-0.203
0.028	-0.129	0.973	0.128
-0.132	-0.056	-0.016	1.204
-0.024	0.242	0.287	0.495
0.062	0.892	0.338	-0.292
0.217	0.056	0.862	-0.134
0.317	-0.105	0.403	0.385
-0.201	0.257	0.958	-0.013
0.082	1.147	-0.752	0.523

* figures are rounded

TABLE A.6
PREDICTED COST SHARES FROM NONLINEAR TRANSLOG MODEL*, 1974-1991

Land	Labour	Draught Animals	Fertilizer
0.318	0.367	0.024	0.292
0.330	0.503	0.161	0.006
0.235	0.124	0.112	0.530
0.000	0.000	0.064	0.936
0.394	0.307	0.000	0.299
0.318	0.473	0.165	0.044
0.271	0.167	0.122	0.440
0.023	0.010	0.080	0.888
0.372	0.356	0.027	0.245
0.315	0.490	0.195	0.000
0.196	0.299	0.209	0.296
0.000	0.000	0.119	0.880
0.376	0.383	0.041	0.200
0.346	0.465	0.189	0.000
0.511	0.379	0.110	0.000
0.415	0.000	0.010	0.575
0.265	0.236	0.245	0.254
0.478	0.514	0.007	0.002

* figures are rounded

APPENDIX B

ESTIMATION OF A PRODUCTION FUNCTION FOR GROUNDNUT IN THE GAMBIA

B1.1 Estimation of Groundnut Production Function

Construction of an aggregate input index under the Geometric approach requires estimating the Cobb-Douglas (CD) production function from equation (3.20) of Chapter 3. Production data for the period 1964-1991 (Table A.1, Appendix A) are used. Equation (3.20) is converted into an equivalent linear function by taking logs on both sides such that

$$\ln Q = \ln A + bt + \alpha \ln R + \beta \ln L + \gamma \ln K + \delta \ln F + \epsilon_i, \qquad \textbf{(B.1)}$$

where Q, R, L, K, and F represent output, land, labour, draught animals (a proxy for capital), and fertilizer, respectively. The regression error is ϵ_i. Equation (B.1) is estimated by ordinary least squares using the Shazam econometric computer program (White 1993).

The Geometric theoretical foundation is based on constant returns-to-scale (CRS) technology, therefore the null hypothesis of CRS (H_o: $\alpha+\beta+\gamma+\delta=1$) must be tested. The F-statistic on the restriction was calculated to be 9.04. Given an F-critical value of 7.95 with 1 and 22 degrees-of-freedom at the 0.01 level of significance, H_0 was rejected. The CRS restriction was subsequently imposed on (B.1). The estimation results are presented in Table B.1.

TABLE B.1
OLS REGRESSION RESULTS FOR GROUNDNUT PRODUCTION FUNCTION

Variable N=28	Estimated Coefficient	Standard Error	T-Ratio (22 df)
Land	0.304	0.260	1.168
Labour	0.232	0.186	1.246
Draught Animals	0.475**	0.286	1.660
Fertilizer	-0.011	0.07[illegible]	-0.155
Time	0.004	0.010	0.116
Constant	-2.005*	0.802	-2.499
R^2=0.4896 R^2-Adj.=0.4009 F-Stat=5.516	* = significant at the .01 level ** = significant at the .10 level		

B2.1 Statistical Tests

Econometric analyses may be hampered by autocorrelation, heteroskedasticity, and collinearity. To check the validity of the empirical results in Table B.1, it is necessary to test for the presence of these processes[1]. The following sub-sections deal with these issues.

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[1]It is not the intention here to provide complete theoretical descriptions for the statistical tests considered. If more rigorous explanations are required, the reader is referred to Judge et al (1988) and Maddala (1992).

B2.1.1 Autocorrelation Test

Autocorrelation can occur because of inertia, specification bias, or improper functional form (Judge et al 1988). The repercussions are inefficient parameter estimates and misleading test statistics that are critical for inference. A popular test is the Durbin-Watson statistic (DWS). Because the DWS depends on the explanatory variables present in a particular sample[2], there is no unique critical value that will lead to the rejection or acceptance of the null hypothesis (no first-order serial correlation). However, lower and upper bound values have been established that permit a statistical decision regarding the existence of positive or negative serial correlation, if the DWS falls outside these critical points. The DWS for the CD model was found to be 1.75. This figure does not lie outside the critical values established at the 0.05 level of significance, hence one cannot conclude whether autocorrelation does or does not exist.

The Breusch-Godfrey (BG) asymptotic test is a more general approach that allows testing of any order of autocorrelation. The least squares residuals (ϵ_{it}) from the original CD model are regressed on $\epsilon_{i,t-1}$, $\epsilon_{i,t-2}, \ldots,$ $\epsilon_{i,t-p}$, and

---

[2]The DWS is computed from the errors of the regression, which are dependent on the given explanatory variables.

all of the explanatory variables. The BG statistic is determined by the formula

$$BG = nR^2 \sim \chi^2_p, \quad \textbf{(B.2)}$$

where p indicates the autocorrelation order to be examined, n is the number of observations, and R^2 is the coefficient of multiple determination. An evaluation was conducted for first, second, and third-order autocorrelation. The BG statistics and chi-square critical values are found in Table B.2. The results show that autocorrelation is rejected for all three orders at the 0.01 level.

TABLE B.2
BREUSCH-GODFREY AUTOCORRELATION TEST

Test	Computed BG Value	Degrees of Freedom	Critical Chi-Square*	Auto-correlation
Order 1	0.224	1	6.635	No
Order 2	0.286	2	9.210	No
Order 3	1.428	3	11.355	No

* 0.01 level of significance

B2.1.2 Heteroskedasticity Test

Heteroskedasticity is usually observed with cross-sectional data. For example, the amount of randomness may differ between small and large farms. The variance of the error term (ϵ_i) is usually greater with smaller independent X_i's, where X_i is the i^{th} explanatory variable (Pindyck and Rubinfeld 1981). When heteroskedasticity is present, least squares places more weight on observations with larger variances. As a result, the estimates are inefficient because they do not have the lowest variance possible.

Several strategies have been developed to test for heteroskedasticity (e.g., Glejser, Goldfeld-Quandt). Many of the tests are restrictive in terms of versatility. In the absence of *a priori* information about the variance properties, case-specific tests may be of questionable power. The Breusch-Pagan (BP) test is a general procedure that covers a wide range of situations (Maddala 1992). Furthermore, the test does not depend on the functional form, nor does it require identification of the variable(s) causing the difficulty. The null hypothesis is based on the absence of heteroskedasticity (i.e., homoskedasticity). To implement the test, the explanatory variables are regressed on the error variance of the unrestricted CD model. The test statistic is calculated as

$$BP = \frac{RSS}{\sigma^4} \sim \chi^2_{(p-1)}, \qquad \textbf{(B.3)}$$

where RSS is the regression sum of squares, σ is the standard deviation, and p is the number of parameters in the model. The test statistic was computed to be 5.04. Given a chi-square critical value of 15.09 at the 0.01 level, the null hypothesis of homoskedasticity cannot be rejected.

B2.1.3 Collinearity Test

Having considered autocorrelation and heteroskedasticity, collinearity will now be assessed. Collinearity among explanatory variables will not hinder the predictive power of a model as long as the values of the independent variables obey the same near-exact linear dependencies as the original design matrix **X** (Judge et al 1988). However, the effects of individual coefficients may not be discernable. Collinearity may cause the coefficients to have high variances, thereby yielding low t-statistics. Consequently, it may be difficult to distinguish which parameters are truly significant in explaining the variation of the dependent variable. Moreover, in addition to high R^2-statistics, models plagued with collinearity may suffer from "sign-switching" coefficients. The implication is that statistical inference may be invalid.

Several tests have been proposed for detecting collinearity. Nevertheless, no single method is complete in and of itself. One simple diagnosis involves examining the estimated correlation coefficients (r) associated with the explanatory variables. Although pairwise correlations are not capable of providing insight into complex interrelationships among several variables, they can provide valuable clues for the researcher. The threshold value for determining whether or not problematic collinearity exists is subjective. Judge et al (1988) suggested that collinearity is serious when $r > 0.80$ or > 0.90. Hamal (1991) adopted $r = 0.95$ as the critical point. In this study, $r >= 0.90$ serves as the guideline.

Table B.3 contains the factor input correlation estimates. The findings suggest that fertilizer and draught animals are strongly correlated, but below the *ad hoc* threshold level. It would be prudent to explore the situation in more depth.

An alternate approach is to employ the auxiliary regression technique reported in Judge et al (1988); each independent variable is regressed on all the others. If the estimated regression equations yield high R^2-adjusted statistics and significant F-statistics, collinearity may be a problem. The advantage of this test is that it improves the chances of identifying the suspect variables. Again, subjective judgement determines the R^2-adjusted cut-off point. Table B.4 summarizes the results of this test.

TABLE B.3
SIMPLE CORRELATION ANALYSIS

Variables	Correlation Coefficient	Collinearity
Land-Labour	-0.030	No
Land-Draught	0.005	No
Land-Fertilizer	-0.551	No
Draught-Labour	-0.174	No
Fertilizer-Labour	-0.045	No
Fertilizer-Draught	0.679	No

TABLE B.4
AUXILIARY REGRESSION ANALYSIS

Dependent Variable	R^2-Adjusted	F-Stat (3,24) df	Collinearity
Land	0.521	10.779*	No
Labour	-0.074	0.381	No
Draught Animals	0.642	17.133*	No
Fertilizer	0.744	27.196*	No

* significant at the 0.01 level

Even though three of the auxiliary equations are significant at the 0.01 level (land, labour, and fertilizer), collinearity does not seem to be particularly severe (i.e., none of the R^2-adjusted statistics are >= 0.90). The R^2-adjusted value is actually negative with the labour equation.

A final test involves the principal components (PC) model (Judge et al 1988). This methodology offers a more complete framework for systematically analyzing collinearity. One feature of the PC model that is especially useful is the information that it provides regarding the proportion of the variance of the estimate accounted for by each principal component. Collinearity may be serious if a component corresponding to a high condition number contributes significantly to the variance of more than one variable. Belsley et al (1980) stated that condition numbers > 30 indicate severe linear associations. As shown in Table B.5, the variance proportion estimates confirm that fertilizer and draught animals are highly correlated.

TABLE B.5
PRINCIPAL COMPONENTS ANALYSIS*

Condition Number	Land	Labour	Draught Animals	Fertilizer
1.000	0.00194	0.00000	0.00004	0.20670
12.300	0.53578	0.00600	0.00407	0.07853
24.958	0.01846	0.94476	0.00035	0.00319
194.700	0.44382	0.04924	0.99554	0.70658

* columns show the proportion of total variation of the variable coefficients associated with each condition number

The above analyses have identified a potential collinearity problem. The difficulty now is to ascertain whether or not the parameter estimates have been severely distorted. Returning to Table B.1, note that the R^2-adjusted, F-test, and standard error statistics are not extraordinarily high. In situations where collinearity has plagued the estimation, these statistics are typically large in magnitude. Also, the fertilizer coefficient is very small and statistically insignificant. This is supported by casual observation of its role in the overall production process. Obviously, if this parameter estimate was excessively large it would defy qualitative judgement. Furthermore, the relative magnitudes of the remaining coefficients are in line with *a priori* expectations.

Collinearity could be minimized if additional information were available to the researcher. Unfortunately, this was not the case. Alternatively, the variable(s) causing the problem could be dropped from the estimation process. This is where the "sign-switching" of coefficients could come into play. If collinearity has had an adverse impact on the estimation process, removal of the suspect variable(s) could cause a directional change in some of the remaining coefficients. Such a scenario is not possible here. Re-estimating the model with fertilizer excluded would not change the parameter signs.

Leamer (1975) proved that there can be no change in the sign of any coefficient that is more significant than the coefficient of the excluded variable. Indeed, all of the other variables are more significant than fertilizer.

Finally, a principal components regression model was run to test the robustness of the original parameter estimates. Hayami and Ruttan (1985) used this procedure to correct for collinearity in their study involving forty-three underdeveloped countries. The estimation results were not significantly different from the original model[3]. It is concluded that collinearity has not had a detrimental effect on the parameter estimates in Table B.1.

B3.1 Summary

Both qualitative and quantitative analyses indicate that the CD estimates in Table B.1 have not been seriously distorted by autocorrelation, heteroskedasticity, or collinearity. Therefore, these coefficients are used to construct an aggregate input index for the Geometric TFP analysis in Section 5.2.1 of Chapter 5.

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[3]A formal presentation of the principal components regression results is not reported here.

APPENDIX C:

RESULTS FROM NONLINEAR MODEL

TABLE C.1
PARAMETER ESTIMATES OF THE NONLINEAR TRANSLOG MODEL, 1974-1991

Parameter[1]	Estimate[2]	T-Ratio[3]
β_1	0.5336*	15.919
γ_{11}	0.057*	4.129
$\gamma_{12} = \gamma_{21}$	-0.0198*	-2.546
$\gamma_{13} = \gamma_{31}$	-0.0584*	-13.674
$\gamma_{14} = \gamma_{41}$	0.0216**	2.118
α_1	-0.0466***	-1.662
θ_1	0.0063*	4.032
β_2	-0.1544**	-1.847
γ_{22}	0.0162*	2.838
$\gamma_{23} = \gamma_{32}$	0.0146*	8.279
$\gamma_{24} = \gamma_{42}$	-0.0110	-1.077
α_2	0.0390*	2.514
θ_2	0.0018***	1.441
β_3	0.7983*	8.771
γ_{33}	0.0247*	5.726
$\gamma_{34} = \gamma_{43}$	0.0192*	4.075
α_3	-0.0715*	-7.638
θ_3	0.0077*	-6.250
$\beta_4 = (1-\beta_1-\beta_2-\beta_3)$	-0.1776**	-2.125
$\gamma_{44} = (-\gamma_{41}-\gamma_{42}-\gamma_{43})$	-0.0299*	-2.925
$\alpha_4 = (-\alpha_1-\alpha_2-\alpha_3)$	0.0790*	5.091
$\theta_4 = (-\theta_1-\theta_2-\theta_3)$	-0.0005	-0.368

1. The numbers 1, 2, 3, and 4 denote land, draught animals, fertilizer, and labour, respectively.
2. * significant at the 0.01 level; ** significant at the 0.05 level; *** significant at the 0.10 level
3. The degrees-of-freedom for this model are calculated as df=(m*n)-K, where m is the number of share equations, n is the number of observations, and K is the total number of variables in the system (Johnston 1984). As such, df=(3*18)-18 = 36.

TABLE C.2 OWN-ALLEN PARTIAL ELASTICITIES OF SUBSTITUTION, NONLINEAR TRANSLOG MODEL			
Input	1974-1979	1980-1991	1974-1991
Land (σ_{11})	-1.96*	-1.72*	-1.80*
Draught (σ_{22})	-8.30*	-6.59*	-7.09*
Fertilizer (σ_{33})	-1.65*	-1.93*	-1.83*
Labour (σ_{44})	-2.73*	-3.03*	-2.92*

* significant at the 0.01 level

TABLE C.3 ALLEN PARTIAL ELASTICITIES OF SUBSTITUTION, NONLINEAR TRANSLOG MODEL			
Input	1974-1979	1980-1991	1974-1991
Land-Draught (σ_{12})	0.15*	0.41*	0.34*
Land-Fertilizer (σ_{13})	0.37*	0.38*	0.38*
Land-Labour (σ_{14})	1.28**	1.26**	1.27**
Draught-Fertilizer (σ_{23})	1.47*	1.40*	1.43*
Draught-Labour (σ_{24})	0.58	0.65	0.63
Fertilizer-Labour (σ_{34})	1.19*	1.22*	1.21*

1. $\sigma_{ij} > 0$ (< 0) implies that the i^{th} and j^{th} inputs are substitutes (complements)
* significant at the 0.01 level
** significant at the 0.05 level

TABLE C.4
OWN AND CROSS-PRICE ELASTICITIES OF INPUT DEMAND, NONLINEAR TRANSLOG MODEL

Period	Input	Land	Draught	Fert.	Labour
1974-79	Land	-0.52*	0.01*	0.13*	0.38**
	Draught	0.04*	-0.73*	0.52*	0.17
	Fert.	0.10*	0.13*	-0.05*	0.35*
	Labour	0.34*	0.05**	0.42*	-0.81*
1980-91	Land	-0.51*	0.05*	0.12*	0.35**
	Draught	0.12*	-0.74*	0.44*	0.18
	Fert.	0.11*	0.16*	-0.05*	0.34*
	Labour	0.38*	0.07**	0.38*	-0.83*
1974-91	Land	-0.52*	0.04*	0.12*	0.36**
	Draught	0.10*	-0.74*	0.47*	0.18
	Fert.	0.11*	0.15*	-0.05*	0.34*
	Labour	0.36*	0.07**	0.40*	-0.82*

1. A cross-price elasticity (η_{ij}) > 0 implies that the i^{th} and j^{th} inputs are substitutes.
* significant at the 0.01 level
** significant at the 0.05 level

TABLE C.5
TECHNICAL CHANGE AND SCALE EFFECTS, 1974-1991, NONLINEAR TRANSLOG MODEL

Input	Technical Effect (θ_i)	Scale Effect (α_i)
Land	0.006*	-0.047*
Draught Animals	0.002**	0.039*
Fertilizer	0.008*	-0.071*
Labour	0.000	0.079*

1. $\theta_i > 0$, $\theta_i < 0$, and $\theta_i = 0$ imply that technical change is i^{th} input-using, i^{th} input-saving, and Hicks-neutral, respectively; $\alpha_i > 0$, $\alpha_i < 0$, and $\alpha_i = 0$, imply that the scale effect is i^{th} input-using, i^{th} input-saving, and neutral, respectively;
* significant at the 0.01 level; ** significant at the 0.10 level

APPENDIX D

GAUSS PROGRAMS

Model 1: Linear Resticted SUR

```
new; library pgraph; n1=18; flg=0;  flgg=0; nk=1;
load x1[18,10]=c:\work\jhenry\tlog.prn;
n=rows(x1);
p1=x1[.,5]; p2=x1[.,4]; p3=x1[.,2];  p4=x1[.,3];
q1=x1[.,7];     q2=x1[.,9];     q3=x1[.,10];     q4=x1[.,8];
y=ln(x1[.,6]);
co=p1.*q1+p2.*q2+p3.*q3+p4.*q4;
s1=(p1.*q1)./co;     s2=(p2.*q2)./co;     s3=(p3.*q3)./co;
s4=(p4.*q4)./co;
p1=ln(p1); p2=ln(p2); p3=ln(p3); p4=ln(p4);
x=ones(n,1)~p1~p2~p3~p4~y~seqa(1,1,n);
b1=s1/x; e1=s1-x*b1; b2=s2/x; e2=s2-x*b2;
b3=s3/x; e3=s3-x*b3; b4=s4/x; e4=s4-x*b4;
b=b1|b2|b3;  e=e1~e2~e3; vcv=((e'*e)./n).*.invpd(x'*x);
k=rows(b);  r1=zeros(1,k); r2=r1; r3=r1; r4=r1; r5=r1; r6=r1;
r1[.,2:5]=1~1~1~1; r2[.,9:12]=1~1~1~1; r3[.,16:19]=1~1~1~1;
r4[.,3]=1;  r4[.,9]=-1;  r5[.,4]=1;  r5[.,16]=-1;  r6[.,11]=1;
r6[.,17]=-1;
r=r1|r2|r3|r4|r5|r6;
bs=b-vcv*r'*invpd(r*vcv*r')*r*b;
vcvs=vcv-vcv*r'*invpd(r*vcv*r')*(r*vcv);
se=sqrt(diag(vcvs)); ts=bs./se; ttr=bs~se~ts;
b=b4|b2|b3; e=e4~e2~e3; vcv=((e'*e)./n).*.invpd(x'*x);
r4=zeros(1,k);  r5=r4;  r4[.,3]=1;  r4[.,12]=-1;  r5[.,4]=1;
r5[.,19]=-1;
r=r1|r2|r3|r4|r5|r6;
bs=b-vcv*r'*invpd(r*vcv*r')*r*b;
bf=reshape(bs,3,7)';
vcvs=vcv-vcv*r'*invpd(r*vcv*r')*(r*vcv);
se=sqrt(diag(vcvs)); ts=bs./se; k1=cols(x);
ttt=ttr|(bs[1:k1,.]~se[1:k1,.]~ts[1:k1,.]);
if flg==1; output file=c:\work\jhenry\jh5.out on; endif;
"The Restricted Linear SUR Results";
i=1; nq=4; j1=1; j2=k1; bb=zeros(k1,nq); s=s1~s2~s3~s4;
sh=zeros(n,nq); ei=sh;
do while i < nq+1; " ";
bb[.,i]=ttt[j1:j2,1];
sh[.,i]=x*bb[.,i]; ei[.,i]=s[.,i]-sh[.,i];
rss=ei[.,i]'*ei[.,i];    ybi=s[.,i]-meanc(s[.,i])*ones(n,1);
tss=ybi'*ybi;
rs=1-rss/tss; dw=sumc((ei[2:n,i]-ei[1:(n-1),i])^2)/rss;
if i==1; "The Land Equation:"; endif;
if i==2; "The Machinery Equation:"; endif;
if i==3; "The Fertilizer Equation:"; endif;
```

```
if i==4; "The Labour Equation:"; endif;
"The R-Squared Value is:"; rs;
"The Durbin-Watson Value is:"; dw;
"The Betas, Standard Errors and t-values are:";
ttt[j1:j2,.]; j1=j1+k1; j2=j2+k1; i=i+1; endo;
output off; {bg,mm,freq}=hist(vec(ei),10);
b2=bb[2:5,.]';
c1=0; c2=0; t=1; do while t < n+1;
st=sh[t,.]';
gam=b2-diagrv(eye(nq),st)+st*st';
{lr,li}=eigrg(gam);
if maxc(lr) < 0.00000001; c1=c1+1; endif;
if minc(st) > 0; c2=c2+1; endif; t=t+1; endo;
if flg==1; output file=c:\work\jhenry\jh5.out on; endif;
"The Number of Years Monotonicity holds is:"; c2;
"The Number of Years Concavity holds is:"; c1;
st=meanc(sh);
gam=b2+st*st'-diagrv(eye(nq),st);
ish=ones(nq,1)./st; ww=diagrv(eye(nq),ish);
ss=ww*gam*ww;
" "; ss;
{lr,li}=eigrg(ss); lr'; " ";
"The Residuals are:";
ei;
output off;
```

Model 2: Linear Restricted SUR with Serially Correlated Errors

```
new; n1=18; flg=1;  flgg=0; nk=1;
load x1[18,10]=c:\work\jhenry\tlog.prn;
n=rows(x1);
p1=x1[.,5]; p2=x1[.,4]; p3=x1[.,2];  p4=x1[.,3];
q1=x1[.,7];     q2=x1[.,9];     q3=x1[.,10];     q4=x1[.,8];
y=ln(x1[.,6]);
co=p1.*q1+p2.*q2+p3.*q3+p4.*q4;
s1s=(p1.*q1)./co;     s2s=(p2.*q2)./co;     s3s=(p3.*q3)./co;
s4s=(p4.*q4)./co;
p1=ln(p1); p2=ln(p2); p3=ln(p3); p4=ln(p4);
xs=ones(n,1)~p1~p2~p3~p4~y~seqa(1,1,n);
rho=0; rhos=0; dd=1; do while dd > .00000001;
pp=eye(n); pp[1,1]=sqrt(1-rho^2); t=2;
do while t < n+1;
pp[t,t-1]=-rho; t=t+1; endo;
x=pp*xs; s1=pp*s1s; s2=pp*s2s; s3=pp*s3s; s4=pp*s4s;
b1=s1/x; e1=s1s-xs*b1; b2=s2/x; e2=s2s-xs*b2;
b3=s3/x; e3=s3s-xs*b3; b4=s4/x; e4=s4s-xs*b4;
ee=e1[2:n,.]|e2[2:n,.]|e3[2:n,.];
el=e1[1:(n-1),.]|e2[1:(n-1),.]|e3[1:(n-1),.];
rho=ee/el; dd=abs(rho-rhos); rhos=rho; rho; dd; endo;
b=b1|b2|b3;  e=e1~e2~e3; vcv=((e'*e)./n).*.invpd(x'*x);
k=rows(b);
r1=zeros(1,k);  r2=r1;  r3=r1;  r4=r1;  r5=r1;  r6=r1;  r7=r1;
r8=r1; r9=r1;
r1[.,2:5]=1~1~1~1; r2[.,9:12]=1~1~1~1; r3[.,16:19]=1~1~1~1;
r4[.,3]=1;  r4[.,9]=-1;  r5[.,4]=1;  r5[.,16]=-1;  r6[.,11]=1;
r6[.,17]=-1;
r7[.,7]=1; r8[.,14]=1; r9[.,21]=1;
if flg==1; output file=c:\work\jhenry\jhrho.out on; endif;
bs=b-vcv*r'*invpd(r*vcv*r')*r*b;
vcvs=vcv-vcv*r'*invpd(r*vcv*r')*(r*vcv);
se=sqrt(diag(vcvs)); ts=bs./se; ttr=bs~se~ts;
b=b4|b2|b3; e=e4~e2~e3; vcv=((e'*e)./n).*.invpd(x'*x);
r4=zeros(1,k);  r5=r4;  r4[.,3]=1;  r4[.,12]=-1;  r5[.,4]=1;
r5[.,19]=-1;
r=r1|r2|r3|r4|r5|r6;
bs=b-vcv*r'*invpd(r*vcv*r')*r*b;
bf=reshape(bs,3,7)';
vcvs=vcv-vcv*r'*invpd(r*vcv*r')*(r*vcv);
se=sqrt(diag(vcvs)); ts=bs./se; k1=cols(x);
ttt=ttr|(bs[1:k1,.]~se[1:k1,.]~ts[1:k1,.]);
if flg==1; output file=c:\work\jhenry\jhrho.out on; endif;
"The Restricted Linear SUR Results";
i=1; nq=4; j1=1; j2=k1; bb=zeros(k1,nq); s=s1~s2~s3~s4;
ss=s1s~s2s~s3s~s4s;
sh=zeros(n,nq);  sh1=sh;
do while i < nq+1; " ";
bb[.,i]=ttt[j1:j2,1];
```

```
sh1[.,i]=xs*bb[.,i]; es=ss[.,i]-sh1[.,i];
t=2; do while t < n+1;
sh1[t,i]=sh1[t,i]+rho*es[t-1,.]; t=t+1; endo;
sh[.,i]=x*bb[.,i]; ei=s[.,i]-sh[.,i];
rss=ei'*ei; ybi=s[.,i]-meanc(s[.,i])*ones(n,1); tss=ybi'*ybi;
rs=1-rss/tss; dw=sumc((ei[2:n,.]-ei[1:(n-1),.])^2)/rss;
if i==1; "The Land Equation:"; endif;
if i==2; "The Machinery Equation:"; endif;
if i==3; "The Fertilizer Equation:"; endif;
if i==4; "The Labour Equation:"; endif;
"The R-Squared Value is:"; rs;
"The Durbin-Watson Value is:"; dw;
"The Betas, Standard Errors and t-values are:";
ttt[j1:j2,.]; j1=j1+k1; j2=j2+k1; i=i+1; endo;
output off;
output file=b:pshare.out on; sh1; output off;
b2=bb[2:5,.]';  sh=sh1;
c1=0; c2=0; t=1; do while t < n+1;
st=sh[t,.]';
gam=b2-diagrv(eye(nq),st)+st*st';
{lr,li}=eigrg(gam);
if maxc(lr) < 0.00000001; c1=c1+1; endif;
if minc(st) > 0; c2=c2+1; endif; t=t+1; endo;
if flg==1; output file=c:\work\jhenry\jhrho.out on; endif;
"The Number of Years Monotonicity holds is:"; c2;
"The Number of Years Concavity holds is:"; c1;
st=meanc(sh);
gam=b2+st*st'-diagrv(eye(nq),st);
ish=ones(nq,1)./st; ww=diagrv(eye(nq),ish);
ss=ww*gam*ww;
" "; ss;
{lr,li}=eigrg(ss); lr';
output off;
```

Model 3: Nonlinear Restricted SUR

```
new; n1=18; flg=1;  flgg=0; nk=1; kkl=0; ci=1;
load x1[18,10]=c:\work\jhenry\tlog.prn;
n=rows(x1);
p1=x1[.,5]; p2=x1[.,4]; p3=x1[.,2];  p4=x1[.,3];
q1=x1[.,7];     q2=x1[.,9];     q3=x1[.,10];     q4=x1[.,8];
y=ln(x1[.,6]);
co=p1.*q1+p2.*q2+p3.*q3+p4.*q4;
s1=(p1.*q1)./co;     s2=(p2.*q2)./co;     s3=(p3.*q3)./co;
s4=(p4.*q4)./co;
p1=ln(p1); p2=ln(p2); p3=ln(p3); p4=ln(p4); tr=seqa(nk,1,n);
xk=ones(n,1)~p1~p2~p3~p4~seqa(nk,1,n);
x=ones(n,1)~p1~p2~p3~p4~y~seqa(nk,1,n);
bb=zeros(7,4); bb[1,.]=.25*(1~1~1~1);
a1=bb[1,1];     a11=bb[2,1];     a12=bb[3,1];     a13=bb[4,1];
a1y=bb[6,1];
a2=bb[1,2];                              a22=bb[3,2];  a23=bb[4,2];
a2y=bb[6,2];
a3=bb[1,3];                                            a33=bb[4,3];
a3y=bb[6,3];
t1=0; t2=0; t3=0;
bh=a1|a11|a12|a13|a1y|t1|a2|a22|a23|a2y|t2|a3|a33|a3y|t3;
nq=3; k=rows(bh); stage=1; p=eye(nq); cp=20;
a1=bh[1,1];     a11=bh[2,1];     a12=bh[3,1];     a13=bh[4,1];
a1y=bh[5,1];  t1=bh[6,1];
a2=bh[7,1];                              a22=bh[8,1];  a23=bh[9,1];
a2y=bh[10,1]; t2=bh[11,1];
a3=bh[12,1];                                          a33=bh[13,1];
a3y=bh[14,1]; t3=bh[15,1];
a4=1-a1-a2-a3; a4y=-(a1y+a2y+a3y); t4=-(t1+t2+t3);
a14=-(a11+a12+a13);  a24=-(a12+a22+a23);  a34=-(a13+a23+a33);
a44=-(a14+a24+a34);
b1=a1|a11|a12|a13|a14|a1y|t1; b2=a2|a12|a22|a23|a24|a2y|t2;
b3=a3|a13|a23|a33|a34|a3y|t3; b4=a4|a14|a24|a34|a44|a4y|t4;
yy1=ln(s1)-ln(s4); yy2=ln(s2)-ln(s4); yy3=ln(s3)-ln(s4);
yb1=s1-meanc(s1)*ones(n,1); tss1=yb1'*yb1;
yb2=s2-meanc(s2)*ones(n,1); tss2=yb2'*yb2;
yb3=s3-meanc(s3)*ones(n,1); tss3=yb3'*yb3;
yb4=s4-meanc(s4)*ones(n,1); tss4=yb4'*yb4;
do while stage < 3;
s=1; obj=0; iter=0; toler=abs(s-obj);
do while toler > .000001;
iter=iter+1; der=zeros(nq*n,k); shh=zeros(n,nq+1);
e=zeros(nq*n,1); t=1; j1=1; j2=nq;
do while t < n+1;
sh1=(x[t,.]*b1); sh2=(x[t,.]*b2);
sh3=(x[t,.]*b3); sh4=(x[t,.]*b4);
shh[t,.]=sh1~sh2~sh3~sh4;
e1t=ln(s1[t,.]/s4[t,.])-ln(sh1/sh4);
e2t=ln(s2[t,.]/s4[t,.])-ln(sh2/sh4);
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```
e3t=ln(s3[t,.]/s4[t,.])-ln(sh3/sh4);
e[j1:j2,.]=p*(e1t|e2t|e3t);
da1=1/sh1|0|0;     da2=0|1/sh2|0;     da3=0|0|1/sh3;
da4=-(1/sh4)*(1|1|1);
da11=p1[t,.]*da1;    da12=p2[t,.]*da1;    da13=p3[t,.]*da1;
da14=p4[t,.]*da1;
da21=p1[t,.]*da2;    da22=p2[t,.]*da2;    da23=p3[t,.]*da2;
da24=p4[t,.]*da2;
da31=p1[t,.]*da3;    da32=p2[t,.]*da3;    da33=p3[t,.]*da3;
da34=p4[t,.]*da3;
da41=p1[t,.]*da4;    da42=p2[t,.]*da4;    da43=p3[t,.]*da4;
da44=p4[t,.]*da4;
da1y= y[t,.]*da1; da2y= y[t,.]*da2; da3y= y[t,.]*da3; da4y=
y[t,.]*da4;
dt1 = tr[t,.]*da1; dt2= tr[t,.]*da2; dt3=tr[t,.]*da3; dt4=
tr[t,.]*da4;
da1=da1-da4; da2=da2-da4; da3=da3-da4;
da11=da11-da14-da41+da44;
da12=da12-da14-da41+da21-da24-da42+2*da44;
da13=da13-da14-da41+da31-da34-da43+2*da44;
da22=da22-da24-da42+da44;
da23=da23-da24-da42+da32-da34-da43+2*da44;
da33=da33-da34-da43+da44;
da1y=da1y-da4y; da2y=da2y-da4y; da3y=da3y-da4y;
dt1=dt1-dt4; dt2=dt2-dt4; dt3=dt3-dt4;
der[j1:j2,.]=p*(da1~da11~da12~da13~da1y~dt1~da2~da22~da23~da
2y~dt2
                ~da3~da33~da3y~dt3);
t=t+1; j1=j1+nq; j2=j2+nq;
endo;
chat=invpd(der'*der); j=chat*(der'*e);
s=e'*e;
obj=s; c=0; bh0=bh; l=ci;  if kk1==1; s=50; kk1=0; endif;
cc=0;
do while (obj >= s and cc == 0); fg=0;
c=c+1; l=.5*l; bh=bh0+j.*l;
j1=1; j2=nq;
a1=bh[1,1];    a11=bh[2,1];    a12=bh[3,1];    a13=bh[4,1];
a1y=bh[5,1];  t1=bh[6,1];
a2=bh[7,1];                        a22=bh[8,1];  a23=bh[9,1];
a2y=bh[10,1]; t2=bh[11,1];
a3=bh[12,1];                                    a33=bh[13,1];
a3y=bh[14,1]; t3=bh[15,1];
a4=1-a1-a2-a3; a4y=-(a1y+a2y+a3y); t4=-(t1+t2+t3);
a14=-(a11+a12+a13); a24=-(a12+a22+a23); a34=-(a13+a23+a33);
a44=-(a14+a24+a34);
b1=a1|a11|a12|a13|a14|a1y|t1; b2=a2|a12|a22|a23|a24|a2y|t2;
b3=a3|a13|a23|a33|a34|a3y|t3; b4=a4|a14|a24|a34|a44|a4y|t4;
e=zeros(nq*n,1); t=1; es=zeros(n,nq); sh=zeros(n,nq+1);
sh=x*b1~x*b2~x*b3~x*b4;
if(minc(minc(sh)) > 0);
```

```
cc=1; endif; cc;
if cc==1;
do while t < n+1;
sh1=(x[t,.]*b1); sh2=(x[t,.]*b2);
sh3=(x[t,.]*b3); sh4=(x[t,.]*b4);
e1t=ln(s1[t,.]/s4[t,.])-ln(sh1/sh4);
e2t=ln(s2[t,.]/s4[t,.])-ln(sh2/sh4);
e3t=ln(s3[t,.]/s4[t,.])-ln(sh3/sh4);
e[j1:j2,.]=p*(e1t|e2t|e3t);
es[t,.]=e1t~e2t~e3t;
t=t+1; j1=j1+nq; j2=j2+nq;
endo;  obj=e'*e; s; obj; endif;  endo; if stage==1; save
bh=bh; endif;
toler=abs(s-obj); endo;
vc=chat;
sterr=sqrt(diag(vc));
print " ";
print " "; print "The SSE is:";print s;
print "The Standard Error is";
print " ";
print "The Estimated Parameter Standard Errors and t's";
print " ";
t=bh./sterr; ff=bh~sterr~t; print ff;
if stage == 1;
sig=(es'*es)./n; sigi=invpd(sig); p=chol(sigi); save p=p;
endif;
stage=stage+1; endo;
yb1=shh[.,1]-meanc(shh[.,1])*ones(n,1); rs1=yb1'*yb1/tss1;
yb2=shh[.,2]-meanc(shh[.,2])*ones(n,1); rs2=yb2'*yb2/tss2;
yb3=shh[.,3]-meanc(shh[.,3])*ones(n,1); rs3=yb3'*yb3/tss3;
yb4=shh[.,4]-meanc(shh[.,4])*ones(n,1); rs4=yb4'*yb4/tss4;

dw1=sumc((es[2:n,1]-es[1:(n-1),1])^2)/(es[.,1]'*es[.,1]);
dw2=sumc((es[2:n,2]-es[1:(n-1),2])^2)/(es[.,2]'*es[.,2]);
dw3=sumc((es[2:n,3]-es[1:(n-1),3])^2)/(es[.,3]'*es[.,3]);
rs=rs1|rs2|rs3|rs4; dw=dw1|dw2|dw3;

sea1=sterr[1,1]; sea11=sterr[2,1]; sea12=sterr[3,1];
sea13=sterr[4,1]; sea1y=sterr[5,1]; set1=sterr[6,1];
sea2=sterr[7,1]; sea22=sterr[8,1]; sea23=sterr[9,1];
sea2y=sterr[10,1]; set2=sterr[11,1]; sea3=sterr[12,1];
sea33=sterr[13,1]; sea3y=sterr[14,1]; set3=sterr[15,1];
r=zeros(rows(bh),1); r[2:4,1]=-1|-1|-1; sea14=sqrt(r'*vc*r);
r=zeros(rows(bh),1);  r[3,1]=-1;  r[8,1]=-1;  r[9,1]=-1;
sea24=sqrt(r'*vc*r);
r=zeros(rows(bh),1);  r[4,1]=-1;  r[9,1]=-1;  r[13,1]=-1;
sea34=sqrt(r'*vc*r);
r=zeros(rows(bh),1); r[2,1]=1; r[3,1]=2; r[4,1]=2;
r[8,1]=1; r[9,1]=2; r[13,1]=1; sea44=sqrt(r'*vc*r);
r=zeros(rows(bh),1);  r[5,1]=-1;  r[10,1]=-1;  r[14,1]=-1;
sea4y=sqrt(r'*vc*r);
```

```
r=zeros(rows(bh),1);   r[6,1]=-1;   r[11,1]=-1;   r[15,1]=-1;
set4=sqrt(r'*vc*r);
r=zeros(rows(bh),1);   r[1,1]=-1;   r[7,1]=-1;   r[12,1]=-1;
sea4=sqrt(r'*vc*r);
se1=sea1|sea11|sea12|sea13|sea14|sea1y|set1;
se2=sea2|sea12|sea22|sea23|sea24|sea2y|set2;
se3=sea3|sea13|sea23|sea33|sea34|sea3y|set3;
se4=sea4|sea14|sea24|sea34|sea44|sea4y|set4;
bb=b1~b2~b3~b4; se=se1~se2~se3~se2;
if flg==1; output file=c:\work\jhenry\jh6.out on; endif;
"The Restricted NSUR Results";
" ";
"The R-Squared values are:"; rs';
" ";
"The Durbin-Watson values are:"; dw'; " ";
i=1; do while i < nq+2;
if i==1; "The Land Share Betas, t-values and Standard Errors
are:"; endif;
if i==2; "The Machinery Share Betas, t-values and Standard
Errors are:"; endif;
if i==3; "The Fertilizer Share Betas, t-values and Standard
Errors are:"; endif;
if i==4; "The Labour Share Betas, t-values and Standard Errors
are:"; endif;
" "; te=bb[.,i]./se[.,i]; tt=bb[.,i]~se[.,i]~te; tt; i=i+1;
endo;
b2=bb[2:5,.]'; yr=seqa(31+nk,1,n);
c1=0; c2=0; t=1; do while t < n+1;
st=sh[t,.]';
gam=b2-diagrv(eye(nq+1),st)+st*st'; ss=yr[t,.]~(st');
{lr,li}=eigrg(gam);
if maxc(lr) < 0.00000001; c1=c1+1; endif;
if minc(st) > 0; c2=c2+1; endif;
t=t+1; endo;
"The Number of Years Monotonicity holds is:"; c2;
"The Number of Years Concavity holds is:"; c1;
st=meanc(sh);
gam=b2+st*st'-diagrv(eye(nq+1),st);
ish=ones(nq+1,1)./st; ww=diagrv(eye(nq+1),ish);
ss=ww*gam*ww;
" "; ss; {lr,li}=eigrg(ss); lr'; output off;
```

Model 4: Nonlinear Restricted SUR with Serially Correlated Errors

```
new; n1=18; flg=1;  flgg=0; nk=1; kkl=0; ci=1;
load x1[18,10]=c:\work\jhenry\tlog.prn;
n=rows(x1);
p1=x1[.,5]; p2=x1[.,4]; p3=x1[.,2];  p4=x1[.,3];
q1=x1[.,7];     q2=x1[.,9];     q3=x1[.,10];     q4=x1[.,8];
y=ln(x1[.,6]);
co=p1.*q1+p2.*q2+p3.*q3+p4.*q4;
s1=(p1.*q1)./co;     s2=(p2.*q2)./co;     s3=(p3.*q3)./co;
s4=(p4.*q4)./co;
p1=ln(p1); p2=ln(p2); p3=ln(p3); p4=ln(p4); tr=seqa(nk,1,n);
xk=ones(n,1)~p1~p2~p3~p4~seqa(nk,1,n);
x=ones(n,1)~p1~p2~p3~p4~y~seqa(nk,1,n);
bb=zeros(7,4); bb[1,.]=.25*(1~1~1~1);
a1=bb[1,1];     a11=bb[2,1];     a12=bb[3,1];     a13=bb[4,1];
a1y=bb[6,1];
a2=bb[1,2];                           a22=bb[3,2];  a23=bb[4,2];
a2y=bb[6,2];
a3=bb[1,3];                                         a33=bb[4,3];
a3y=bb[6,3];
t1=0; t2=0; t3=0;
bh=a1|a11|a12|a13|a1y|t1|a2|a22|a23|a2y|t2|a3|a33|a3y|t3;
nq=3; k=rows(bh); stage=1; p=eye(nq); cp=20;
a1=bh[1,1];     a11=bh[2,1];     a12=bh[3,1];     a13=bh[4,1];
a1y=bh[5,1];  t1=bh[6,1];
a2=bh[7,1];                           a22=bh[8,1];  a23=bh[9,1];
a2y=bh[10,1]; t2=bh[11,1];
a3=bh[12,1];                                       a33=bh[13,1];
a3y=bh[14,1]; t3=bh[15,1];
a4=1-a1-a2-a3; a4y=-(a1y+a2y+a3y); t4=-(t1+t2+t3);
a14=-(a11+a12+a13); a24=-(a12+a22+a23); a34=-(a13+a23+a33);
a44=-(a14+a24+a34);
b1=a1|a11|a12|a13|a14|a1y|t1; b2=a2|a12|a22|a23|a24|a2y|t2;
b3=a3|a13|a23|a33|a34|a3y|t3; b4=a4|a14|a24|a34|a44|a4y|t4;
yy1=ln(s1)-ln(s4); yy2=ln(s2)-ln(s4); yy3=ln(s3)-ln(s4);
yb1=s1-meanc(s1)*ones(n,1); tss1=yb1'*yb1;
yb2=s2-meanc(s2)*ones(n,1); tss2=yb2'*yb2;
yb3=s3-meanc(s3)*ones(n,1); tss3=yb3'*yb3;
yb4=s4-meanc(s4)*ones(n,1); tss4=yb4'*yb4;
rh=zeros(nq,1);
do while stage < 3;
tol=1;  rh=zeros(nq,1);
do while tol > .000001;
s=1; obj=0; iter=0; toler=abs(s-obj);do while toler > .000001;
iter=iter+1; der=zeros(nq*n,k); shh=zeros(n,nq+1);
e=zeros(nq*n,1); t=1; j1=1; j2=nq;
et1=zeros(nq,1); dert=zeros(nq,k); dert1=dert;
do while t < n+1;
sh1=(x[t,.]*b1); sh2=(x[t,.]*b2);
```

```
sh3=(x[t,.]*b3); sh4=(x[t,.]*b4);
shh[t,.]=sh1~sh2~sh3~sh4;
e1t=ln(s1[t,.]/s4[t,.])-ln(sh1/sh4);
e2t=ln(s2[t,.]/s4[t,.])-ln(sh2/sh4);
e3t=ln(s3[t,.]/s4[t,.])-ln(sh3/sh4);
if t==1;
e1t=sqrt(1-rh[1,1]^2)*e1t;
e2t=sqrt(1-rh[2,1]^2)*e2t;
e3t=sqrt(1-rh[3,1]^2)*e3t;
e[j1:j2,.]=p*(e1t|e2t|e3t);
el=e1t|e2t|e3t;
else;
et=e1t|e2t|e3t;
e[j1:j2,.]=p*((et-diagrv(eye(nq),rh)*el));
el=et;
endif;
da1=1/sh1|0|0;      da2=0|1/sh2|0;      da3=0|0|1/sh3;
da4=-(1/sh4)*(1|1|1);
da11=p1[t,.]*da1;    da12=p2[t,.]*da1;    da13=p3[t,.]*da1;
da14=p4[t,.]*da1;
da21=p1[t,.]*da2;    da22=p2[t,.]*da2;    da23=p3[t,.]*da2;
da24=p4[t,.]*da2;
da31=p1[t,.]*da3;    da32=p2[t,.]*da3;    da33=p3[t,.]*da3;
da34=p4[t,.]*da3;
da41=p1[t,.]*da4;    da42=p2[t,.]*da4;    da43=p3[t,.]*da4;
da44=p4[t,.]*da4;
da1y= y[t,.]*da1; da2y= y[t,.]*da2; da3y= y[t,.]*da3; da4y=
y[t,.]*da4;
dt1 = tr[t,.]*da1; dt2= tr[t,.]*da2; dt3=tr[t,.]*da3; dt4=
tr[t,.]*da4;
da1=da1-da4; da2=da2-da4; da3=da3-da4;
da11=da11-da14-da41+da44;
da12=da12-da14-da41+da21-da24-da42+2*da44;
da13=da13-da14-da41+da31-da34-da43+2*da44;
da22=da22-da24-da42+da44;
da23=da23-da24-da42+da32-da34-da43+2*da44;
da33=da33-da34-da43+da44;
da1y=da1y-da4y; da2y=da2y-da4y; da3y=da3y-da4y;
dt1=dt1-dt4; dt2=dt2-dt4; dt3=dt3-dt4;
dert=(da1~da11~da12~da13~da1y~dt1~da2~da22~da23~da2y~dt2~da3
~da33~da3y~
dt3);
if t==1;
rhh=(sqrt((1-rh[1,1]^2))|sqrt((1-rh[2,1]^2))|sqrt((1-rh[3,1]
^2)));
der[j1:j2,.]=p*(diagrv(eye(nq),rhh)*dert);
dert1=dert;
else;
rhh=(rh[1,1]|rh[2,1]|rh[3,1]);
der[j1:j2,.]=p*(dert-diagrv(eye(nq),rhh)*dert1);
dert1=dert;
```

```
endif;
t=t+1;
j1=j1+nq; j2=j2+nq;
endo;
chat=invpd(der'*der); j=chat*(der'*e);
s=e'*e;
obj=s; c=0; bh0=bh; l=ci;
do while (obj >= s and c < 50); fg=0;
c=c+1; l=.5*l; bh=bh0+j.*l; cc=0;
j1=1; j2=nq;
a1=bh[1,1];    a11=bh[2,1];    a12=bh[3,1];    a13=bh[4,1];
a1y=bh[5,1];  t1=bh[6,1];
a2=bh[7,1];                     a22=bh[8,1];  a23=bh[9,1];
a2y=bh[10,1]; t2=bh[11,1];
a3=bh[12,1];                                  a33=bh[13,1];
a3y=bh[14,1]; t3=bh[15,1];
a4=1-a1-a2-a3; a4y=-(a1y+a2y+a3y); t4=-(t1+t2+t3);
a14=-(a11+a12+a13); a24=-(a12+a22+a23); a34=-(a13+a23+a33);
a44=-(a14+a24+a34);
b1=a1|a11|a12|a13|a14|a1y|t1; b2=a2|a12|a22|a23|a24|a2y|t2;
b3=a3|a13|a23|a33|a34|a3y|t3; b4=a4|a14|a24|a34|a44|a4y|t4;
e=zeros(nq*n,1);  t=1;  es=zeros(n,nq);  sh=zeros(n,nq+1);
esk=es;
sh=x*b1~x*b2~x*b3~x*b4;
if(minc(minc(sh)) > 0);
cc=1; endif; if cc==0; "Negative Share Encountered"; endif;
if cc==1;
do while t < n+1;
sh1=(x[t,.]*b1); sh2=(x[t,.]*b2);
sh3=(x[t,.]*b3); sh4=(x[t,.]*b4);
e1t=ln(s1[t,.]/s4[t,.])-ln(sh1/sh4);
e2t=ln(s2[t,.]/s4[t,.])-ln(sh2/sh4);
e3t=ln(s3[t,.]/s4[t,.])-ln(sh3/sh4);
esk[t,.]=e1t~e2t~e3t;
if t==1;
e1t=sqrt(1-rh[1,1]^2)*e1t;
e2t=sqrt(1-rh[2,1]^2)*e2t;
e3t=sqrt(1-rh[3,1]^2)*e3t;
es[t,.]=e1t~e2t~e3t;
e[j1:j2,.]=p*(e1t|e2t|e3t);
el=e1t|e2t|e3t;
else;
et=e1t|e2t|e3t;
es[t,.]=(et-diagrv(eye(nq),rh)*el)';
e[j1:j2,.]=p*((et-diagrv(eye(nq),rh)*el));
el=et;
endif;
t=t+1; j1=j1+nq; j2=j2+nq;
endo;  obj=e'*e; s; obj; endif;   endo; if stage==1; save
bh=bh; endif;
toler=abs(s-obj); endo;
```

```
vc=chat;
sterr=sqrt(diag(vc));
print " ";
print " "; print "The SSE is:";print s;
print "The Standard Error is";
print " ";
t=bh./sterr; ff=bh~sterr~t;
rho1=esk[2:n,1]/esk[1:(n-1),1];
rho2=esk[2:n,2]/esk[1:(n-1),2];
rho3=esk[2:n,3]/esk[1:(n-1),3];
tol=maxc(abs(rh-(rho1|rho2|rho3)));
rh=rho1|rho2|rho3;
"The Value of Tol is:"; tol; "The Rho vector is:"; rh';
endo;
if stage == 1;
sig=(es'*es)./n; sigi=invpd(sig); p=chol(sigi); save p=p;
endif;
stage=stage+1; endo;
output file=c:\work\jhenry\nshare1.out on;
"The Predicted Shares from the Non-Linear Model are:";
seqa(1,1,n)~sh; output off;
yb1=shh[.,1]-meanc(shh[.,1])*ones(n,1); rs1=yb1'*yb1/tss1;
yb2=shh[.,2]-meanc(shh[.,2])*ones(n,1); rs2=yb2'*yb2/tss2;
yb3=shh[.,3]-meanc(shh[.,3])*ones(n,1); rs3=yb3'*yb3/tss3;
yb4=shh[.,4]-meanc(shh[.,4])*ones(n,1); rs4=yb4'*yb4/tss4;
dw1=sumc((es[2:n,1]-es[1:(n-1),1])^2)/(es[.,1]'*es[.,1]);
dw2=sumc((es[2:n,2]-es[1:(n-1),2])^2)/(es[.,2]'*es[.,2]);
dw3=sumc((es[2:n,3]-es[1:(n-1),3])^2)/(es[.,3]'*es[.,3]);
rs=rs1|rs2|rs3|rs4; dw=dw1|dw2|dw3;
sea1=sterr[1,1]; sea11=sterr[2,1]; sea12=sterr[3,1];
sea13=sterr[4,1]; sea1y=sterr[5,1]; set1=sterr[6,1];
sea2=sterr[7,1]; sea22=sterr[8,1]; sea23=sterr[9,1];
sea2y=sterr[10,1]; set2=sterr[11,1]; sea3=sterr[12,1];
sea33=sterr[13,1]; sea3y=sterr[14,1]; set3=sterr[15,1];
r=zeros(rows(bh),1); r[2:4,1]=-1|-1|-1; sea14=sqrt(r'*vc*r);
r=zeros(rows(bh),1);   r[3,1]=-1;   r[8,1]=-1;   r[9,1]=-1;
sea24=sqrt(r'*vc*r);
r=zeros(rows(bh),1);   r[4,1]=-1;   r[9,1]=-1;   r[13,1]=-1;
sea34=sqrt(r'*vc*r);
r=zeros(rows(bh),1); r[2,1]=1; r[3,1]=2; r[4,1]=2;
r[8,1]=1; r[9,1]=2; r[13,1]=1; sea44=sqrt(r'*vc*r);
r=zeros(rows(bh),1);   r[5,1]=-1;   r[10,1]=-1;   r[14,1]=-1;
sea4y=sqrt(r'*vc*r);
r=zeros(rows(bh),1);   r[6,1]=-1;   r[11,1]=-1;   r[15,1]=-1;
set4=sqrt(r'*vc*r);
r=zeros(rows(bh),1);   r[1,1]=-1;   r[7,1]=-1;   r[12,1]=-1;
sea4=sqrt(r'*vc*r);
se1=sea1|sea11|sea12|sea13|sea14|sea1y|set1;
se2=sea2|sea12|sea22|sea23|sea24|sea2y|set2;
se3=sea3|sea13|sea23|sea33|sea34|sea3y|set3;
se4=sea4|sea14|sea24|sea34|sea44|sea4y|set4;
```

```
bb=b1~b2~b3~b4; se=se1~se2~se3~se2;
if flg==1; output file=c:\work\jhenry\jh8.out on; endif;
"The Restricted NSUR Results";
" ";
"The R-Squared values are:"; rs';
" ";
"The Durbin-Watson values are:"; dw'; " ";
i=1; do while i < nq+2;
if i==1; "The Land Share Betas, t-values and Standard Errors
are:"; endif;
if i==2; "The Machinery Share Betas, t-values and Standard
Errors are:"; endif;
if i==3; "The Fertilizer Share Betas, t-values and Standard
Errors are:"; endif;
if i==4; "The Labour Share Betas, t-values and Standard Errors
are:"; endif;
" "; te=bb[.,i]./se[.,i]; tt=bb[.,i]~se[.,i]~te; tt; i=i+1;
endo;
b2=bb[2:5,.]'; yr=seqa(31+nk,1,n);
c1=0; c2=0; t=1; do while t < n+1;
st=sh[t,.]';
gam=b2-diagrv(eye(nq+1),st)+st*st'; ss=yr[t,.]~(st');
{lr,li}=eigrg(gam);
if maxc(lr) < 0.00000001; c1=c1+1; endif;
if minc(st) > 0; c2=c2+1; endif;
t=t+1; endo;
"The Number of Years Monotonicity holds is:"; c2;
"The Number of Years Concavity holds is:"; c1;
st=meanc(sh);
gam=b2+st*st'-diagrv(eye(nq+1),st);
ish=ones(nq+1,1)./st; ww=diagrv(eye(nq+1),ish);
ss=ww*gam*ww;
" "; ss; {lr,li}=eigrg(ss); lr'; output off;
```