THE SAUDI AGRICULTURAL SECTOR MODEL: STRUCTURE AND POLICY APPLICATIONS

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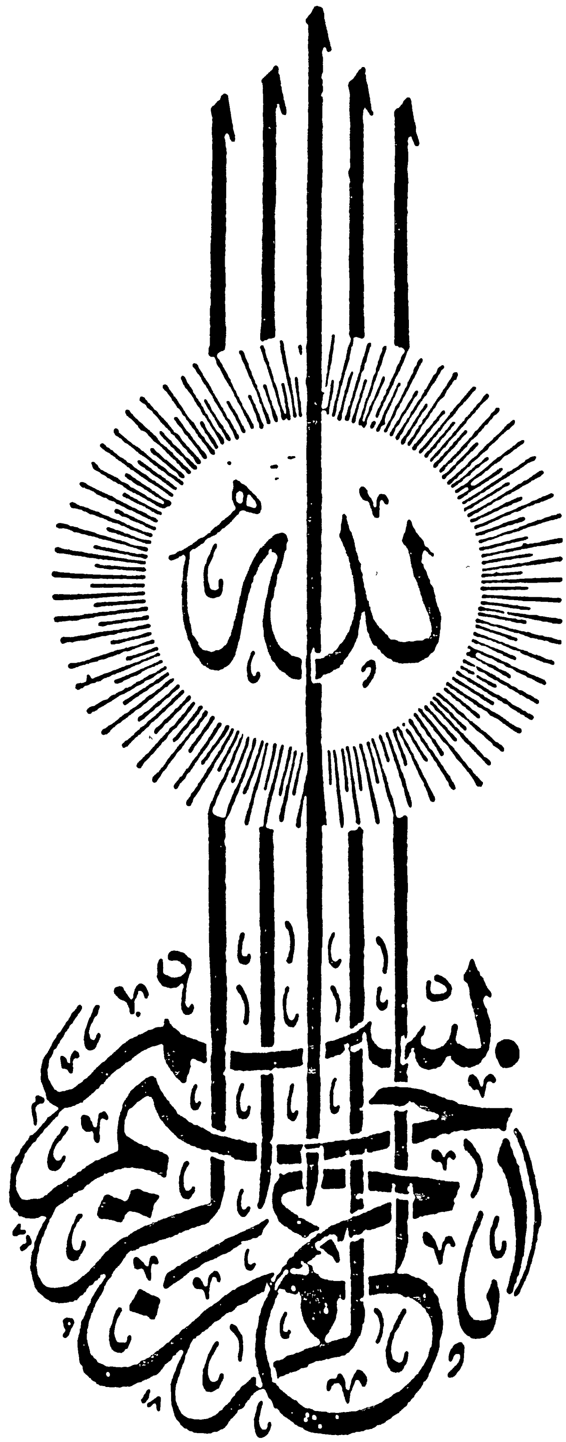

In the name of Allah the most merciful and the most beneficient

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MODEL: STRUCTURE AND

POLICY APPLICATIONS

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CHAPTER I

INTRODUCTION

Over the past decade, the agricultural sector of the Saudi Arabian economy has manifested a dynamic ability to satisfy much, if not all, of the Kingdom's food needs for the foreseeable future.

The agricultural sector offers an opportunity as well as a challenge to Saudi Arabia. It offers an opportunity because agriculture has the potential for making a substantial contribution towards the diversification of the economy, providing employment to the rural population, and lowering dependence on foreign supplies for vital food commodities. It also offers a challenge because of the scarcity of water, harsh climate conditions, low soil fertility, sand encroachment, and shortage of skilled and unskilled manpower.

It has been and remains the policy of the government to attain economic objectives through encouraging, rather than supplanting the private sector. The private sector is encouraged to build upon the infrastructure put in place by the government public sector. As a result, agricultural private sector investment was substantial during the previous and the current five-year development plans from 1980 to 1990. The Saudi government has offered generous incentives for agricultural investment for many years, but it was only at the end of the 1970s that investors began to take advantage of these incentives on a very large scale.

Parallel with the rapid rise in national income and population growth, there has been an increase in the demand for food stuffs. The food import bill during the 1970s and early 1980s increased dramatically reaching a level of $4.7 billion in 1983 and making the Kingdom the third largest food importer in the world.

Food security and food self-sufficiency has become an important goal for policy makers since the late 1970s. Twenty billion dollars were allocated to the agricultural sector during the third development plan from 1980-1985. The scale of spending put agriculture in the league of the biggest development programs since the 1973 oil era.

A broad range of policies are used to pursue the agricultural goals including interest free loans, subsidies on agricultural inputs, and price supports on selected commodities such as wheat, barley, and dates.

The results have been a successful transformation of desert dunes to fertile fields. Production of wheat increased from 150 thousand tons in 1975 to 2.5 million tons in 1987. Expansion in the production of wheat has been so successful that an excess of one million tons annually has been available for export. At the same time, the Kingdom has become self-sufficient or nearly so in eggs, chicken, and milk.

Problem Statement

Large commercial farms characterize the present trend of wheat, dairy, and broiler farming in Saudi Arabia. Saudi Arabia agriculture is very much a matter of big business rather than farming in the traditional sense. Most new investors are reaping large benefits from the subsidies and have had little past connections with land and farming. Large commercial farms dominate agricultural production and enjoy apparent economies of size over small farms.

It was only recently recognized in the fourth development plan (1985-1990) that the unconstrained expansion of output, namely wheat production using modern technologies, has had significant negative effects through agricultural surpluses, rapid depletion of nonrenewable water resources, and skewed results in distribution of benefits. It became evident that the success arising from the structure of the incentives calls for a modification of that structure or otherwise distortions will arise in the economy with increasing long-term social costs. An emerging issue in the new agricultural era is the desired balance between large scale modern farms and the more traditional indigenous sector of the agricultural and rural sector. Distribution of wealth and increasing the well being of traditional farmers is a major strategic goal of the development plans. However, because the incentives are based on volume of production rather than on income, agricultural programs tend to benefit large farms over small farms.

The dilemma of conflicting agricultural policy impacts for large versus small farms has been commonly experienced throughout the world. Kramer (1986) states that the U.S. farm program payments are frequently justified on the ground that they protect family farms or that they help financially stressed farmers. However, most benefits go to the larger wealthier farmers. The Canadian price-income support programs have resulted in a similar trend. Sprigg and Van Kooten (1988) state that one of the important problems arising when commodity-based subsidy programs are used to distribute national income to needy farm families is the tendency to confer greater benefits on larger production units because benefits are determined by size of output. Lloyd (1987) argues that in the light of the current low and unstable incomes of Australian and New Zealand farmers, government short term assistance should not include output-based subsidies that encourage overproduction and usually provide most assistance to those in least need. The emphasis instead should be placed on welfare type assistance for financially stressed farmers.

The remarkable achievements in the Saudi agriculture over the last decade were mainly through large scale high-tech farming. However, improving welfare of traditional farmers is the second main objective of the development plan next to food self-sufficiency. The issue can be reduced to two main questions: should small farms with limited efficiency be conserved and should farms using efficient capital intensive technology be encouraged?

Hypothesis

Considering past impressive development in the agricultural sector, the hypothesis to be examined can be narrowed to two premises:

1. Self-sufficiency in wheat production can be attained within the currently available resources of irrigated land and fixed investments (e.g. machineries, irrigation equipment) but at lower government and social costs.
2. The large farms are significant net gainers from current agricultural policies while the small farms are less well off because: a) large farms enjoy the advantages of current technology with the associated economies of size in producing and marketing their products over small farms and b) large farms are better able to finance the current high technologies such as wells as deep as 2,000 meters, capital intensive technologies of production, and management services needed for use of high technologies than are small farms.

Objectives

The general objective of this study is to develop an economic framework to analyze the impact of different agricultural policies on the Saudi agricultural sector with reference to farm size. Specific objectives of this study are to:

1. develop an agricultural sector model for policy analysis, reflecting the unique features of the Saudi agricultural sector;
2. evaluate the current wheat price support policy for its distributional impact on large versus small farms; and
3. propose modified agricultural policies to improve the welfare of the small farmers.

Overview of Research Procedure

To demonstrate operations of the agricultural sector in Saudi Arabia, a mathematical programming model is developed to address and analyze selected programs and policies. The Saudi Agricultural Sector Model is a national model including six major commodity groups which represent the bulk of domestic production. Resources included are land, labor, and capital. Farmers are divided into two groups, commercial (large farms) and traditional (small farms). After validating the model for the base year (1985), different simulations are made for selected policies and their impacts on different farm sizes are discussed.

Thesis Organization

The remainder of this study is divided into six chapters. Chapter II contains a description of the change in agricultural structure over the last decade. The literature review of related studies pertaining to this research are presented in Chapter III. In Chapter IV, the study will address the theoretical development of the Saudi Agricultural Sector Model.

Chapter V discusses the data, analysis, and results of the sector model for the base period. Simulation analyses of different policy instruments and their policy implications are presented and discussed in Chapter VI. Finally, Chapter VII contains the summary and policy conclusions of the study.

CHAPTER II

AN OVERVIEW OF THE AGRICULTURAL SECTOR IN SAUDI ARABIA

By the early 1980s, agriculture in the Kingdom had entered a period of unprecedented growth, following a pattern first seen in other sectors of the economy. Rapid expansion in agriculture did not begin until 1979, whereas, by that time the country's industry and infrastructure already had 10 years of intense development. During the decade 1963-1973, a small but steady expansion had taken place in the cultivated area, with moderate emphasis on mechanizing small farms. Then came a period of rapid growth in total cultivated area and the expansion of wheat production where the area in wheat jumped from 67 thousand hectares to 600 thousand hectares between 1979 and 1986.

The agricultural dynamic expansion was the result of a deliberate policy strategy launched by the Saudi government. The strategy included the following programs: 1) the Ministry of Agriculture and Water increased the size of land plots for free distribution; 2) the government increased the subsidy for wheat production; and 3) the Saudi Arabian Agricultural Bank made available large blocks of funds necessary to finance such development.

As a result of these programs the Saudi agricultural sector has been one of the fastest growing economic sectors in the world. According to the United States Department of Agriculture statistics (USDA, 1988), the annual compound growth rate of agricultural production in Saudi Arabia from 1977-1986 was 16.9 percent, the highest level in the world. Not only wheat but other commodities have experienced dramatic increases in output and changes in the structure of production. The emergence of factory-style production units for poultry and eggs, large integrated meat and dairy farms, and greenhouses for vegetables over the last decade are part of the new agricultural era.

Major changes in agricultural production, however, have brought about new policy concerns including high government cost, over production of wheat, rapidly depleting groundwater supplies, and apparent benefits absorbed in major part by large farms. Ritchie (1986), among others, has identified the high government costs and the rapidly depleting natural groundwater supplies.

A comprehensive overview of the Saudi agricultural policies and performance of the agricultural sector over the last decade is presented in this chapter. The overview presents the agricultural input, output, and infrastructural policies. The performance of the agricultural sector is presented as a discussion of key background information and the associated structural changes in use of resources (irrigated area, capital investment, and labor) and growth in production of major commodities.

Agricultural Development Objectives

Until the mid-sixties, with a smaller and more frugal population, Saudi Arabia was able to produce about half of its food requirements. Food imports started rising just after the oil revenue boom of 1973. The food import bill increased ten fold from $300 million to $3 billion between 1973 and 1979. The food import bill jumped to its highest level of $6 billion in 1982. Food imports increased to 75 percent of national demand mainly due to increases in national income and population including a relatively large guest labor force in the vicinity of 3 million expatriates. The annual average food import bill of $5 billion during the mid 1980s ranked the country among the largest food importing countries in the world. The political vulnerability of food security became a policy priority at this time (Gardner, 1988).

Diversifying the economic base and reducing dependency on oil was another strategic objective of the economy. Bringing wealth to the outlaying provinces and reducing the drift of people away from the land and to the cities were further important goals of the decision makers.

The first three 5-year Development Plans (1970-1985) show government policy goals for the agricultural sector of (1) increasing domestic food production, and hence lowering food imports and (2) developing the rural areas. However, emphasis over the period changed from one of rapid development of physical infrastructure to that of increasing the role of the private sector in increasing production but with a continuing government policy role of providing incentives.

The Fourth Development Plan (1985-1990) is more cost conscious emphasizing efficiency and improved productivity of resource use. The three major objectives of the plan provide an overall framework for agricultural development and are to:

1) achieve a satisfactory rate of increase in farm output at minimum cost by encouraging innovations which exploit the possibilities for technical change most appropriate to the Kingdom's natural resource endowments;
2) achieve a broadly based improvement in the welfare of the rural population; and
3) increase the productive and marketing efficiency of agricultural producers and to attract private capital investment into agriculture through the provision of loans on easy credit terms.

By the 1984 wheat harvest, the country had achieved wheat self-sufficiency of one million tons for the first time in contemporary history. The output went beyond self-sufficiency though with a released 300 thousand tons for export. The Saudi government incentives for increased wheat production were not intended to produce a surplus for export, the subsidies were to provide incentives until they were no longer needed for self-sufficiency (Wallace, 1985).

Bowen-Jones (1986) argues that project costs in many sectors in the Gulf countries were relatively high by international standards because of the need to move fast, and time has its own price. Ritchie (1987) noted that, agricultural policy will continue the support programs indefinitely (but) will be progressively modified to suit the needs of the planned continuing development of the agri-industrial base. Saudi Arabia is building on this established base with the (purpose) of further improving its agricultural production and (preparation for) the next stage of industrializing the food processing sector.

Agricultural Policies in the Last Decade

The Saudi Government has a long history of support to agriculture. The vast income from oil revenues is distributed to the Saudi populace through a comprehensive system of subsidized goods and services, controlled prices, and interest free loans.

The government has allocated massive resources to subsidize the agricultural sector. The results have been impressive when judged by any standard. In doing so, the Kingdom has also inherited some of modern agriculture's most persistent problems: increasing agricultural surpluses (e.g. wheat and eggs), a growing grain storage problem (e.g. wheat), and an increasing financial drain on the national budget (Gardner and Parker, 1988).

Humaidan (1980) argued that essentially the agricultural subsidies are transfer payments disbursed by the government to farmers to elicit a specific response from them. Such payments are intended to enable farmers to enjoy the fruits of the economic boom generated by gains in petroleum revenue and to reduce the overall average cost of food production.

Equity considerations, however, are now becoming more apparent. Al-Hamoudi (1984) states that the Saudi agricultural policies, due to lack of information for better planning, are often in the form of blanket policies applied to all farmers of the country regardless of individual differences. However, individual farm differences in terms of soil, weather, farm size, and labor availability are prominent. Under such circumstances, the use of policies that don't take these differences into account inevitably lead to undue waste of scarce resources.

Humaidan (1980) considered the programs as a partial fulfillment of the government's pledge to achieve a reasonable balance between the economic and social rewards available from food production and associated activities in rural communities, and those available from other forms of economic endeavors in urban areas. Joffe (1985) concluded that a large part of the domestic traditional rural agricultural labor force have not benefited from the agricultural growth because of the dependence on capital intensive technologies and guest labor expertise. The traditional labor force will be increasingly excluded through its inability to invest and its lack of appropriate skills. Gurdon (1985) said that Saudi Arabia is another example of a Middle East country which concentrated on large scale, capital intensive dairy and poultry projects, mainly at the expense of the traditional sector. In other words, the programs have led to the encouragement of large scale projects rather than expansion by settled farmers.

The government has used a variety of policy tools to achieve its objectives. It is possible to group the policies into two major categories. The first is a series of price policies which include input subsidies, interest free loans, and output support prices. In the second category are what might be called "infrastructural" policies such as research for technological change, retention dams for irrigation, and agricultural extension services.

Input Subsidies

The Saudi government's incentives to invest in the agricultural sector are attractive. The Saudi Arabian Agricultural Bank (SAAB) offers interest free loans for 80 percent of the cost of a project up to $1.5 million and 60 percent for projects up to $6 million. Fertilizers and animal feed are eligible for 50 percent cost subsidies and selected farm equipment subsidies equal 30 to 50 percent of cost. The air-freight for importing cattle is paid by the government. The full list of input subsidies and loans are provided as follow:

1. Land acquisition. Land is free upon approval of the project from the Ministry of Agriculture and Water (MOAW).
2. Poultry equipment. Subsidies are granted for 30 percent of the c.i.f. price or 20 percent if the project is benefiting from a loan from the Saudi Arabian Agricultural Bank (SAAB). Subsidies are given only on MOAW tested and approved equipment brands.
3. Dairy equipment. The same subsidy terms apply as for poultry.
4. Agricultural machinery and equipment. Subsidies of 50 percent of c.i.f. price of engines and pumps and 40 percent for other equipment such as ploughs are paid by (SAAB).

5. Agricultural loans. Loans are available from SAAB for investment and working capital. Loans may be given for land reclamation; equipment purchase; and the cost of seed, fertilizers, and drilling wells. Most loans are for 10 years. Repayment of land reclamation loans is spread over a longer period. Loans may be up to $6 million and/or 50 percent of the project cost. All loans are interest free. There is a two year grace period before repayment starts. Most loans are given according to fixed rates per item. For example, a set amount is loaned per cow for dairy projects.
6. Agro-industrial loans. Loans are for investment capital covering up to 50 percent of costs and are provided by the Saudi Industrial Development Fund (SIDF).
7. Transport of milk cows. The SAAB pays all air-freight for milking cows provided there are at least 50 cows in a consignment.
8. Seed potatoes. The MOAW pays all costs (c.i.f.) for 5 tons of seed potatoes. It then gives a subsidy of $267 per ton up to 15 tons.
9. Date palms. The MOAW gives a subsidy of $13 per tree if at least 30 tress are planted.
10 Chemical fertilizers. The MOAW gives a subsidy of 50 percent of the c.i.f. price provided the merchant importer/seller abides by the MOAW stipulated price.
11. Pesticides. The MOAW gives 100 percent subsidy.
12. Animal feeds. The SAAB gives 50 percent subsidies on cost.

The goal of increasing agricultural production was expected to be met by these programs which reduce input costs for farmers and encourage use of improved inputs.

Total loans increased from SR145 million in 1974/75 to eight times that amount in 1979/80 and peaked at SR4,166 million in 1982/83. Subsidies increased from SR46 million in 1974/75 to SR436 million in 1979/80 and peaked at SR1,378 million in 1984/85. Both loans and subsidies have gradually lowered since the peak period (Table I).

Output Support Program

If a farmer produces grains or dates he benefits significantly from production subsides. Most of the subsidies are paid to the producer on a fixed rate per ton basis.

The highly visible centerpiece of the Saudi agricultural policy program was the guaranteed wheat procurement price of SR3.5 per kilogram ($1000 per metric ton). Once self-sufficiency was attained in the 1984 season, the support price was lowered to SR2 per kilogram ($550 per ton or $15 a bushel). Although this still guarantees a wide margin over the world price, wheat growing in Saudi Arabia is costly.

The government issued a barley support price policy in September, 1986 instructing the state owned Grain Silos and Flour Mills Organization (GSFMO) to buy barley from farmers at the heavily subsidized price of SR1 per kilogram ($267 per ton or $4.80 per bushel). The government decision was to reduce the wheat surplus by encouraging farmers, especially major companies, to allocate more land for barley instead of wheat and to lower imports of barley which had

TABLE I

AGRICULTURAL LOANS AND SUBSIDIES, SAUDI ARABIA

	(SR* Millions)	
	Loans	Subsidies
1974/75	145	46
1975/76	269	134
1976/77	490	182
1977/78	586	237
1978/79	709	348
1979/80	1127	436
1980/81	2551	616
1981/82	2933	979
1982/83	4166	1321
1983/84	3496	1023
1984/85	2322	1378
1985/86	1551	994
1986/87	1019	405
1987/88	841	265

Source: Saudi Arabian Monetary Agency Annual Reports.

* U.S. $1 = S.R. 3.62

increased to 5 million tons annually and made the country one of the world's largest importers.

The driving force behind the Saudi demand for barley is the expanding livestock projects. It is believed that poultry consumes about one-third of the barley and dairy about one-fourth. The remaining amount is used for sheep and goats in the grazing areas (Parker, 1987).

Dates buying price of $800 per ton was introduced in 1983 for dates delivered to the processing factory. This policy was effective in increasing incomes of the bulk of the traditional farmers (Field 1985).

Rice, maize, sorghum, and millet are all included in the grain support program but at relatively low levels of $80, $67, $40, and $40 per ton, respectively.

Output price support programs have proven to be useful in increasing production throughout the world. Price support policies are more efficient instruments to increase production than input subsidy policies. Based on parameter and elasticity results for rice policy in Bangladesh, Nehring (1985) concluded that a 10 percent increase in output price will generate a 4.7 percent increase in output. By contrast a 10 percent decrease in the price of fertilizer would generate only a 0.6 percent increase in output. Tolley et. al (1983) noted that the effectiveness of a price support policy depends, among other things, on the price elasticity of output supply. The higher the supply elasticity, the greater the output response obtained from a given price support.

Output price support programs have been reportedly generating higher producer welfare than input subsidies, however, they promote output in commercial farms while small farms are less fortunate (FAO, 1987; Nehring, 1985).

Infrastructure and Institutional Development

Symbolic of the importance government attaches to agricultural development is the number of agencies involved. The agricultural policies and programs in Saudi Arabia are implemented and coordinated by three governmental institutions: The Ministry of Agriculture and Water (MOAW), the Saudi Arabian Agricultural Bank (SAAB), and the Grain Silos and Flour Mills Organization (GSFMO).

A primary government agency implementing agricultural policy is the Ministry of Agriculture and Water. It's wide ranging responsibilities are incorporated into seven broad programs: physical infrastructure, production, land development, agricultural services, economic studies, agricultural research, extension support, and training.

The SAAB is the main government channel for disbursing agricultural loans and input subsidies. The bank was established in 1964 and offers short, medium, and long term interest free loans.

The Grain Silos and Flour Mills Organization is in charge of administering the price support programs, including but not limited to wheat and barley procurement. It is a state owned authority with the main purposes of attaining a national bufferstock of grains and providing processed feed for the livestock farmers.

Saudi Arabia followed what Barker and Hayami (1976) called short and long run approaches of attaining self-sufficiency. The long run approach is through improvement in physical and institutional infrastructure such as irrigation and research and extension systems. However, because such programs require large investments and long gestation periods, there is always a temptation for governments to adopt shorter run policies such as supporting product prices and subsidizing inputs.

Extensive agricultural research, training, and extension programs coincidentally with water development projects have adjoined the direct financial support to the farmers. Linking production areas with marketing centers through an extended road network allows vegetable producers to efficiently market their crop where the best prices are paid. The construction of dams across valleys to utilize rain water for irrigation was greatly expanded in the 1980s. Only 16 dams were in place in 1975, but by 1985 the number of dams rose to 180.

The public and private grain storage capacity has increased to 3.25 million tons, a level never attained previously in the Kingdom (U. S. Department of Commerce, 1987).

Results of Agricultural Development Programs

Resources

Irrigated Area. The cultivated land holding area correlates with the trend of agricultural development. It increased from 150 thousand hectares in the mid 1970s to about 2.5 million hectares in 1986. The proven arable land of the Kingdom is reported to be 4.5 million hectares out of a total area for the country of 220 million hectares.

The government continues to distribute fallow lands to individuals and agricultural companies for cultivation and setting up agro-based projects. The total cumulative area and beneficiaries since 1975 is presented in Table II. Average size of land parcel distributed varies by category of beneficiary. Up to

TABLE II

LAND DISTRIBUTION SCHEME UP TO 1986, SAUDI ARABIA

Year	No. of Beneficiaries (Cumulative)	Area (Hectares) (Cumulative)
1975	6,400	40,000
1981	21,000	138,000
1986	51,134	905,302

Source: Saudi Arabian Monetary Agency Reports.

1986 the land distribution by category was as follow: land received by individuals averaged 6 hectares, owners of agro-based projects averaged 108 hectares, and land received by companies averaged 21,000 hectares.

The current policy reflects the MOAW's emphasis to encourage large-scale projects. The strategy also considers water conservation. According to MOAW policy, distribution of small plots to individuals is discouraged in favor of large scale projects because it reportedly reduces the number of wells drilled and enables the use of equipment such as center pivot sprinklers which are water saving (MOAW, 1984a).

The average size holding was 7 hectares in 1974 and increased to 10 hectares in 1982 based on two major surveys conducted by the MOAW. This indicates a general structure of small farm size. However, it also reflects the weight of the bulk of traditional small farms located in the southwest and eastern regions. On the other hand, most modern new wheat farms range in size from 400 to 1000 hectares.

Land grants are a method of distributing wealth within a country. The virgin land distribution policy places all public land under the supervision of the Department of Land Utilization, Ministry of Agriculture and Water. The land is distributed to potential investors after feasibility studies are conducted.

Historically, the cultivated areas of Saudi Arabia were developed where water was plentiful. Rainfall varies from the relatively well-watered terraces of the southwest (250-500 millimeters per year) to the almost waterless sand of the Empty Quarter.

The Ministry of Agriculture and Water, with assistance of an international consultant firm, undertook a major geological survey which identified the principal aquifers, both renewable and fossil (MOAW, 1984b). Most modern agricultural development has taken place in areas of traditional farming which for centuries has drawn on nine principal aquifers. These aquifers have been described as forming a "fertile crescent" from Tabouk in the northwest through the main agricultural areas of Hail, Qasim, Rayadh, Al Kharj, and on down to Wadi Al Dawasir. The most important is the Al Saq aquifer, especially in the eastern part of Qasim province where much of the wheat development has taken place. Another major aquifer is Umm Radmah, particularly important to the traditional date gardens of Al Hasa in the eastern region (Searight, 1986).

A major uncertainty in the Saudi farming is the water resource. Reports of falling water tables have been common in the 1980s. Agriculture claims the major share of water consumption, accounting for 83 percent or 7.4 billion cubic meters in 1987. Underground water resources are the main source of water supply. Non-renewable aquifers provide 73 percent of current water supply and the total proven reserves is estimated at 500 billion cubic meters. The remaining supply comes from surface water, renewable underground water, and desalination projects for civil use (SAMA, 1987).

Pivot sprinklers contribute to the extensive mining of the aquifers in Saudi Arabia. The estimated water extraction rate ranges from 1200 to 2000 gallons per minute (Barker, 1982; Hassan, 1984). Reports of falling water tables are numerous. Farmers near Hail in the north found that their water table fell by more than 10 meters in a season. In Al Kharje Oasis near Riyadh, an integrated dairy farm complex has experienced a 4 meter drop in their water table. Farmers in Al Dawaser in the south-central region have added one meter to their tube depth (Field, 1985).

Irrigation techniques have concentrated on center pivot sprinklers. Some projects have drilled up to 50 wells from an easily accessible aquifer to feed a system of center pivot sprinklers. An 84 meter long irrigation arm rotates on large electrically-driven wheels once every 24 hours. The water sprays onto 50 hectare circles of wheat or alfalfa. The longest of these arms observed is 500 meters and can be used to evenly disburse dissolved fertilizers and insecticides. The number of central pivot units increased from 2700 in 1982 to 14,000 units in 1985, ranking Saudi Arabia as the largest market for sprinklers in the world. The center pivots serve more than 90 percent of the irrigated area in the country (Nimah, et al., 1985b).

Expansion in the number of central pivot systems has been justified because of their labor and water efficiency. One sprinkler system can be operated by one man to irrigate 50 hectares that used to be irrigated by 30 laborers in the traditional surface irrigation technique. However, the unconstrained extraction of underground water calls for the search of a more water saving technology such as the drip irrigation technique and/or the enforcement of regulations to limit water pumping.

Capital Investment. Investment in agriculture accelerated in the 1980s, and wheat was the primary commodity target. For private businessmen, agriculture has been one of the most profitable sectors in the last 10 years. Real estate development, contracting, and manufacturing of building materials were other sectors attracting investor capital in the 1970s.

As a result of the generous support provided to agriculture and to those interested in agricultural production, a considerable number of investors have invested their own capital in agricultural projects. Two types of investors can be identified:

(1) Private individuals investing in a diverse set of agricultural projects. There are hundreds of such projects -- categorized by resource requirements as large, medium, and small.

(2) Large scale share holding companies. The majority of these companies has been established since 1980 with capital assets ranging between SR300 million to SR400 million ($80 million to $107 million) and with participation by thousands of Saudi investors. These companies are identified by name and described below:

(a) The National Agricultural Development Company (NADEC). Capital assets are SR400 million ($107 million) with the government holding 20 percent of the shares and the remainder held by 126,533 share-holders. This company is developing major agricultural projects for wheat, fodder production, dairy, meat production, and sheep husbandry.

(b) Hail Agricultural Development Company (HADCO) in Hail. This company has capital assets of SR300 million ($80 million) and 57,023 shareholders.

(c) Tabuk Agricultural Development Company (TADCO) in Tabuk. This company has capital assets of SR200 million ($53 million) and 292,555 shareholders.

(d) Qaseem Agricultural Company in Qaseem Region. This company has assets of SR500 million ($134 million) and 352,292 shareholders.

(e) The Eastern Company for Agricultural Development. This company has capital assets of SR300 million ($80 million).

(f) The Jouf Agricultural Development Company. Assets of the company are SR200 million ($54 million) with 75 percent of the stock open to the public. The remaining 25 percent is government owned. This company carried out a 70,000 hectare wheat program in the North Central region in 1987.

(g) The National Agricultural Marketing Company (Themar). This company has capital assets of SR26.83 million ($7.2 million). The number of shareholders is 158 with a maximum share holding of SR0.5 million ($133,000) per individual.

The above companies represent the high technology capital intensive agricultural projects. These companies, together with other large projects having limited ownership, represent the large scale companies in the Kingdom (MOAW, 1984a; EIU, 1988).

The increased agricultural development has increased agribusiness activities. Investors are creating new outlets for imported machinery, fertilizers, and pesticides. Operation and management services are provided to owners of land by management firms. Consulting firms are conducting agricultural project feasibility studies for potential owners. Finally, custom service agribusiness is important during the grain harvest season.

Capital is provided interest free to farmers by the Saudi Arabian Agricultural Bank (SAAB) and to major agricultural companies by the Saudi Industrial Development Fund (SIDF). Therefore, capital is readily available for Saudi agricultural development (Al Hamoudi, 1984).

Value added in agriculture increased substantially in the 1980s. From the mid 1970s to the early 1980s the relative contribution of agriculture to GDP varied from 0.91 percent to 1.75 percent (Table III). Beginning in 1983 there has been a constant growth of the agricultural value added to GDP share reaching 5.4 percent in 1987. The absolute increase in value added has jumped from SR4.6 billion in 1980 to SR14.35 billion in 1987, an increase of

TABLE III

AGRICULTURAL SECTOR CONTRIBUTION
TO GDP AT CURRENT PRICES, SAUDI ARABIA, 1975-1987
(SR MILLION)

Year	GDP in Producer's Value (1)	Value Added in Agriculture (2)	Agriculture as Percent of GDP (3)
1975	139,224	1,392	0.99
1976	163,893	1,586	0.97
1977	203,942	1,866	0.91
1978	223,818	3,909	1.75
1979	247,622	4,196	1.70
1980	383,590	4,648	1.21
1981	517,994	5,572	1.10
1982	522,176	6,740	1.30
1983	411,801	8,724	2.12
1984	368,399	9,611	2.61
1985	322,920	11,141	3.45
1986	274,720	12,589	4.58
1987	264,072	14,352	5.43

Source: Saudi Arabian Monetary Agency Annual Report (different issues), Riyadh, Saudi Arabia.

208 percent in less than a decade. However, total GDP declined by 31 percent for the same period because of lower oil revenues.

Data from the social accounting matrix of Saudi Arabia show domestic factor income by economic sector allocated to operating surpluses and compensation to employees. Operating surpluses are interpreted as a return to land, capital, and other rents. Compensation to employees is a return to labor. Between 1979 and 1982, the allocation between operating surplus and compensation of employees centered around 60 and 40 percent, respectively for the agricultural sector. This would mean that about 60 percent of value added in agriculture is attributed to land, capital, and other rents. If these shares hold for 1986, the operating surplus would be about SR3,021 per hectare for the 2.5 million hectares of land holdings.

Labor Employment. The agricultural sector employed about 40 percent of the total work force in 1974. However, with the energy shock, much of the agricultural labor moved to urban areas seeking higher paying jobs in construction, industry, and government. This has led to a decrease in the share of agricultural employment to 14 percent by 1985. The decline in rural manpower contributed to the adoption of capital intensive technologies in agriculture and the increased productivity of the employment remaining in agriculture.

Agricultural employment in Saudi Arabia has experienced a reversal in trends since 1970 (Table IV). Employment peaked in about 1975 at 695 thousand, declined to 545.6 thousand in 1980, and increased again to 617.4 thousand by 1985. During the Third Development Plan of 1980-1985, the agricultural labor force expanded at an average annual rate of 2.6 percent.

The percentage share of agricultural employment has declined from 40 percent in 1970 to about 14 percent in 1985. During that period, major

TABLE IV

TOTAL EMPLOYMENT AND EMPLOYMENT IN AGRICULTURE, SAUDI ARABIA, 1970-1985 (IN THOUSAND)

	1970	1975	1980	1985
Agricultural Employment	445.8	695.0	545.6	617.4
Total Employment	1103.8	1746.5	3026.0	4446.0
Agricultural Percentage of Total Employment	40.4	39.8	18.0	13.9
Average Annual Growth Rate of Agricultural Employment		11.1	-4.3	2.6

Source: Ministry of Planning, Development Plans (1970-1985), Riyadh, Saudi Arabia.

structural changes have taken place in the economy creating significant effects on employment including the following:

1. Total employment has increased more than 4 fold from 1.1 million in 1970 to 4.4 million in 1985. An expanding economy allowed creation of infrastructural projects and expansion in the capacities of the oil industry, services, trade, and other sectors. Despite a decline in the agricultural labor share, the absolute employment in agriculture increased from 545.6 thousand in 1980 to 617.4 thousand in 1985, an increase of about 14 percent.
2. Capital-labor substitution has been significant in the Saudi agriculture sector and has increased productivity of agricultural labor (Al-Turkey, 1986). The contribution of agriculture to the GDP increased from SR1,392 million in 1975 to SR11,141 million in 1985. The agricultural GDP per worker increased from SR2,003 to SR18,045 over the same period or about a 9 fold increase. This is largely due to the effect of intensive use of high technology, high yielding seed varieties, and chemical fertilizers.
3. Expatriate labor (guest workers) has augmented the Saudi labor in agriculture and other sectors. The expatriate labor force represents about 60 percent of the total labor force and has included both skilled and unskilled labor. Modern technologies have been brought in through specialized agricultural management companies in all types of agriculture including dairy, wheat and fodder farms, greenhouses, and irrigation.

Agricultural Production

Agriculture was the leading sector in terms of sectoral rates of growth of the Saudi economy in 1986. According to the Saudi Monetary Agency (1986) the sectors of agriculture, utilities, and petroleum refining registered the highest rates of growth at 13, 11.4, and 2 percent, respectively. The three five-year-development plans (1970-1985) show increasing but moderate agricultural growth rates. Those rates averaged 3.6 percent in the first plan, 6.9 percent in the second plan, and 9.5 percent in the third plan. Domestic food production from 1976 to 1986 is given in Table V. Saudi Arabia produced about $740 million worth of food in 1976, doubled to $1.5 billion in 1982, and more than doubled again to $3.6 billion in 1986. This is a phenomenal annual growth of 18 percent.

The greatest success of the agricultural sector is observed in four major commodity groups (Table VI), wheat, poultry products, vegetables, and dairy products. Wheat and poultry meat increased about 25 fold between 1976 and 1986 and eggs increased about 14 fold. For the same period, watermelon production tripled and grapes, tomatoes, milk, and dates doubled in volume of production. On the other hand, production of less profitable grains such as corn, millet, and sorghum declined.

Wheat. The total grain production in the Kingdom in 1986 was 2.6 million tons, of which 2.5 million tons were wheat grown on an area of 630 thousand hectares (SAMA, 1987). These data surpass the U.S.D.A. reported figures in Table VI for wheat by about 200 thousand tons. Parker (1987) reported that Saudi Arabia was the world's fastest growing wheat producer and exporter in

TABLE V

SAUDI ARABIA VALUE OF FOOD PRODUCTION, 1976-1986

Year	Food Production ($ Million)
1976	739.31
1977	849.10
1978	896.59
1979	988.95
1980	953.74
1981	1,103.10
1982	1,495.60
1983	2,025.73
1984	2,620.85
1985	3,136.04
1986	3,630.04

Source: World Indices of Agricultural and Food Production, 1977-86. USDA, ERS, Statistical Bulletin Number 759, March 1988.

TABLE VI

SAUDI ARABIA AGRICULTURAL PRODUCTION BY COMMODITY, 1976-1986

Commodity	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
	....	....	....	....	....	1,000 tons	....	....	....	....	....
Wheat	93	125	120	150	142	187	417	817	1407	2047	2285
Rice, paddy	3	3	3	3	3	3	3	2	1	1	1
Corn	15	16	16	16	16	3	4	5	5	6	6
Barley	12	14	15	16	5	6	6	13	7	10	12
Millet	17	13	13	12	9	8	11	7	7	8	9
Sorghum	153	165	182	118	109	91	147	80	125	135	127
Onions	54	106	95	118	59	14	80	57	68	73	77
Watermelon	283	140	179	332	193	385	478	616	820	855	875
Cantaloupes	42	30	27	30	40	48	55	53	64	72	80
Tomatoes	197	167	212	200	232	235	266	349	360	385	412
Oranges	14	15	19	21	15	17	24	35	37	42	47
Grapes	42	56	53	60	62	61	67	85	79	92	105
Dates	257	382	411	412	414	371	417	438	450	470	507
Beef and Veal	24	21	23	24	25	27	30	33	37	40	44
Mutton and Lamb	45	46	46	47	49	53	58	60	62	65	75
Poultry Meat	12	15	20	24	50	55	82	137	201	250	305
Milk	200	305	331	337	214	231	277	320	335	353	420
Eggs	15	19	20	29	29	54	75	105	130	160	210

Source: World Indices of Agricultural and Food Production, 1977-86. USDA, ERS, Statistical Bulletin Number 759, March 1988.

the 1980s. It appears that Saudi Arabia will become the top Arab wheat producer.

The 1987 harvest as reported in the Economist Intelligence Unit Report (EIU) show that production from 687 registered farm companies and projects rose to 1,544,000 tons. Total production, taking into account the many smaller farms who are eligible to sell to the Grain Silos and Flour Mills Organization (GSFMO), is estimated at 2.5 million tons (EIU, 1988). These data suggest that the large agricultural companies and projects produce about 62 percent of the total wheat while the bulk of the small farms are producing only 38 percent of the total volume. Hence, most of the output-based price support program benefits are absorbed by the new high-tech, large agricultural enterprises.

Book value of wheat production costs are declining as farmers become more experienced and as fixed costs are written off. Tolley et. al (1983) observed that over time, output price support may facilitate farm investment in new technology, thereby limiting future price increases. The Saudi Arabian Agricultural Bank estimated average production cost per ton to be around $500 in 1981 (SAAB, 1981). In 1985, reported production costs centered around $240 per ton. The lowest production costs reported are about $190 per ton for the most efficient and cost conscious farmers (Nimah, et al., 1985a).

Initial fixed capital costs were studied in a representative large project by a team of agricultural engineers in Saudi Arabia. Apart from the agricultural machinery and site development, the main factors making farming a costly venture is the digging of wells and irrigation equipment. In Saudi Arabia, the depth to water varies from 500 to 1000 plus meters. Such depths are very costly, especially when compared to the 300 feet depths reported in much of the United States. The digging of wells and purchasing and installing sprinkler irrigation systems accounted for 30 and 27 percent, respectively, of the total fixed investment for the representative project (Nimah, et al., 1985a).

Official Saudi figures put wheat sales abroad in 1987 at 1.4 million tons and donations at 337,000 tons. Wheat sales in 1987 were reported to the USSR, Colombia, China, Indonesia, Malta, Lebanon, Norway, Jordan, Portugal, the United Arab Emerates, and West Germany (EIU, 1988).

Concerns of excess capacity in wheat production and the need to lower barley imports (about 5 million tons annually) enhanced the lowering of the wheat output support price in 1985 from $1000 a ton to $571 a ton. A barley output support price of $265 per ton was introduced to encourage barley production. The five largest agricultural companies were encouraged to switch 30 percent of their wheat area to barley. The fourth five year development plan has clearly expressed the objective of stabilizing wheat production and expanding production of other crops (such as fruits and vegetables) and livestock (MOP, 1985).

Vegetables and Fruits. Most vegetable production is for local markets and thus the volume is low, markets are widely scattered, and sometimes markets are in remote areas with few marketing services. Saudi Arabia vegetable production equalled more than 1 million tons in 1986, double the amount of 1977 output, with melons, tomatoes, squash, eggplant, and cucumbers the main crops. Demand for some vegetables has grown faster than local output resulting in higher prices. The shift of some vegetable areas to wheat production, together with a large guest labor force, has contributed to a rise in vegetable imports, particularly from Turkey and Jordan.

Hundreds of agribusiness projects have installed greenhouses to produce more vegetables. As of 1986, the number of greenhouses peaked at

236 compared to 158 in the preceding year. Considerable success is observed in greenhouse production especially in raising cucumbers and tomatoes with enclosed humidity controlled conditions. By using the hydroponic techniques, farmers are able to harvest products year round.

Fruits also have increased in production from 420 thousand tons in 1980 to 720 thousand tons in 1986. Date production has increased to 550 thousand tons ranking the country as the largest date producer in the world.

Export of vegetables occurs seasonally to neighboring countries especially in watermelon and tomatoes. Date exports equal 21,000 tons annually with larger volumes expected in the future in response to output price support and a recent expansion of processing and packing plants.

Parker (1985) and others note that the market move to wheat has caused a crowding out of vegetables, especially onion. Farmers have found it more profitable to grow wheat on newly irrigated land than vegetables because of favorable wheat prices and the use of mechanized farming that greatly reduce the need for manual labor.

Poultry. During the last ten years the poultry industry has been booming in the Kingdom. An unprecedented expansion in the poultry industry has led to self-sufficiency in the production of eggs and a more steady progress in broiler production. Saudi poultry projects provide more than 70 percent of the national demand for broilers. Consumption of chicken has been greatly stimulated in recent years by the high price of substitutes, mainly lamb. Saudi Arabia has the highest per capita consumption of poultry meat in the world (Qureshi, 1986).

Subsidies for feed and facilities have contributed to the rise in poultry meat production from 82 thousand tons in 1982 to about 305 thousand tons in 1986. With continued growth in the poultry industry the Kingdom should be self-sufficient in broiler meat production by 1990. Broiler meat imports, mostly from

France and Brazil, have declined from 212 thousand tons in 1982 to 83 thousand tons in 1986. Although the price of local chicken is not controlled, it averages about SR7 or $2 per bird in the retail market.

Egg production saturated the domestic demand in 1984 of 2 billion eggs and allowed about 10,000 tons for export to neighboring Gulf countries. Exports are forecasted to increase substantially in the future.

The major problems facing the poultry industry are related to performance in the high-tech operations and distribution of marketings over the year. Poultry houses are ranked among the best in the world but problems remain in obtaining required cooling, ventilation, and humidity for improved broiler production and performance. A number of processing plants are reported to be operating at 75 percent of capacity because of maintenance problems. The lack of marketing infrastructure and institutions has led to periodic glutted markets, low prices, and discouraged producers, particularly the small producers.

Future prospects for the poultry industry are bright. Ease of entrance and the generally reasonable marketing outlets have encouraged many businessmen to invest in the industry. The egg producers are mainly two segments. There are some small 10,000 bird laying flocks, and several others of up to a million layers. Broiler producers are more conglomerated, with about 14 companies having the capacity to produce more than a million broilers a year, but the two largest companies located in western and central regions have a combined capacity of 135 million birds. There is still room for growth in poultry meat production to replace imports. Exports of poultry products to neighboring Gulf countries started five years ago. The industry in Saudi Arabia has a comparative advantage over countries at a farther distance in delivering fresher products. However, it remains to be determined whether the industry can reduce costs sufficiently that subsidies are no longer necessary.

Dairy and Other Livestock. Milk production increased by 15 percent in 1986 to 457 thousand tons, up from 417 thousand tons in previous years. This data surpasses the U.S.D.A. reported figures in Table VI. This could, however, meet about 30 percent of the total domestic consumption of 1.5 million tons. The gap between consumption and domestic production was filled by imports of more than 700 thousand tons of powdered milk (SAMA, 1987).

Dairy farms are usually large, thereby allowing them to develop integrated marketing facilities including processing plant, cold storage, and refrigerated trucks. Thirty-eight dairy projects are operating in the country with about 37,000 cows. Joint ventures are common with Saudi partnerships occurring with Danish dairies and the Mastock systems of Northern Ireland. One of the newly established dairy farms is claimed to be one of the world's largest integrated dairy complexes.

Productivity is high by international standards reaching 6200 liters of milk per cow (Arbus, 1983). Cows are fed green alfalfa year round.

The lack of milk cooperatives or independent processors imply that new producers must invest not only in cows but also in processing and marketing operations. This restricted entry discourages small producers. Field (1985) suggested that the major Saudi agricultural companies should encourage small dairy farmers by purchasing their unprocessed milk in return for a fair price. Thus, the burden of processing, cold storage, and marketing would be alleviated for the small producers.

Farms producing other livestock have attracted investors in recent years. According to the MOAW there were 94 sheep fattening and breeding farms in

1986 with an annual production capacity of 1.39 million head. Eight beef feedlot farms are in operation, producing 109 thousand head per year. However, the raising of camels, cattle, goats, and sheep is still a major traditional practice in the grazing and rural areas. The total number of sheep in the Kingdom including both traditional and specialized feedlot farms runs up to 7.6 million head (MOAW, 1986).

Most of the locally produced red meat comes from animals imported live for slaughtering. Imports from Turkey, Australia, and East Africa make up the 63 percent deficiency in domestic production.

Productivity

Structure of Traditional and Commercial Producers. The rapid expansion in agricultural production in Saudi Arabia started in 1979. Although the take-off stage correlates with the beginning of large farm development, the traditional small farms of 4-7 hectares still make-up the bulk of the holdings under cultivation (Table VII).

The traditional farm is generally serviced by a single well and employs a belt driven pump powered by a diesel engine. It normally has cultivated crops, date palm trees, and possibly other crops such as grapes and citrus. The cultivated crops would consist of some vegetables such as squash, tomatoes, eggplants, carrots, and watermelons; a small amount of wheat, millet, or sorghum; and possibly some alfalfa for sheep.

The farmland is generally irrigated through locally lined open channels and on-farm basin systems. This system will irrigate uneven ground that can not be serviced by sprinkler pivot systems. Management and operation is by the owner and his family members or by tenants in some cases. Small amounts of hired labor are used on a permanent or temporary basis.

Table VII

NUMBER AND AREA OF HOLDINGS BY SIZE, SAUDI ARABIA, 1982

Size Classes (Hectare)	Area (Hectare)	Number
Under 5	202,675	153,695
5-50	693,232	51,920
51-500	663,860	6,240
Over 500	575,266	302
Total	2,135,033	212,157

Source: Ministry of Agriculture and Water "Census of Agriculture according to farm size 1981-1982" Riyadh 1985.

Vegetable and fruit products are transported by the owner to the market. Because of a lack of cold storage, traditional farmers have few choices but to sell their products at harvest time regardless of price.

The large commercial farms are generally fully irrigated using center pivot sprinklers, are worked with 250 plus horsepower wheel tractors, and use the most modern implements. Operation and management is frequently contracted using experts from the United States or Europe and the bulk of manual labor comes from East Asian countries. Land preparation is usually combined with application of chemical fertilizers to eliminate nutrient deficiencies. If the farm is producing wheat, private grain silos are established in the field to hold grain temporarily until it is delivered to the governmental grain silos.

Yields. The primary impacts of the new technologies in the Saudi agriculture have been to increase output, lower the average cost of production, and in many instances to increase the size of the farm. The agricultural sector is experiencing a dynamic structural change in response to the new technologies and incentives. This structural change is in itself a source of growth as the national crop composition shifts in favor of higher valued outputs. High yielding varieties , irrigation equipment, and skillful farm management are major sources of growth via yield increases (Norton, 1984).

Significant growth in yield in almost all commodities has occurred in Saudi Arabia. Trends in yields for 12 principal commodities over the 1974-1986 period are presented in Table VIII. It is apparent that the wheat pricing policies have significantly increased yield. Onion yields, on the other hand, declined due to allocating the best land to wheat. Yields of milk and eggs increased even though these products were produced on specialized farms as early as the 1970s.

TABLE VIII

TRENDS IN YIELDS FOR TWELVE MAJOR AGRICULTURAL COMMODITIES, SAUDI ARABIA, 1974-1986.

Year	Wheat	Barley	Sorghum	Tomato	Onion	Dates	Melon	Watermelon	Grapes	Citrus	Milk*	Eggs**
						Tons/Hectare						
1974	1.84	1.48	0.42	11.66	19.07	5.92	28.14	11.96	9.47	8.09	9.03	174
1975	2.13	2.37	0.54	14.42	20.22	6.34	18.75	10.88	14.53	5.48	10.00	177
1976	1.25	1.25	0.51	10.37	16.64	4.25	10.81	19.94	9.33	5.97	10.00	179
1977	1.74	1.66	0.51	11.01	20.88	7.13	18.16	19.67	8.50	6.07	10.00	180
1978	2.00	1.85	0.50	10.67	25.99	7.05	17.53	13.35	12.76	7.48	10.00	188
1979	2.09	1.53	0.52	11.60	22.18	6.69	15.42	17.90	12.33	7.42	10.00	200
1980	2.11	1.24	0.31	11.36	18.12	5.67	18.36	20.14	13.52	7.87	10.50	200
1981	2.55	0.76	0.52	18.05	18.38	5.95	13.37	14.83	15.01	6.32	10.50	202
1982	2.76	1.44	0.69	14.71	10.16	5.83	17.02	16.20	14.81	7.78	10.44	225
1983	3.33	1.98	0.79	13.55	13.36	7.33	20.76	21.14	11.05	7.73	10.76	219
1984	3.47	2.08	0.93	12.08	11.08	8.08	38.10	20.50	12.88	7.67	11.00	220
1985	3.63	2.15	1.15	13.20	11.94	7.62	58.00	20.36	15.22	7.67	11.01	234
1986	3.87	1.88	1.15	13.20	11.40	7.60	57.14	20.33	15.09	7.67	11.29	231
Percentage Change Between 1974-76 and 1984-86	110.34	20.00	120.00	5.60	-37.00	41.30	165.00	15.00	29.50	18.00	14.70	29.00

*Milk yield is tons/cow

**Egg yield is eggs/chicken with average egg weight of 55 grams.

Source FAO computer printout statistics about Saudi Arabia, Rome 1988.

Wheat yields of 8 tons per hectare, i.e. more than double the national average, have been reported in Tabouk of northern Saudi Arabia. Subsidies cover the entire cost of selected wheat seed varieties. The GSFMO accepts only Probate and Mexican Dwarf (Yecora Rojo) wheat varieties for subsidy at this time.

Farm Prices and Incomes

While Saudi Arabia has made substantial gains in agricultural development it nevertheless remains as one of the largest food importers. Domestic prices of goods and services are thus influenced by the trading partners.

Producer prices for selected commodities were assembled from FAO statistics and other sources and are presented in Table IX. The upward trend in prices in the international market in the 1970s is obvious in the Saudi farm gate prices. Unfortunately, there is no available farm gate price series after 1981.

The domestic commodities are facing competition from food imports. The producer price to c.i.f. import price ratios for selected commodities are presented in Table X. The data illustrate that domestic prices for more than half of the selected commodities are higher than the international import price. Dates and most livestock products show domestic producer prices below world market prices. However, feed subsidies reduce the livestock product per unit production cost thus allowing for lower producer prices.

Farm income data are not available for Saudi Arabia. Thus farm income estimates are best represented by net revenue generated from farm plans, given in other studies. This approximation can serve the purpose of obtaining the magnitude of the annual income of farmers with different size land holdings.

TABLE IX

COMMODITY PRICES AT THE PRODUCER LEVEL, SAUDI ARABIA, 1970 - 1981 SR PER TON (CURRENT VALUES)

Year	Wheat	Barley	Sorghum	Watermelon	Melon	Dates	Grapes	Citrus	Onion	Tomato	Lamb	Beef	Broiler	Milk	Eggs
1970	810	630	740	270	490	530	690	450	390	360	5886	5788	3055	2187	2156
1971	800	630	480	250	550	510	640	420	290	340	3651	6148	3212	2940	2379
1972	730	570	320	290	640	500	730	480	440	310	4825	6507	3016	3378	2604
1973	850	660	370	340	740	580	850	560	510	360	6376	7004	3617	2598	2924
1974	1000	780	440	400	870	680	1000	660	600	420	7690	8674	3697	3214	3657
1975	1200	930	520	470	1050	820	1200	790	720	510	5424	7567	3700	4329	3170
1976	1470	1150	640	580	1290	1010	1470	970	890	620	6597	6915	4162	3910	2709
1977	1780	1390	780	710	1560	1220	1780	1170	1070	760	7194	7927	4275	4353	3743
1978	1740	1360	760	690	1520	1190	1740	1140	1050	740	7367	6662	4159	4428	3664
1979	3500	1200	780	710	1560	1220	1790	1170	1080	760	6339	7066	3830	4797	3710
1980	3500	985	830	760	1660	1300	1900	1250	1150	810	6227	7705	4796	3179	4324
1981	3500	975	890	800	1770	1390	2030	1330	1220	860	6746	8073	3586	4769	6662

Sources: Grain prices were obtained from Parker (1988) "Saudi Arabia Coarse Grains Market." For the remaining commodities, farm gate prices are reported by FAO up to 1981.

TABLE X

COMMODITY DOMESTIC PRODUCER TO
C.I.F. IMPORT PRICE RATIOS, SAUDI ARABIA, 1985
U. S. $ PER TON

Commodity	Domestic Producer Price (1)	Import C.I.F. (2)	Domestic To Import Price Ratio (3)
	U.S. $ Per Ton		
Wheat	571.00	280.00	2.04
Barley	219.60	132.00	1.66
Sorghum	261.00	203.00	1.29
Tomato	416.00	184.00	2.26
Onion	451.60	159.00	2.84
Watermelon	292.54	264.00	1.11
Melon	652.20	213.00	3.06
Citrus	483.15	320.00	1.51
Grapes	736.00	633.00	1.16
Dates	495.00	749.00	0.66
Beef	1627.90	1830.00	0.89
Mutton and Lamb	1836.70	2037.00	0.90
Broilers	1162.00	1211.00	0.95
Eggs	1203.87	2183.00	0.55
Milk	988.67	805.00	1.23

Source: Domestic producer prices are projected from Table IX on trend basis. Import C.I.F. prices are obtained from FAO Printouts about Saudi Arabia. 1988 Rome.

Humaidan (1980) estimated the net revenue generated in the Al-Hasa irrigation and drainage project of 16 thousand hectares at SR988 million. Following his convention of considering 4 hectares as the average size farm gives a per farm net return of SR243 thousand.

Battal (1986) reports the optimal production plans for representative farms of different sizes in the Al-Kharj oasis near Riyadh. The annual net return for small and medium size farms was estimated at SR203 thousand. For farms of 792 hectares net returns amounted to SR15.7 million, almost 77 times the income of the small and medium size group. Nimah, et al., (1985a) estimated the production cost for a ton of wheat in a new project with 3500 hectares to be SR722. With the project yield of 5.4 tons per hectare and the wheat support price of SR2,000 per ton, the calculated annual income is about SR6,900 per hectare or SR24.2 million for the project.

In summary, small farm annual net returns fall in the range of SR200-240 thousand while that of the large farm (project) group runs to SR15-25 million.

Government Program Costs

The government is committed to developing the agricultural sector for purposes of reducing the Kingdom's dependence on food imports. Government programs include subsidies to the private sector and major expenditures for infrastructural development. Government direct investments during the last 15 years have included crop research stations, animal breeding centers, grain silos and flour mill complexes, and dams across the valleys.

The amount of subsidies provided to the private sector are presented in Table XI. Government spending for agriculture in the First Development Plan (1970-1975) was estimated at SR280 million. The Second Development Plan

TABLE XI

GOVERNMENT PROGRAM COSTS FOR AGRICULTURE LOANS, INPUT SUBSIDIES, AND WHEAT OUTPUT PRICE SUPPORTS, SAUDI ARABIA, FROM 1970 TO 1988 (SR MILLION)

	Loans	Subsidies		
		Inputs	Output (Wheat)	Total
First Plan (1970-1975)	235	46		46
Second Plan (1975-1980)	3,181	1,337	525	1,862
Third Plan (1980-1985)	15,468	5,317	10,395	15,712
Four Years of the Fourth Plan (1985-1988)	3,411	1,664	15,242	16,906
Total	22,295	8,364	26,162	34,526

Source: Saudi Arabian Monetary Agency Annual Report, 1988.

coincided with the oil shock of 1974 resulting in farm subsidy costs of SR5 billion. A larger commitment, however, is observed in the Third Development Plan (1980-1985) where agricultural program spending amounted to SR31 billion (or U.S. $9 billion), six times as much as the preceding plan. About fifty percent of the third development plan spending was directed toward short and medium term loans while one third was wheat support price payments.

The Fourth Development Plan (1985-1990) shows a reduction in expenditures to the agricultural sector due in part to the persistent decline in oil prices and to the completion of major agricultural infrastructure projects. However, for the first four years of the Fourth Development Plan the spending amount was SR20.32 billion. Wheat price support payments for the last four years represent an even higher proportion of the total wheat program payments of the previous plan.

Between 1970-1988, total program cost was SR57 billion (U.S. $15.4 billion). These payments represent direct loans and subsidies to farmers. Wheat purchase program payments totalled SR26.2 billion since its introduction in 1979. The 1985 wheat harvest of 2.29 million tons is costing SR4.58 billion as output price support expenditures. Exports of 0.79 million tons leaves about 1.5 million tons for domestic consumption. If the local production of wheat is lowered to 1.5 million tons to allow for self sufficiency, the wheat price support payments should be reduced to about SR3 billion.

Agricultural policies in Saudi Arabia are not too different than in many other countries including the developed countries. The amount Saudi Arabia spends on subsidizing agriculture can be compared with other developed countries. Dommen (1987) shows that the cost of supporting agriculture in both the United States and the European Community has grown rapidly. The United

States' outlays for price and income supports reached a record of $25.8 billion in 1986, up from $4 billion in 1981. The European Community price support expenditures were about $22 billion in 1986, up from $13 billion in 1981.

Saudi Arabia could import food from world markets at prices much lower than it currently costs to produce under desert conditions. The Saudi Minister of Agriculture and Water has stated that "obviously Saudi Arabia has chosen the hard path to attain food security by means of self-sufficiency." However, decision makers consider the infrastructural costs as an investment in social overhead. Furthermore, decision makers have determined that investment in agriculture and a degree of food self-sufficiency has brought about a certain amount of national pride and dignity (Al-Sheikh, 1988).

CHAPTER III

LITERATURE REVIEW

The Agricultural Sector Approach

Agricultural sector modelling is a term used to describe a rather wide range of formal analytical efforts to study the agricultural sector of an economy as a system. A growing interest in this area came about in the 1960s as economists became sensitive to the need to formally consider the agricultural sector as a whole as they attempted to study its performance and to analyze policies which affected its participants (Langham and Retzlaff, 1982).

Large scale programming models of the agricultural sector have become common. This trend towards a more structured sector framework has not led to more versatile general purpose policy testing models, but rather has resulted in specific purpose models with rigorously defined structural relationships.

Increased computer capacity and innovations in programming methodology have brought about new opportunities for the construction of large-scale models which reflect much more closely the sector being modelled. As sector programming models have increased in number, they have also increased, individually, in size and complexity. Enormous man-hours and data requirements are commonly reported in popular agricultural sector models throughout the world.

In the forward to the Book of CHAC, Earl O. Heady stated that programming models, econometric models based on time series data (where available), and simulation models all have unique roles to perform in the evaluation of policy outcomes and alternatives. Programming models have an advantage when it is important to indicate "by how much and where" investments and change should be made, particularly when time series data are not generally available.

Programming models are especially useful for analyzing the potential effects of change on resource use, productivity, and the generation of employment and income. In this sense, they are an important set of the quantitative techniques needed to assess development and policy alternatives in all countries (Norton and Solis, 1983).

McCarl and Spreen (1980) made a comprehensive survey of sector models. It included a tool-purpose specification of different approaches. Input - output analysis, econometrics, and mathematical programming were the major modelling endeavors. In studies of the entire economy where linkages between sectors are of interest input-output analysis has been used. In other studies where the objective has involved identification of a sector's structure, various econometric approaches have been taken. To simulate the effect of new policies upon a sector, however, mathematical programming has proven to be a particularly useful tool.

As an illustrative example of such an approach, the CHAC model for Mexico (Norton and Solis, 1983) and the Turkish Agriculture Regional Programming Model (TARP) developed by Cakmak (1987) share common features. They simulate potential reactions of farmers to changes in policy. They present the government policies -- such as price support, input subsidy, etc. -- and evaluate their effects as interventions on producers income, employment, and other variables in a basically competitive market. No attempt has been made to derive "optimal" policies with the models; rather the power of analysis is applied to assist in understanding the multiple consequences that would follow from specific policy options.

The role of the mathematical programming model differs in sector levels compared to farm levels. At the farm level, the mathematical programming model role is normative. That is, the farm level models estimate what would happen given certain goals and resources. Also it prescribes what should be done given certain means to maximize the ends. The decision maker (e. g., farmer) specifies his decision rule (e. g., profit maximization) and the model optimizes the decision rule given the associated constraints.

At the sector level, where the modelling technique typically covers the production and disposition of all major crops and animal products in a country, the usual objective of the model is to determine the behavioral structure of the agricultural sector in response to possible policy changes. In other words, the producer's reaction to external changes are described (descriptive or positive) by corresponding solutions to different policy alternatives.

Sector modelling has received increased emphasis by economists and planners. This emphasis stems from the increased use of governmental policy to encourage economic development and the need to investigate possible outcomes (sometimes unexpected) of different policies to various segments of the agricultural sector.

The farm level programming model does not permit evaluation of optimal allocation of resources at the sectoral level, or costs and benefits of policy alternatives from a social view point. These questions require a broader perspective on markets, prices, regional production possibilities, resource utilization and endowments, distributional impacts, and international trade than is possible with farm level studies. Therefore, sectoral modelling is ideally suited to addressing macro policy issues (Roth, 1986).

Application of sector modelling for policy related questions is enormous. Hazell and Norton (1986) discussed different ways of utilizing existing sector models for Mexico, Egypt, and Turkey. Analysis of pricing policies, evaluation of investment projects, and analysis of comparative advantage for export of certain crops are some of the useful applications of sector modelling.

In the U. S., House (1985) developed the USMP regional agricultural programming model. It is a price endogenous, spatial equilibrium mathematical programming model developed to address contemporary issues in the U. S. agricultural policy. It involves adjusting policy or market variables, and measuring impact on commodity and factor prices, production, utilization, income, and expenditure accounts.

The distributional impact of lower grain prices on different regions in Canada was discussed by MacGregor and Graham (1988). Their study built upon the Canadian Regional Agricultural Model (CRAM) which was developed by Webber, Graham, and Klein (1986). They concluded that the loss of farm value added in response to lower grain prices was greater in regions of intensive grain production. Tewari and Kulshreshtha (1988) used a quadratic programming model of the agricultural sector to assess the impact of rising energy prices on Saskatchewan agriculture. The model predicts that increased energy prices would cause a decrease in the level of production due to lower fertilizer use, product demand, energy use, and consumer surplus.

Models for Market Equilibrium

Many governments and aid donors have recognized that greater emphasis has been placed on understanding the problem of agricultural change. Relations between and among goals need to be understood, as well as the consequences of alternative policy choices on a given target. Hence, the construction of quantitative models for market equilibrium become invaluable for providing effective policy guidelines.

Measurement in economic research should occur with the best methods available. The question is not one of whether to measure or not to measure, but how best to measure (Langham, 1982). Agricultural sector models provide measurements for economic policy analysis and have been developed for different purposes. Researchers have used significantly different techniques depending on the objective and resources available. Simulation system models, econometric models, and mathematical programming models represent the major modelling techniques in the profession.

System Simulation Models

The Korean Model represents an application of the general systems simulation approach. It represents a joint effort of a research team from Michigan State University in close collaboration with officials and researchers in Korea. It is a second generation model building on methods developed and lessons learned in a similar study by a Michigan State University team in Nigeria. The objectives of the Korean Agricultural Sector Model were to analyze and prescribe policies and programs for agriculture in a comprehensive and complex system. No attempt was made to maximize an "objective" function in a mathematical sense (Egbert, 1978).

The authors of the Korean Agricultural Sector Model reported that the model was not a prescriptive, problem-solving model. Rather, it was a descriptive, subject-matter model designed to utilize concepts, data, and theories from the relevant academic disciplines for addressing a set of problems related to the development of the agricultural sector. The model can be used to project and compare the consequences of alternative courses of action related to a particular problem (Lee, et al., 1982).

Large scale simulation systems have been criticized for their considerable resource requirements for model development, maintenance, and computer capacity. The Nigerian Model, for example, required approximately ten man-years of professionals (Thorbeck, 1973). Further, such models are regarded as experimental and potential payoffs come about through increased understanding of basic economic relationships rather than through short- or intermediate-run policy prescription (Langham 1982). Failure to recognize this fact has led to false expectations and disappointment by both policy makers and researchers. If a systems model is to be developed, it should be problem specific and focus on a limited number of relationships.

Econometric Models

Econometric modelling is used for identification of sector structure. It explains how the sector works, identifies the important variables or factors, and their functional relationship, and provides estimates of parameters. Econometric models have been used for single commodity as well as multi-commodity analyses.

Single commodity econometric modelling takes many forms. Commodity demands are usually analyzed in terms of factors affecting consumption and commodity supplies are analyzed in terms of availability and sources of inputs. Elasticities are extracted for analysis of policy implications.

Multi-commodity econometric models have been used to analyze the structure of the U. S. agricultural sector. Ray and Moriak (1976) developed an econometric model called POLYSIM. The crops subsector includes wheat, soybeans, feed grains, and cotton and the livestock subsector includes cattle, calves, sheep and lambs, chickens, turkeys, eggs, and milk. This is a comprehensive model where allowance is made for interaction between the two subsectors.

Another model is the Collins and Taylor (1983) TECHSIM. Major emphasis of this model is on tracing the effect of technological change on welfare of producers and consumers. Changes of technology include pesticide reduction policies, farm size, and genetic improvement in field crops and livestock breeds. Effects of technology are modelled through changes in yields or costs of production. Policies are evaluated based on changes in production, prices, farm rents, and producer and consumer welfare.

The econometric sector models heavily utilize time series data which are readily obtained in developed countries. However, when the structure of the agricultural sector is dynamically changing as in Saudi Arabia, econometric models fail to capture changes caused by new crop varieties, size distribution of farms, and pricing policies.

Hazell and Norton (1986) argued that the main problem with relying only on econometrics is twofold: data difficulties and changes in underlying economic structure. The data problem arises because of insufficient data series with enough degrees of freedom to estimate regional or national cost and production functions econometrically. Data on farm income, farmgate prices, and farm labor are another obstacle to overcome, which forces the researcher to use cross-section farm level survey data.

Mathematical Programming Models

The use of mathematical programming to simulate market behavior has been explored extensively in a number of studies since Samelson first pointed out in 1952 that an objective function exists whose maximization guarantees fulfillment of the conditions of a competitive market.

The mathematical programming framework can be readily used to conduct agricultural policy analysis. The effects of different scenarios are captured by changing parameters and the constraint specifications. Furthermore, it provides regional detail necessary for analyzing interregional impacts of alternative policies. Finally, the technological alternatives in agriculture production are numerous and can fit naturally into a process analysis production framework.

The literature contains several types of agricultural sector programming models. They can be classified according to the level of aggregation (regional, national, multiple country), or by the methodological approach used in the formulation of product supply and demand (exogenous or endogenous prices).

Agricultural Sector Programming Models

Price Exogenous Models

Large-scale price exogenous linear programming models have been used extensively by agricultural economists to simulate the impact of farm programs upon the agricultural sector. These types of models have included the restrictive assumption of fixed market prices or quantities, thereby ignoring the interrelationships of aggregate price and quantity (McCarl and Spreen, 1980). Heady and Egbert (1959) developed a spatial linear programming model for the U. S. agriculture. The model dealt with finding the pattern of production (location and amount of production) of wheat for food, wheat for feed, and feed grains that would meet the final consumption needs for the United States, plus export demands. The study divided the country into 104 producing areas, and aimed at minimizing costs of production and transportation to satisfy national demand plus export demand.

The linear programming simplex method was utilized to arrive at the spatial competitive equilibrium solution. Results of these models indicated regions that should withdraw from production if an "efficient" production was to be obtained.

To partially account for the differences in production efficiencies existing among farms located in the same area, the farm size delineation was addressed by Evindson, Heady, and Srivastava (1975). Their model delineates the farms in each area to three farm size classes. The results of this study show a marked comparative advantage on large over small farms in crop production, and some livestock production. Small farms have, however, a comparative advantage over large farms in other groups of livestock.

A national crop model of Thailand was developed in a joint collaboration effort of the Thailand Ministry of Agriculture, the U. S. Agency for International Development (USAID), and Iowa State University. Stoecker and Khatikran (1982) reported the purpose of this study was to provide a basis for analysis of alternative crop production levels and technologies in relation to livestock production and production in nonagricultural sectors. A fixed point demand model was assumed for this analysis with about 350 to 450 equations analyzed for different policy issues.

The above studies included the restrictive assumption of fixed market prices or quantities, i. e. demand was exogenously determined outside the model. The quantity demanded of each commodity is calculated by multiplying per capita consumption by the number of people in a given region (Stoecker and Li, 1988). This technique does not necessarily represent reality. The quantity demanded of agricultural products is affected by their prices.

Production levels have significant effects on prices. Thus, the levels of production determined have an impact on the quantity demanded through prices (Al-Turki, 1986).

Although the fixed demand models can be used for different economic analysis, their objective function specification fails to simulate the competitive or monopolistic market forms. Therefore, this type of modelling is considered as an extension of the normative farm planning model. The dual solution of this specification is sometimes used to discuss supply prices, but market equilibrium prices can not be obtained (Kutcher and Norton, 1982; Hazell and Norton, 1986).

Sector programming models can not successfully simulate market equilibriums without the introduction of downward-sloping product demand curves. Endogenizing demand allows the model to more closely correspond to how market equilibriums are determined.

Price Endogenous Models

Agricultural policy analysts have long used price endogenous sector models. Such models follow the surplus maximization approach familiarized by Samelson (1952), Takayama and Judge (1964a, 1964b, 1971), and Duloy and Norton (1975).

The notion that an optimization problem could be stated so as to simulate, or describe, the market behavior of economies was introduced by Samelson (1952). Samelson showed that the maximization of a single function (the sum of producer and consumer surpluses or the "net pay off" function) induces the model to replicate a competitive equilibrium in a single-product market. The objective function no longer reflects the behavior of an agent, e. g., producer, but leads to a market equilibrium. Takayama and Judge (1964a, 1964b) extended Samelson's concept to trade between spatially separated markets. Under the assumptions of the existence of price-dependent linear demand and supply functions, and with appropriate constraints, the Takayama-Judge model leads to a competitive equilibrium solution in prices and quantities for all commodities in all regions.

The objective function in this formulation is nonlinear, price times quantity where both factors are endogenous. Takayama and Judge were the first to solve spatial equilibrium problems directly with quadratic programming, and under linear, interdependent demand functions. Thus, the problem becomes that of maximization of a quadratic objective function subject to a set of linear constraints.

A watershed in this work was reached in the 1970s by Duloy and Norton (1973, 1975). They used mathematical programming models to simulate behavior of a complete agricultural sector. To avoid the difficulties of solving quadratic programs they advocated use of the grid linearization technique. This approach can approximately linearize the quadratic objective function to any desired degree of accuracy and still use an LP simplex algorithm.

Stochastic production considerations were introduced by Hazell and Scandizzo (1974). They introduced risk to the "CHAC" model for Mexico as a subjective cost element in the production decision. The result is a significant improvement in the predictive ability of linear programming solutions. Therefore, in most sector modelling techniques the risk behavior of the farmer is accounted for in the objective function.

At the sector level, all sources of supply and demand for agricultural products, including exports and imports, are incorporated in the model. Domestic demand functions are determined econometrically, and are subsequently incorporated in the model. In general, the nature of the partial equilibrium sector model does not incorporate the income effect of the demand side. Therefore, demand functions are not income responsive.

Following the Hazell-Norton notations, a typical price endogenous sector model in its most general form may be written as:

$$\text{Max } Z = \sum_j (\alpha_j - \frac{1}{2} B_j Q_j) Q_j - \sum_j C(S_j) \qquad (3\text{-}1)$$

$$\begin{bmatrix} \text{Sum of producer} \\ \text{and consumer} \\ \text{surplus} \end{bmatrix} = \begin{bmatrix} \text{Area under} \\ \text{demand curve} \\ \text{or gross revenue} \end{bmatrix} - \begin{bmatrix} \text{Area under supply} \\ \text{curve or marginal} \\ \text{cost of production} \end{bmatrix}$$

such that

$Q_j - S_j \leq 0$ for all j (commodities)

$\sum_j a_{kj} X_j = \sum_j (a_{kj}/y_j) S_j \leq b_k$ for all k (resources)

$Q_j, S_j \geq 0$

where y_j is the yield of commodity j per unit of activity X_j. The maximization of producer and consumer surpluses is conditioned by three general considerations: (1) commodity balance which states that sales of commodity j, Q_j, must not exceed its production, S_j; (2) resource k required for the production activities, X_j, can not exceed its availability, b_k; and (3) non-negativity constraint in commodity demand and supply.

The maximand in the above formulation implies that the sector is composed of competitive micro units, none of which can individually influence output or factor prices, and that all producers are motivated by profit maximization. This typical model can be solved with quadratic programming algorithms such as MINOS (Murtagh and Saunders, 1977).

Hazell and Norton (1986) presented the technical steps for efficiently linearizing the quadratic objective function presented above so the model can be solved as a linear programming problem. McCarl and Tice (1982) stated "clearly one should approximate" the quadratic programming problem especially in some certain cases. It is generally simpler and more reliable to approximate large problems with a few quadratic variables. The benefit from approximation increases as the model size increases. Further, linear programming algorithms are more widely available than nonlinear algorithms. In addition to the computational considerations, the linear model has some other advantages for model specification. Among its dual variables are variables which directly measure consumer surplus. Commodity prices can be read directly from the LP solution information on the commodity balance (Norton and Solis, 1983).

The linear programming formulation is illustrated graphically and computationally in Hazell and Norton (1986). The demand side of the model is built from three pieces of data (if no cross price terms are contemplated): the own price elasticity, the initial (base-year) price, and the initial quantity.

The linearized version of the quadratic model can be outlined as follows:

$$\text{Max } Z = \sum_j \sum_s w_{js} D_{js} - \sum_j \sum_t c_{jt} X_{jt} \qquad (3\text{-}2)$$

$$\begin{bmatrix} \text{Area under} \\ \text{demand curve} \end{bmatrix} - \begin{bmatrix} \text{Area under} \\ \text{supply curve} \end{bmatrix}$$

such that

(i) Commodity balances

$$- \sum_t y_{jt} X_{jt} + \sum_s \theta_{js} D_{js} \leq 0 \qquad \text{all } j$$

(ii) Resource constraints

$$\sum_j \sum_t a_{kjt} X_{jt} \leq b_k \qquad \text{all } k$$

(iii) Convex combination constraints

$$\sum_s D_{js} \leq 1 \qquad \text{all } j$$

(iv) Non-negativity constraints

$$X_{jt}, D_{js} \geq 0 \qquad \text{all } j, t, s$$

This linearized approximation model includes a linear objective function both in terms of W and C(Q), which represent total area under demand function, and total cost function respectively, and for each product, a convex combination constraint. The symbol w_{js} denotes the value of the area under the demand curve at point s for product j. The symbol θ_{js} denotes the associated quantities. The sum of the variables D_{js} over s must not exceed unity in value. They are the choice variables regarding position on the demand curve. The convex combination constraint forces the model's solution to be located on or below the demand curve. But it is inefficient to lie below the demand curve, for with the same quantity sold a greater value of Z can be attained by being on the demand curve. Hence, the convex combination constraint effectively dictates that the model's optimal solution will lie on the demand curve, provided of course, it is feasible to do so (Hazell and Norton, 1986).

In the chain of development, several studies have been conducted to construct large scale price endogenous agricultural sector models throughout the world. On a regional basis, Kutcher and Scandizzo (1981) analyzed the agricultural sector of northeast Brazil. The California Agricultural Resource Model (CARM) was developed at the University of California at Davis by Goodman et al. (1985) to replicate the effect of changes in input and output prices and changes in the quantity of some resources on agricultural production in California. National level models for the agricultural sector were analyzed by

Gonzales (1976) for the Philippines to evaluate fertilizer subsidies and rice price ceilings, and other policies on the prices, output, employment, and income. Jabora and Thompson (1980) developed the Senegalese agricultural sector model to evaluate alternative policies and programs for the sector. Le-Si, et al. (1983) developed an agricultural sector model for Turkey, and finally House (1985) developed the USMP (United States Mathematical Programming) Model. Multiple country models that describe production, consumption, and trade of a number of products between several countries were developed at the World Bank by Cappi et al. (1978). A selected set of price endogenous sector models is presented in Table XII.

Selected Agricultural Sector Models

The Dominican Republic Model

The purpose of the Dominican Republic Agricultural Sector model was to evaluate the effects of alternative agriculture policies upon such target variables as rural employment, farm income, farm sector income distribution, foreign exchange, and agricultural prices. The Dominican Republic model was a joint effort of the secretariat for agriculture (SEA) and the United States Agency for International Development (USAID) (House et al., 1980).

The model is limited in coverage to the annual (i. e., no permanent crops or livestock) crop subsector. The model delineated the country into three regions and four farm sizes. The model consists of over eight hundred equations in more than two thousand variables. The model maximizes net social welfare (i.e. the sum of producer and consumer surplus). Because of the nature of this formulation, demand enters the objective function as area under

Table XII

SELECTED PRICE ENDOGNEOUS AGRICULTURAL SECTOR PROGRAMMING MODELS

Country	Model Name	Comments	Reference
Brazil (Northeast)		Simulate the impact of certain policies including policies of technical progress, employment via wage subsidies, and agrarian reform. Recognizes farm size.	Kutcher and Scandizzo (1981)
California	CARM	600 cropping activities spreading over 14 production subregions. Emphasizes fruits and vegetables. No livestock subsector.	Goodman et al. (1985)
Canada	CRAM	A spatial LP model with crop and livestock activities separated on a regional and provincial basis. Allows interregional trade.	Webber et al. (1986)
Dominican Republic		Emphasizes regional and farm size delineations. Traces the impact of rice-bean pricing policies on income.	House et al. (1980)
Malaysia	TIGER	An ex-post analysis of regional investment project to show effect of new technology on farm income and employment, especially good in the treatment of mechanization and draft power.	Bell, Hazell, and Slade (1982)
Mexico	CHAC	The first and largest sector-wide model to use downward-sloping demand and grid linearization.	Duloy and Norton (1973, 1975)
Philippines	MAAGAP	National level model, no regional delineation. A policy impact analysis model which can be characterized as a production-processing-distribution model with demand linkages.	Gonzales (1976)
Senegal		A fairly small model of 10 commodities in a traditional subsistent type of farming. The model is designed to assist policy makers to analyze impacts of substitution policy.	Jabara and Thompson (1980)
Tunisia		A national model with regional delineations, developed to arrive at a demonstration framework for policy analysis, especially good in the treatment of livestock choices.	Condos and Cappi (1976)
Turkey	TASMI TASMII TARP	Three models share major features including analysis of comparative advantage, pricing policies, regional delineation and livestock subsectors.	Le-Si et al. (1982) Norton and Gencage (1985) Cakmak (1987)
U. S.	USMP	A large size spatial and market equilibrium model designed for policy impact analysis accounting for risk.	House (1985)

the demand curve. For this calculation domestic demand elasticities were used to derive the slope for straight line demand curves.

The Dominican Model solution represents market equilibrium for ten major commodities. The model was used to simulate the impact of rice and bean price policy on a variety of government objectives including a) self-sufficiency in beans and rice, b) foreign exchange savings, c) employment in agriculture, d) agriculture income, e) small farm income, and f) income distribution.

Price policy was emphasized in attaining the last three objectives concerning sector income. Prices in the base year (1975) were increased by 41 percent in 5 steps for rice, 32 percent for beans in 4 steps, and 32 percent for a joint increase in both rice and beans in 4 steps, respectively. The effects of the price changes upon each of the objectives were as follows:

1. Sector Income. Of all the simulation series, the joint rice and bean price increases generated the greatest sector income. For corresponding percentage price increases, the rice-only price increase generated almost as much sector income as the joint price increases. Corresponding beans-only price increases generated about half the sector income as the rice-only increases. The rice price increases generated substantially more income than the bean price increases because the total value of crop production increased substantially more (five times as much as bean value of production).
2. Small Farm Income. For the joint rice-bean price increases, small farms tended to increase incomes more than on the medium and large farms. With the rice-only price increases, sector income changes were less pronounced than on small farms. With the bean-

only price changes, small farms received only marginal sector income increases.

3. Distribution of Sector Income Among Farm Groups. In none of the policy simulations does the distribution of sector income among farm groups vary much from the base year pattern. In each set of the simulation series, as prices are increased, there is a slight tendency for small farms to receive a small additional share of total sector income at the expense of the other farm groups.

The Turkish Regional Agricultural Sector Model (TARP)

In 1980, the Turkish Government adopted an outward oriented development strategy which emphasized market forces rather than government direction and intervention. The new policy environment raised fundamental questions about the future performance of the agricultural sector.

The Turkish Agricultural Regional Programming Model (TARP) was designed to study the impact of changes in resource prices (particularly fertilizer) and availabilities and policies on the location, production, and price of agricultural commodities. The model maximizes Marshallian surpluses.

The model was designed to investigate policy related "what if" scenarios in a partial equilibrium static framework. TARP is a sector-wide model in the sense that it describes total national supply (production and imports) and disposition (domestic demand for food, feed, and exports). The production side of the model is decomposed into submodels for each of seven geographical areas. On the demand side, consumer behavior is regarded as price dependent, and thus market clearing commodity prices are endogenous to the model.

Important features of the model included were: 1) endogenous crop and livestock subsectors. The livestock subsector receives inputs from crop production and provides animal power for production. 2) Foreign trade was allowed for a limited number of commodities.

In total, the model is based on 34 single annual crops, 12 perennial crops, and 7 livestock activities. Taking into account seven producing regions, and two production techniques, namely mechanized and non-mechanized crop production, the total number of activities specified in the model is 831.

To trace the effect of eliminating fertilizer subsidy on different policy targets, the study proposed raising the price of fertilizer by 100 percent relative to the original base year price. Phasing out the fertilizer subsidy had significant negative effects on the export of industrial crops and the processing of agricultural products. The aggregate effects of this policy are presented in Table XIII. The immediate effects on production were an upward shift in the supply curves for all crops. The cost of production increased and given a constant demand for crops (partial equilibrium analysis), the cultivated area and production decreased, along with fertilizer use. The significant decline in production occurred in industrial crops. This is principally due to a decrease of 27 percent in cotton and a 3 percent decrease in sugar beet production. Both crops utilized considerable fertilizer.

The aggregate price effects were moderate because of the substitution of exports for domestic consumption. However, wheat prices recorded an increase of 14 percent over the base year price.

Conclusion

The purpose of this chapter was to review major modelling endeavors in the profession. The importance and applications of modelling the agricultural

TABLE XIII

AGGREGATE EFFECTS OF PHASING OUT FERTILIZER SUBSIDY IN TURKEY USING TARP

	Percentage Change From Base Solution[a]
Cultivated area	-4.6
Production level	-2.8
Gross value of production	-2.8
Value of consumption	-1.5
Net trade	-14.8
Price index (all crops)	+3.3
Employment	-3.0

[a] Base solution contains the subsidies.

Source: Cakmak, E. "A Regional Sector Model of Turkish Agriculture: Structure, Validation and Applications." Unpublished Ph.D. dissertation, Standford University, 1987.

sector were discussed. The capability of tracing the impact (direct and indirect) of different policies on different segments of the agricultural sector is of significant concern to policy makers.

Models of market equilibrium vary in technique and purpose. Simulation-systems models, econometric models, and mathematical programming models represent the core of useful tools to analyze the whole or parts of an economy. These economic measurement techniques were reviewed with emphasis on their advantages and disadvantages.

Mathematical programming models appear most appropriate for analyzing the Saudi Arabia agricultural sector. The appropriateness of mathematical programming models arises because of the dynamic nature of the agricultural sector and the availability of secondary and survey data.

Price exogenous as well as price endogenous sector models were presented. The superiority of price endogenous model formulation was discussed supported by detailed examples. Use of the price endogenous agricultural sector model for policy simulation purposes was presented through two country studies. The Dominican Republic agricultural sector model analyzed the impact of output price supports for rice and beans. The Turkish regional agricultural sector model analyzed the impact of eliminating the fertilizer subsidy.

CHAPTER IV

AGRICULTURAL SECTOR MODEL FOR SAUDI ARABIA

Introduction

Agricultural sector models provide measurements for economic policy and have been developed for different purposes.

The agricultural sector in Saudi Arabia entered a period of dynamic growth in the early 1980's. A broad range of policies was used to pursue government goals including interest free loans, subsidies on inputs, and price supports for selected commodities such as wheat, barley, and dates.

The take-off stage in the Saudi agricultural development took place in 1979 when the government initiated a price support policy for wheat of $1000 per ton. The response by farmers, businessmen, and agricultural companies to this generous policy was substantial.

Results of the Saudi agricultural policies however, have brought about new policy concerns including high government cost, over-production of wheat, depleting water resources, and an imbalance of benefits between large and small farms.

To investigate the impacts of Saudi agricultural policies a quantitative sector model is specified. The model assesses the direction and magnitude of different instrumental policies. It facilitates policy makers in their evaluation of output and input price policies introduced in the last decade.

The need for formal modelling of the Saudi agricultural sector was realized in the Second Development Plan for 1975-1980. A decade later, the Fourth Development Plan for 1985-1990 reinforced the need for a formal program to collect and update information on production costs, record prices of principal crops, and assess the different policy impacts on the farming population. To the best of the author's knowledge, there have been no quantitative sector modelling frameworks implemented by local or international agencies for Saudi Arabia. However, a conceptual framework of the agricultural sector was developed by Al-Turki (1986). He proposed the first agricultural sector model for Saudi Arabia. The Al-Turki model is regional in nature and includes temporary crops. It is a price endogenous model allowing different scenarios to assess the impact of changing input policies and tracing the impacts on selected policy variables.

The Saudi Agricultural Sector Model proposed in this dissertation is designed to evaluate the impact of changing input subsidies and output support prices on the agricultural sector. More specifically, it simulates the impact of output support price policies by farm size.

The model replicates the performance of the agricultural sector in the base year 1985. The selection of 1985 is a reasonable compromise between allowing sufficient time for tracing out the wheat output support price policy initiated in 1979 and the concern for severe current data limitations for Saudi agriculture. The dynamic growth in Saudi agriculture emphasizes the need for research using the most recent years. However, the latest agricultural census is for 1982. Time series data on cultivated area and production are available for more recent years. Therefore, the selected base year of 1985 allows observation for 6 years of wheat harvest after initiation of policy. Wheat production increased from 150 thousand metric tons to 2 million metric tons during the 6 year period between 1979 and 1985 as shown in Table VI of Chapter II.

Specifications of the Model

The main elements of any agricultural sector model are given in Hazell and Norton (1986) as: (1) a description of types of economic behavior (profit maximization, risk aversion); (2) production technology available to producers; (3) resource availability; (4) specification of market environment (perfect competition, monopoly, access to interregional or international trade); and (5) specification of the policy environment for the sector (subsidies, price supports, import quotas, tariffs).

These five elements define the sector as an economic unit. The sector model is price endogenous with complete specification of sources of supply (domestic production plus imports) and disposition of output (domestic demand plus export).

The basic structure of the Saudi Agricultural Sector Model includes an objective function, resource constraints, and commodity balances. Extensive use is made of demand segment variables, along with associated convex combination constraints. The production side of the model includes two submodels representing small and large farm sizes reflecting traditional and commercial farms in Saudi Arabia[1] . On the demand side, consumer behavior is regarded as price dependent, and thus market clearing commodity prices are endogenous to the model.

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[1] Traditional farms are < 20 hectares while commercial farms are ≥ 20 hectares.

Objective Function

The model maximizes the sum of producers' and consumers' surplus (net social welfare). The model assumes that producers and consumers are price takers and hence they operate in perfectly competitive markets, where market clearing is assured. The objective function is the algebaric sum of the value of area under the demand curve, output subsidies, and export revenue, minus costs of both purchased inputs and imports. Following the Hazell-Norton notation, the mathematical formulation of the objective function is described as follows:

$$\text{Max } Z = \sum_j \sum_s W_{js} D_{js} + \sum_j \sum_t S_j Y_{jt} X_{jt} - \sum_f P_f J_f \qquad (4.1)$$

$$\begin{bmatrix} \text{Max} \\ \text{consumers} \\ \text{plus} \\ \text{producers} \\ \text{surplus} \end{bmatrix} = \begin{bmatrix} \text{area under} \\ \text{demand curve} \end{bmatrix} + \begin{bmatrix} \text{output} \\ \text{subsidies} \end{bmatrix} - \begin{bmatrix} \text{purchased} \\ \text{inputs} \end{bmatrix}$$

$$+ \sum_j P_j^e E_j - \sum_j P_j^m M_j$$

$$+ \begin{bmatrix} \text{export} \\ \text{revenue} \end{bmatrix} - \begin{bmatrix} \text{import costs} \end{bmatrix}.$$

Commodity Balances

Commodities produced and imported balance those that are consumed locally and exported. The model generates domestic demand and allows for export and import at exogenous prices. Commodity balances are represented as follows:

$$- \sum_{t} Y_{jt} X_{jt} + \sum_{s} \theta_{js} D_{js} + E_j - M_j \leq 0 \text{ for all j (commodity)} \qquad (4.2)$$

$$- \begin{bmatrix} \text{domestic} \\ \text{production} \end{bmatrix} + \begin{bmatrix} \text{consumption} \end{bmatrix} + \begin{bmatrix} \text{exports} \end{bmatrix} - \begin{bmatrix} \text{imports} \end{bmatrix} \leq 0 .$$

Input Balances

The purchased input balance equations equate usage levels with supply for all inputs:

$$\sum_{j} \sum_{t} a_{fjt} X_{jt} - J_f \leq 0 \text{ for all purchased inputs} \qquad (4.3)$$

$$\begin{bmatrix} \text{amount of purchased} \\ \text{input used} \end{bmatrix} - \begin{bmatrix} \text{supply of} \\ \text{purchased} \\ \text{input} \end{bmatrix} \leq 0 .$$

Resource Constraints

Each production activity defines the use of labor, land, and capital per activity unit. The resource constraint set ensures that the amount of labor, land, and capital used by the agricultural sector is less than or equal to the amount available:

$$\sum_{j} \sum_{t} a_{kjt} X_{jt} \leq b_k \text{ for all k resources} \qquad (4.4)$$

$$\begin{bmatrix} \text{amount of resources} \\ \text{used} \end{bmatrix} \leq \begin{bmatrix} \text{available} \\ \text{resources} \end{bmatrix} .$$

Export Limits

The model allows exports of commodities to certain limits:

$$E_j \leq \bar{e}_j . \tag{4.5}$$

Government Budget Constraint

The cost of output support price and input subsidies cannot exceed the government budget for the agricultural sector:

$$\sum_j \sum_t S_j Y_{jt} X_{jt} + \sum_f \bar{g}_f P_f' J_f \leq \bar{g} \tag{4.6}$$

$$\begin{bmatrix}\text{output subsidies}\end{bmatrix} + \begin{bmatrix}\text{purchased} \\ \text{input} \\ \text{subsidies}\end{bmatrix} \leq \begin{bmatrix}\text{government budget} \\ \text{for agriculture}\end{bmatrix} .$$

Convexity Constraints

The model's optimal solution is guaranteed to lie on the demand curve provided imposition of the convexity constraint:

$$\sum_s D_{js} \leq 1 \quad \text{for all j commodities} \tag{4.7}$$

$$\begin{bmatrix}\text{sum of demand} \\ \text{segments}\end{bmatrix} \leq \begin{bmatrix}1\end{bmatrix} .$$

Non-negativity Constraints

This constraint ensures that all activities in the model hold positive levels:

$$X_{jt}, D_{js}, J_f, E_j, M_j \geq 0 .$$

Definition of Parameters

W_{js} Area under the demand curve for commodity j at segment s (SR1,000)

Y_{jt} Yield of crop j, technology t (MT/activity unit)

S_j Output subsidies(SR/MT)

P_f Cost of purchased input f (SR/MT)

P_j^e Export price of commodity j (f.o.b. SR/MT)

P_j^m Import price of commodity j (c.i.f. SR/MT)

θ_{js} Quantities associated with demand at segment s for product j (MT)

a_{fjt} Purchased inputs required for product j of input f, technology t (MT/activity unit)

a_{kjt} Requirement of resource k for product j, technology t (per activity unit)

b_k Amount of resource k available (SR 1,000)

$\bar{g}$ Government spending in base year

$\bar{g}_f$ Subsidy proportion for cost of purchased input f (%)

$\bar{e}_j$ Export limit for commodity j (MT)

Activities

D_{js} Choice variable regarding position on demand curve for product j at segment s

X_{jt} Activity level under crop j, technology t

J_f Purchased input f (MT)

E_j Export of commodity j (MT)

M_j Import of commodity j (MT)

Commodities (j)	Resources (k)
Wheat	Land
Fodder	Labor
Other grains	Capital
Tomatos	Fertilizer
Cucumber	Other purchased inputs
Onions	
Watermelon	
Melon	
Squash	
Okra	Technologies (t)
Eggplant	
Carrots	Traditional ...... small
Other vegetables	Commercial ... large
Dates	
Citrus	
Other Fruits	

Data Components of the Model

Data for the model were collected from several sources. The Saudi Ministry of Agriculture and Water (MOAW) publications, Ministry of Planning (MOP) publications, and the Saudi Arabian Monetary Agency's (SAMA) annual reports were the major national data sources for this research. The United States Department of Agriculture (USDA), the Food and Agriculture Organization (FAO), and the International Monetary Fund (IMF) are the major international sources for data about Saudi Arabia's agricultural economy.

Data availability (quantity and quality) is a significant problem for modelling the Saudi agricultural sector. Cost of production data by type of producer are the least available. The MOAW publications seldom have enterprise budgets for crops. Such data are obtained only from a limited number of research studies. Farm gate prices for different commodities are available only up to 1981 in FAO Production Yearbooks. Saudi sources provide only retail prices for some commodities. Furthermore, farm income data and production costs using different technologies are, in general, not available.

Land Use

The cultivated land area by commodity is available in two main sources: (1) the census of agriculture by farm size for 1982 and (2) an annual sample survey of agriculture up to 1984. The Agricultural Statistical Yearbook extends the sample survey information to 1986.

The agricultural census provides land use by farm size thus allowing definition of crop area by small size (i.e. farms of < 20 hectares) and large size (i. e. farms of ≥ 20 hectares). Cultivated land area by farm size for 1982 is shown in Table XIV Unfortunately, the most recent census data of crop area by farm size is limited to the year 1982.

The Agricultural Statistical Yearbook (MOAW 1986) provides crop area according to specialized and non-specialized farm types. Specialized farms produce one major crop, e.g. wheat. A modification thus is implemented to utilize the statistical yearbook data for updating of census data to the base year 1985. Allocation of land based on the statistical yearbook definitions is provided in Table XV for 1982. To allocate the 1985 base year data by the definition of traditional and commercial crop area, the procedure is:

(1) Compare crop area by farm type (specialized and non-specialized) for 1982 and 1985. Compute the difference between 1982 and 1985 for both farm types (Table XV).

TABLE XIV

CROP AREA ACCORDING TO FARM SIZE, 1982
(Hectares)

Crops	Total	Traditional < 20ha	Commercial ≥ 20ha
1. Temporary			
a. Grains			
Wheat	149,306	24,924	124,382
Barley	3,094	2,849	243
Other Grains	120,349	82,324	38,025
Total Grains	272,748	110,096	162,651
b. Vegetables			
Tomatoes	20,243	10,741	9,503
Cucumbers	3,832	1,599	2,233
Onion	1,609	285	1,360
Watermelon	36,785	9,066	27,719
Melon	8,728	1,884	6,843
Squash	8,288	1,339	6,949
Okra	3,216	1,708	1,509
Eggplant	11,901	9,931	1,971
Carrots	395	154	242
Other Vegetables	29,124	14,418	14,707
Total Vegetables	124,124	51,288	73,036
c. Fodders	122,634	63,415	59,218
2. Permanent			
Dates	68,568	44,844	23,724
Citrus	1,435	833	603
Other permanent	7,438	5,266	2,173
Total Permanent	77,441	50,942	26,499
TOTAL CROPS	596,942	275,540	321,405

Source: Census of Agriculture According to Farm Size for 1981-1982. MOAW 1985.

TABLE XV

CROP AREA AND CHANGE IN CROP AREA BY SPECIALIZED AND NON-SPECIALIZED FARM TYPE (HECTARES), 1982-1985

Crops	1982			1985			Change from 1982-1985		
	Total	Specialized	Non-Specialized	Total	Specialized	Non-Specialized	Total	Specialized	Non-Specialized
1. Temporary									
a. Grains									
Wheat	151,058	16,398	134,660	566,417	294,289	272,128	415,359	277,891	137,468
Barley	3,121		3,121	32,276	23,837	8,438	29,155	23,837	5,317
Other Grains	109,866		109,866	44,773		44,773	-65,093		-65,093
Total Grains	264,045	16,398	247,647	643,467	318,126	325,339	379,422	301,728	77,692
b. Vegetables									
Tomatoes	20,376	46	20,330	24,359	300	24,059	3,983	254	3,729
Cucumbers	1,388	64	1,324	3,140	272	2,868	1,752	208	1,544
Onion	1,623		1,623	1,240		1,240	-383		-383
Watermelon	28,174		28,174	18,600		18,600	-9,574		-9,574
Melon	7,309		7,309	5,726		5,726	-1,583		-1,583
Squash	3,858		3,858	4,080	17	4,063	222	17	205
Okra	1,227		1,227	3,100		3,100	1,873		1,873
Eggplant	3,248		3,248	4,148		4,148	900		900
Carrots	399		399	1,190		1,190	799		791
Other Vegetables	32,728	4	32,427	21,045		21,045	-11,681	-4	-11,679
Total Vegetables	100,330	114	100,216	86,630	589	86,039	-13,700	475	-14,177
c. Fodders	155,032	6,114	148,918	139,050	20,320	118,730	-15,982	14,206	-30,188
2. Permanent									
Dates	68,583		68,583	63,033		63,033	-5,550		-5,550
Citrus	1,447		1,447	2,081		2,081	634		634
Other permanent	7,505		7,505	13,123		13,123	5,618		5,618
Total Permanent	77,534		77,534	78,237		78,237	702		702
Total Crops	596,942	22,626	574,314	947,383	339,035	608,346	350,441	316,409	34,032

Source: Agricultural Statistical Yearbook, MOAW 1986.
Agricultural Sample Survey, MOAW 1984.

(2) Add 46 percent of the change in non-specialized crop area by crop to the 1982 traditional crop area (Table XVI). This gives an estimate of traditional crop area for 1985.

(3) Total change in specialized area 1982-1985 is added to commercial crop area in 1982 (Table XIV). Add 54 percent of the change (1982-1985) in the non-specialized crop area to the 1982 commercial crop area. This gives total estimates of the commercial crop area for 1985 (Table XVII).

A further adjustment of the data is made to agree with the data in the Agricultural Statistical Yearbook for 1987. For example, the total wheat area calculated from Tables XVI and XVII is 564,665 hectares while the reported wheat area in the Statistical Yearbook is 566,417 hectares. The adjusted traditional and commercial crop areas for 1985 are presented in Table XVIII.

Commodity Balances

Presenting supply and demand equilibrium through commodity balances is a basic element in most agricultural sector models that does not appear in farm level models. Sources of domestic supply are frequently shown by region, irrigated vs non irrigated, and farm size (small vs large farms). The commodity balances ensure that production plus imports (supply) are equal to domestic demand plus exports (disposition) for a base year. This study uses 1985 as the base year.

Domestic Commodity Production. Sources of production for this model are traditional (small) and commercial (large) farms. Crop area, production, and yield by farm size is presented in Table XIX for 1982. Total production of wheat, for example, was 416,750 tons of which 56,100 tons were produced by traditional farms of less than 20 hectares and the remainder of 360,650 tons

TABLE XVI

TRADITIONAL CROP AREA FOR THE BASE YEAR OF 1985 (HECTARES)

Crops	Crop Area-Trad. 1982	Multiply Change (1982-1985) In Non-Specialized Area by 46%	Estimated Traditional Crop Area 1985
1. Temporary			
a. Grains			
Wheat	24,924	63,235	88,159
Barley	2,849	2,446	5,295
Other Grains	82,323	-29,943	52,380
Total Grains	110,096	35,738	145,834
b. Vegetables			
Tomatoes	10,741	1,715	12,456
Cucumbers	1,599	710	73
Onion	249	-176	73
Watermelon	9,066	-4,404	4,662
Melon	1,884	-728	1,156
Squash	1,339	44	1,443
Okra	1,708	862	2,570
Eggplant	9,931	414	10,345
Carrots	154	364	518
Other Vegetables	14,417	-5,372	9,045
Total Vegetables	51,088	-6,521	44,567
c. Fodders	63,414	-13,886	49,528
2. Permanent			
Dates	44,844	-2,553	42,291
Citrus	833	292	1,125
Other permanent	5,366	2,584	7,850
Total Permanent	50,942	324	51,266
Total Crops	275,540	15,655	290,248

TABLE XVII

COMMERCIAL CROP AREA FOR THE BASE YEAR OF 1985 (HECTARES)

Crops	Crop Area-Commercial 1982	Change in Specialized Area 1982 to 1985	Multiply Change (1982-1985) in Non-specialized Area by 54%	Estimated Commercial Crop Area 1985
1. Temporary				
a. Grains				
Wheat	124,382	277,891	74,233	476,506
Barley	243	23,837	2,871	26,951
Other Grains	38,025		-35,150	2,875
Total Grains	162,651	301,730	41,954	506,334
b. Vegetables				
Tomatoes	9,503	254	2,014	11,771
Cucumbers	2,233	208	834	3,275
Onion	1,360		-207	1,153
Watermelon	27,719		-5,170	22,549
Melon	6,843		-855	5,988
Squash	6,949	17	111	7,077
Okra	1,509		1,011	2,520
Eggplant	1,971		486	2,457
Carrots	242		427	669
Other Vegetables	14,707	-4	-6,307	8,396
Total Vegetables	73,036	475	-7,656	65,855
c. Fodders	59,218	14,206	-16,302	57,122
2. Permanent				
Dates	23,724		-2,997	20,727
Citrus	603		342945	
Other permanent	2,173		3,034	5,207
Total Permanent	26,499		379	26,879
Total Crops	321,405	316,411	18,375	656,188

TABLE XVIII

ADJUSTED TRADITIONAL AND COMMERCIAL
CROP AREA FOR 1985

Crops	Traditional Area (Ha)	Commercial Area (Ha)	Total Area (Ha)
1. Temporary			
a. Grains			
Wheat	88,433	477,984	566,417
Barley	5,300	26,976	32,276
Other Grains	42,443	2,330	44,773
Total Grains	136,176	507,290	643,466
b. Vegetables			
Tomatoes	12,524	11,835	24,359
Cucumbers	1,298	1,842	3,140
Onion	74	1,166	1,240
Watermelon	3,187	15,413	18,600
Melon	927	4,799	5,726
Squash	691	3,389	4,080
Okra	1,565	1,535	3,100
Eggplant	3,352	796	4,148
Carrots	519	671	1,190
Other Vegetables	10,915	10,132	21,047
Total Vegetables	35,052	51,578	86,630
c. Fodders	64,574	74,476	139,050
2. Permanent			
Dates	42,301	20,732	63,033
Citrus	1,131	950	2,081
Other permanent	7,890	5,233	13,123
Total Permanent	51,322	26,915	78,237
Total Crops	287,124	660,259	947,383

TABLE XIX

CROP AREA, PRODUCTION, AND YIELD BY FARM SIZE, 1982

Crop	Traditional Small Farm < 20 Hectares			Commercial Large Farm ≥ 20 Hectares			Total		
	Area Ha	Prodctn Ton	Yield Ton/Ha	Area Ha	Prodctn Ton	Yield Ton/Ha	Area Ha	Prodctn Ton	Yield Ton/Ha
1. Temporary									
a. Grains									
Wheat	25,170	56,100	2.28	125,480	360,650	2.87	150,650	416,750	2.77
Barley	2,870	4,150	1.44	240	360	1.50	3,110	4,510	1.45
b. Vegetables									
Tomatoes	9,540	148,680	15.58	10,870	151,120	13.90	20,410	299,800	14 69
Cucumbers	1,613	16,743	10.38	2,253	25,634	11.38	3,866	42,377	10.96
Onion	250	4,250	17.00	1,400	12,230	8.74	1,650	16,480	9.99
Watermelon	9,140	85,290	9.33	27,990	417,660	14.92	37,130	502,950	13.55
Melon	1,890	22,990	12.16	6,910	109,280	15.81	8,800	132,270	15.03
Squash	1,350	16,500	12.22	2,500	25,080	10.00	3,850	41,580	10.80
Okra	1,720	8,850	5.10	1,520	10,410	6.85	3,240	19,260	5.94
Eggplant	1,500	1,673	11.15	1,700	26,500	15.59	3,200	28,173	8.80
Carrots	150	2,400	16.00	240	4,670	19.46	390	7,070	18.13
c. Fodders									
Alfalfa	4,330			7,630			11,960		
2. Permanent									
Dates	45,200	322,820	7.14	23,930	78,530	3.28	69,130	401,350	5.81
Citrus	840	6,890	8.20	620	2,550	4.11	1,460	9,440	6 47

Source: Census of Agriculture, MOAW 1985.

was produced by commercial farms. These data are adjusted by the sample survey data to give the 1985 production levels.

The sample survey data, however, are reported by non-specialized and specialized farms (Table XV). From the previous results on crop area, the non-specialized category includes small and large farms. However, the specialized category is interpreted to include only large farms.

The reported wheat yield for 1982 from the census data is 2.28 and 2.87 tons per hectare for the small and large farms, respectively. Total average yield is 2.77 tons per hectare (Table XIX). The yield from the sample survey for 1982 is 2.66 and 3.57 tons per hectare for non-specialized and specialized, respectively (Table XX).

The sample survey data for production and yield for 1985 are provided in Table XXI. Yield for wheat is 3.05 and 4.96 tons per hectare for non-specialized and specialized farms, respectively. Total yield is 4.04 tons per hectare which reflects about a 46 percent increase over the 1982 yield of 2.77 tons per hectare.

The procedure for updating the data in Table XIX to 1985 is to utilize the information reported in Tables XX and XXI and to arrive at the results presented in Table XXII. The method involves splitting the non-specialized category reported in Table XX and XXI into small (< 20 hectares) and large (≥ 20 hectares) farm categories. The procedure generates yield levels for traditional (small) and commercial (large) farms and total yield in 1985. The adjusted data for traditional and commercial farms are reported in Table XXII for 1985.

<u>Domestic Demand</u>. Commodity demand functions are included within the structure of the Saudi Agricultural Sector Model and hence market equilibrium prices are determined endogenously by the demand and supply

TABLE XX

PRODUCTION AND YIELD DATA BY NON-SPECIALIZED AND SPECIALIZED FARM TYPE, 1982

Crops	Production (Ton)			Yield (Ton/Ha)		
	Non-Specialized	Specialized	Total	Non-Specialized	Specialized	Total
1. Temporary						
a. Grains						
Wheat	358,121	58,614	416,735	2.66	3.57	2.77
Barley	4,508	0	4,508	1.44		1.44
Other Grains	68,203		68,203	0.57		0.65
Total Grains						
b. Vegetables						
Tomatoes	296,510	3,278	299,788	14.88	71.25	14.88
Cucumbers	14,399	17,421	31,820	10.76	65.06	20.92
Onion	16,482	0	16,482	10.16		10.16
Watermelon	456,512	0	456,512	16.20		16.20
Melon	124,375	0	124,375	17.00		17.00
Squash	41,496	0	41,496	10.26		10.26
Okra	6,345	0	6,345	5.17		5.17
Eggplant	43,460	0	43,460	12.55		12.55
Carrots	7,114	0	7,114	17.83		17.83
c. Fodders			1,838,060			20.00
2. Permanent						
Dates	399,576	0	399,576			5.83
Citrus	9,440	0	9,440			6.52

Source: Sample Survey. MOAW Riyadh 1984.

TABLE XXI

AREA, PRODUCTION, AND YIELD FOR NON-SPECIALIZED AND SPECIALIZED FARMS, 1985

	TOTAL			NON-SPECIALIZED			SPECIALIZED		
	Area Ha	Production MT	Yield MT/Ha	Area Ha	Production MT	Yield MT/Ha	Area Ha	Production MT	Yield MT/Ha
Crops									
1. Temporary									
a. Grains									
Wheat	566,418	2,289,995	4.04	272,128	830,794	3.05	294,289	1,459,201	4.96
Barley	32,276	120,519	3.73	8,438	20,232	2.40	23,837	100,287	4.21
b. Vegetables									
Tomatoes	24,358	326,754	13.42	24,059	292,620	12.16	300	34,134	113.78
Cucumbers	3,140	70,417	22.43	1,378	36,268	26.32	272	34,149	125.55
Onion	1,242	11,492	9.25	1,242	11,492	9.25			
Watermelon	18,600	374,246	20.12	18,600	374,246	20.12			
Melon	5,725	162,613	28.40	5,726	162,613	28.40			
Squash	4,063	45,045	11.09	4,063	45,045	11.09			
Okra	3,130	17,448	5.57	1,136	17,448	15.36			
Eggplant	4,147	39,425	9.51	4,148	39,425	9.50			
Carrots	1,192	17,380	14.58	1,192	17,380	14.58			
c. Fodders									
Alfalfa	139,050			119,024			20,027		
Other Fodder	92,933			83,179			9,754		
2. Permanent									
Dates	63,033	457,433	7.26	63,033	457,443	7.26			
Citrus	2,081	11,141	5.54	2,081	11,141	5.35			
Total Crops									

Source: Agricultural Statistical Yearbook, MOAW Riyadh 1987.

TABLE XXII

ADJUSTED CROP AREA, PRODUCTION, AND YIELD BY TRADITIONAL AND COMMERCIAL FARMS, 1985.

	Area (Hectares)			Production (Tons)			Yield (Ton/Hectare)		
	Traditn	Commercial	Total	Traditn	Commercial	Total	Traditn	Commercial	Total
Crops									
1 Temporary									
a Grains									
Wheat	88,433	477,984	566,417	227,098	2,062,897	2,289,995	2 57	4 32	4 04
Other Grains	47,743	29,306	77,049	112,673	117,224	229,897	2 36	4 00	3 73
Total Grains	136,176	507,290	643,466						
b Vegetables									
Tomatoes	12,524	11,835	24,359	146,643	180,111	326,754	11 71	15 22	13 41
Cucumbers	1,298	1,842	3,140	19,569	50,848	70,417	15 08	27 60	22 43
Onion	74	1,166	1,240	1,259	10,233	11,492	17 01	8 78	9.27
Watermelon	3,187	15,413	18,600	44,193	330,053	374,246	13 86	21 41	20 12
Melon	927	4,799	5,726	21,035	141,578	162,613	22 69	29 50	28 40
Squash	691	3,389	4,080	9,027	36,018	45,045	13 06	10 63	11 04
Okra	1,565	1,535	3,100	7,561	9,887	17,448	4 83	6 44	5 63
Eggplant	3,352	796	4,148	29,698	9,722	39,420	8 86	12 21	9 50
Carrots	519	671	1,190	6,758	10,622	17,380	13 02	15 83	14 61
Other Vegetables	10,915	10,132	21,047	127,815	154,209	280,024	11 71	15 22	13 40
Total Vegetables	35,052	51,578	86,630						
c Fodders	64,574	74,476	139,050	1,291,480	1,489,520	2,781,000	20	20	20
2 Permanent									
Dates	42,301	20,732	63,030	373,449	83,994	457,443	8 83	4 05	7.26
Citrus	1,131	950	2,081	7,521	3,620	11,141	6 65	3 81	5 35
Other permanent	7,890	5,233	13,123	52,468	19,938	72,406	6 65	3 81	5 52
Total Permanent	51,322	26,915	78,234						
Total Crops	287,124	660,259	947,383						

interaction. Extensive use of the grid linearization technique proposed by Hazell and Norton (1986) for demand segmentation is implemented.

Following Hazell and Norton (1986), the steps to linearize the demand function and to include the results directly in the objective function are as follows: (1) obtain the parameter values for initial prices of crop (P_{jo}), initial quantities (Q_{jo}), and the own price elasticity of demand (η_j). Cross price elasticities are not included. (2) Calculate the intercept (α_j) and the slope (β_j) parameters of the linearized inverse demand function as follows:

$$\beta_j = -\frac{dP_j}{dQ_j} = -\frac{P_{jo}}{\eta_j Q_{jo}} > 0$$

and

$$\alpha_j = P_{jo} + \beta_j Q_{jo} > 0.$$

(3) Establish the relevant range of the demand function. In most cases the prices of the first and the last segments are adequately measured by 50 percent and 200 percent of the base year price, respectively. Following this range, (P^l_j, P^u_j) = (.5 P_{jo}, 2 P_{jo})are the lower and upper prices used to translate to the quantity axis:

$$Q^l_j = \frac{\alpha_j - P^u_j}{\beta_j}$$

$$Q^u_j = \frac{\alpha_j - P^l_j}{\beta_j}.$$

(4) Establish the length of segments between points on the demand function. That length depends on Q^u_j and Q^l_j and the number of segments. The selected

number of segments for the Saudi Model is eleven. The segment length is obtained as follows:

$$K_j = \frac{Q_j^u - Q_j^l}{n - 1}$$

where n is the number of segments. The 11 quantities on the demand function are:

$$\theta_{jo} = Q_j^l$$

$$\theta_{j1} = Q_j^l + K$$

$$\theta_{j2} = Q_j^l + 2K$$

.

.

.

$$\theta_{j10} = Q_j^l + 10\,K_j = Q_j^u .$$

Finally, the values of W_{js} (area under demand curve) and R_{js} (revenues) are calculated as follows:

$$W_{js} = \alpha\,\theta_{js} - \frac{1}{2}\beta_j\,\theta^2_{js}$$

$$R_{js} = \alpha\,\theta_{js} - \beta_j\,\theta^2_{js}$$

Figure 1 represents the area under the demand curve (W_{js}) in relation to the demand function in the linearized case. The choice variables are among points 1, 2, and 3 on the W_{js} curve. The associated quantities are found on the horizontal axes of both diagrams in the figure, and the corresponding prices and values of W_{js} and R_{js} are found on the vertical axes. The model will select one or two of the adjacent specified points on the piecewise linearized frontier but not on the envelop W_{js}. However, the model cannot choose more than two points, otherwise the solution is not efficient.

An illustrative example is provided for wheat demand in the Saudi model. Kahtani (1989) calculated the wheat parameters as follows:

Step 1 $\eta_j = -0.15$ $P_{jo} = 2.66$ (thousand SR/ton) $Q_{jo} = 1442.5$ (thousand tons)

Step 2

$$\beta_j = -\frac{P_{jo}}{\eta_j Q_{jo}} = 0.012$$

$$\alpha_j = P_{jo} + \beta_j Q_j = 19.97$$

Step 3

$$P_j^u = 2 P_{jo} = 5.32$$

$$P_j^l = .5 P_{jo} = 1.33$$

$$Q_j^u = \frac{\alpha_j - P_j^l}{\beta_j} = 1553.3$$

$$Q_j^l = \frac{\alpha_j - P_j^u}{\beta_j} = 1220.8$$

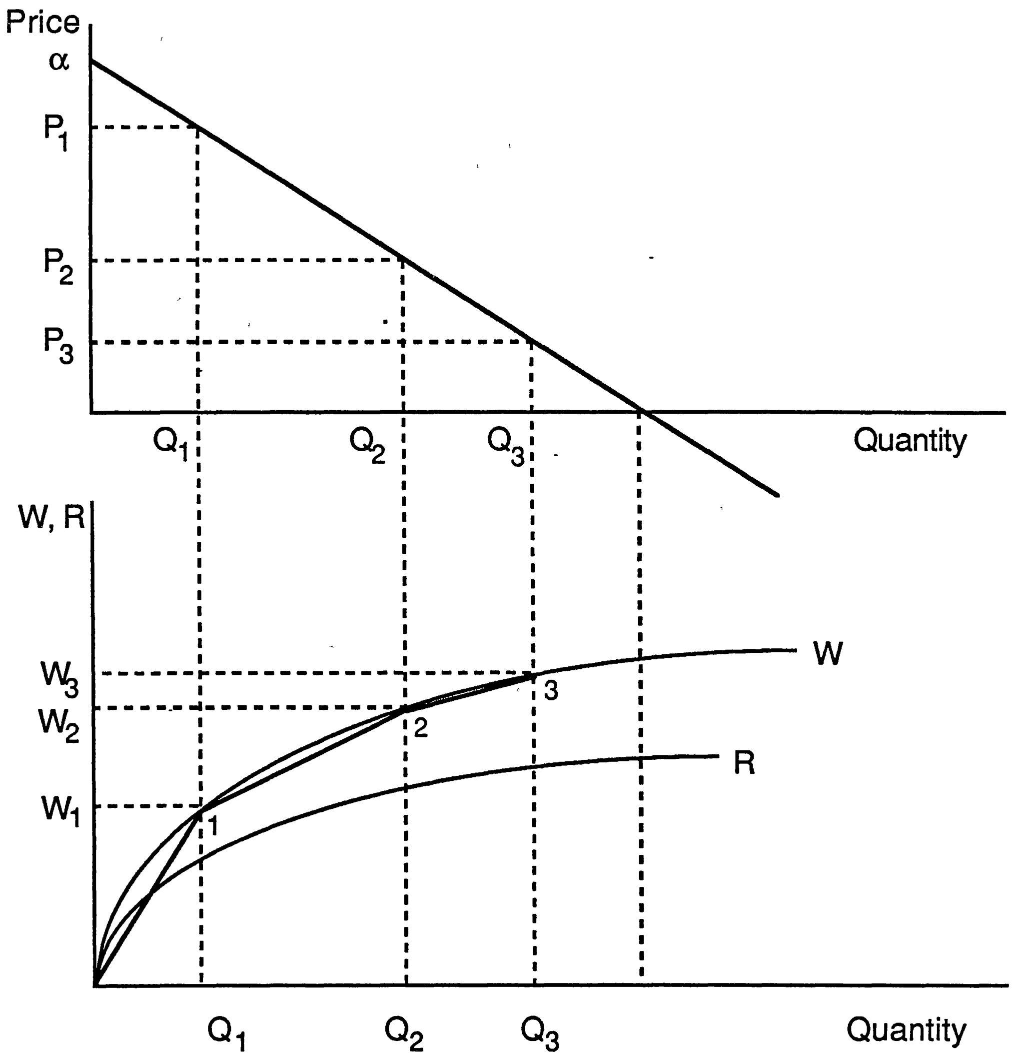

Figure 1. The Demand Function and the Objective Function

Step 4 The segment length is $K_j = \frac{Q_j^u - Q_j^l}{11 - 1} = 33.25$

and therefore the quantities at each point are

$$\theta_{j0} = Q_j^l = 1220.8$$

$$\theta_{j1} = Q_j^l + K = 1254.05$$

$$\theta_{j2} = Q_j^l + 2K = 1287.3$$

.

.

.

$$\theta_{j10} = Q_j^l + 10K = 1553.3$$

Step 5 Sample of the objective function entries and quantities are:

	Point 0	Point 1
W_{js}	15437.3	15607.3
θ_{js}	1220.80	1254.05

Demand elasticities, initial product prices, and initial quantities for selected commodities in the base year, 1985, are provided in Table XXIII.

A Note on Price Elasticity at the Farm Gate Level. The own price elasticity together with the initial price and quantity are the only required information to segment a linear demand function. Price elasticity is the ratio which expresses the percentage change in quantity associated with a given percentage change in price.

Relationships between price elasticities of demand at various market levels (e.g. farm gate or derived level, and retail or primary level) are discussed

TABLE XXIII

RETAIL PRICE ELASTICITY, RETAIL PRICE, AND CONSUMPTION OF SELECTED COMMODITIES IN 1985, SAUDI ARABIA

Reference	Kahtani (1989)			Mohamad (1988)		
Commodity	Elasticity	Retail Price At Constant 1980 Value (1000 SR/MT)	1985 Consumption (1000 MT)	Elasticity	Retail Price At Constant 1980 Value (1000 SR/MT)	1985 Consumption (1000 MT)
Wheat (or wheat equivalent)	-0.15	2.66	1442.5	-0.40	1.73	1500.0
Tomatoes	-0.51	4.62	373.4	-1.19	4.08	486.8
Onion	-0.81	2.28	124.6	-0.71	3.60	147.0
Watermelon	-0.26	2.61	830.9			
Eggplant	-0.34	3.91	40.4	-1.21	4.38	43.0
Carrots	-0.04	4.77	6.4			
Okra	-1.13	10.92	11.5			
Dates	-0.14	8.6	386.6			

in Tomek and Robinson (1982). Three possible cases are considered and depend on the behavior of the marketing margin.

Case 1: Constant Marketing Margin

$$M = P_{RT} - P_{FG}$$

where M represents the marketing margin per unit, P_{RT} is the retail price per unit, and P_{FG} is the farm gate price per unit for the respective commodity. In this case, the marketing margin per unit is assumed constant regardless of the amount marketed of the commodity. The two demand curves at the different market levels are parallel and the price elasticity at the farm gate level is calculated as follows:

$$E_{FG} = E_{RT} \left(\frac{P_{FG}}{P_{RT}}\right)$$

where E_{FG} and E_{RT} are the price elasticities at the farm gate and retail levels, respectively.

Case 2: Fixed Percentage Marketing Margin

$$M = a\, P_{RT}$$

where "a" represents the fixed percentage of the prevailing price. The derived demand elasticity at the farm gate level coincides with the primary retail level price elasticity.

Case 3: Combination of Constant and Fixed Percentage Marketing Margin

$$M = c + a\, P_{RT} \qquad \text{where } c \geq 0 \qquad 0 \leq a < 1$$

In general, the marketing margin varies directly with the retail price and indirectly with the quantity marketed. The specified marketing margin in this case includes an absolute amount "c" and a constant percentage "a" of the prevailing retail price.

The price elasticity at the farm gate level in this specification is derived as follows:

$$E_{FG} = E_{RT}\left[1 - \frac{c}{(1-a)P_{RT}}\right]$$

If $a = 0$ then the situation is similar to case 1*.

If $c = 0$ then the situation is similar to case 2.

The requirement of a greater than, or equal to zero, value for "c" rules out any regression specification of the marketing margin on retail price that results in a negative intercept. The equational form of the marketing margin M should force a zero or positive value for "c". Likewise, if the specification results in a negative or a greater than unity value for "a", then a correction is needed. To calculate the price elasticities at the farm gate level, the third case outlined above will be followed.

The price elasticity for tomato is used as an example of how the farm gate price elasticity is calculated from the retail price elasticity. The required data are presented in Table XXIV. Farm gate price is available only up to 1981 from FAO sources. Retail prices, however, are available from Kahtani up to 1985. The marketing margin schedule is calculated as the difference in retail price and the farm gate price from 1973 to 1981. When the marketing margin is regressed on

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* If $a = 0$ then $E_{FG} = E_{RT}(1 - \frac{c}{P_{RT}}) = ERT\,(\frac{P_{FG}}{P_{RT}})$ since $c = P_{RT} - P_{FG}$

TABLE XXIV

FARM GATE PRICES, RETAIL PRICES, AND MARKETING MARGINS FOR TOMATO, 1973-1985

Year	Nominal Farm Gate Price (SR/MT)	CPI 1980 = 100	Real Farm Gate Price (SR/MT)	Real Retail Price (SR/MT)	Marketing Margin (SR/MT)
1973	360	40.2	896	3,360	2,464
1974	420	48.8	861	3,220	2,359
1975	510	65.6	777	3,400	2,623
1976	620	86.4	718	4,100	3,382
1977	760	96.2	790	3,900	3,110
1978	740	94.7	781	4,000	3,219
1979	760	96.4	788	4,180	3,392
1980	810	100.0	810	4,200	3,390
1981	860	102.7	837	4,100	3,263
1982		102.1	803	3,860	3,057
1983		101.5	793	3,810	3,017
1984		100.3	805	3,870	3,065
1985		98.0	761	3,660	2,899

Source: Data in first column were obtained from FAO Statistical Printouts. Data on CPI were obtained from IMF Statistics. Retail prices were obtained from Kahtani (1989). Marketing margin up to 1981 is the difference between retail and farm gate price. Marketing margin from 1981-1985 is calculated by the equation $M = 0.7919 P_{RT}$. Real farm gate prices from 1981-1985 are the difference between the calculated marketing margin and the real retail price.

retail price, the resulting model is as follows (standard errors of the regression coefficients are in parenthesis):

$$M = -1084.97 + 1.072773\, P_{RT}$$
$$\quad (15.617) \quad (0.04247)$$

$$\bar{R}^2 = 0.988$$

Results of the regression model show a good fit indicated by the high $\bar{R}^2$. However, c should be ≥ 0 and a should be < 1.

Imposing the restriction of c ≥ 0 the following results were obtained:

$$M = 0.7919\, P_{RT}$$
$$\quad (0.01026)$$

$$\bar{R}^2 = 0.92$$

The resulting price elasticity at the farm gate level is the same as the retail level and equal to -0.51.

The regression model is also used to forecast farm gate prices from 1981 to 1985.

Similar procedures were used to calculate farm gate price elasticities for the other commodities. The estimated marketing margin models, price elasticities at the farm gate level, and the calculated farm gate prices for the different commodities at the base year 1985 are reported in Table XXV.

Trade. Export and import prices are obtained from FAO sources for Saudi Arabia. It is assumed that Saudi Arabia is a small country in the international market and therefore a price taker for food commodities. Prices are determined internationally and domestic demand and supply adjust accordingly, but not vice versa. The border prices are reported in Table XXVI.

TABLE XXV

MARKETING MARGINS, PRICE ELASTICITIES AT RETAIL AND FARM GATE LEVELS, AND FARM GATE PRICES FOR SELECTED COMMODITIES IN SAUDI ARABIA, 1985

Crop	Regression Model For Marketing Margin	$\bar{R}^2$	Price Elasticity At Retail	Price Elasticity At Farm Gate	Farm Gate Prices For Base Year 1985 At Constant 1980 Value (SR/MT)
Barley				-0.31*	825
Tomatoes	$M = 0.79196\, P_{RT}$ (0.01025)	0.92	-0.51	-0.51	761
Onion	$M = 0.60875\, P_{RT}$ (0.02763)	0.77	-0.81	-0.81	892
Watermelon	$M = 120.4827 + 0.65545\, P_{RT}$ (79.41) (0.23705)	0.52	-0.26	-0.21	779
Eggplant	$M = 0.63542\, P_{RT}$ (0.02110)	0.85	-0.34	- 0.34	1316
Carrots	$M = 0.82433\, P_{RT}$ (0.02431)	0.97	- 0.04	- 0.04	838
Squash				-1.13*	1557
Melon				-0.57*	2272
Dates	$M = 0.840635\, P_{RT}$ (0.01296)	0.97	-0.14	-0.14	1371

* Elasticities were calculated by the author.

TABLE XXVI

IMPORT (C.I.F.) PRICE AND EXPORT (F.O.B.) PRICES FOR SELECTED AGRICULTURAL COMMODITIES, 1985, SAUDI ARABIA

Commodity	Import Price C.I.F.	Export Price F.O.B.
	SR/ton	
Wheat	-----	865
Barley	482	--------
Tomato	666	--------
Onion	576	--------
Watermelon	----	956
Eggplant	616	--------
Dates	-----	1,543

Source: FAO. Statistical Printouts for Saudi Arabia, 1987. Exchange rate of 1985 U.S. $1 = SR3.6221 was obtained from IMF Statistics, IMF (1988).

Quantities imported and exported of selected food commodities are included in Table XXVII. Saudi Arabia is importing significant quantities of barley, tomatoes, and onions. Saudi Arabia is a traditional exporter of dates and watermelon.

Resource Use

The production technologies for the Saudi agricultural sector model are initially specified in fixed proportions of labor, capital, and land. The production activities and resource constraints are determined at the national level for traditional (small) and commercial (large) farms.

Labor. The total compensation for labor as incorporated in the model is obtained by utilizing the Saudi Social Accounting Matrix (SAM) for 1981. According to the SAM, 40 percent of the value added in agriculture for the period 1979-82 is attributed to labor. Value added in agriculture as reported in Table III amounted to SR11,141 million in 1985. If labor share remains at 40 percent for 1985, then the total compensation to labor in agriculture in 1985 is SR4,456.4 million.

According to the Ministry of Agriculture and Water (MOAW) census, the total labor (number) employed in the agricultural sector in 1981 was 680,034. The accounting of total labor by permanent, temporary, and occasional and by farm size is given in Table XXVIII. The census data suggests that temporary labor works 3 to 6 months per year and occasional labor works less than 3 months per year. This represents a 37 percent and a 12.5 percent of a person year equivalent, respectively. Therefore, total person year equivalents in 1981 was 363,938. The calculation for the 1985 person year equivalents is provided

TABLE XXVII

SELECTED COMMODITY BALANCES FOR SAUDI ARABIA, 1985 (METRIC TONS)

Commodity	Production	Import	Export	Change In Stock	Total Available	Consumption	Other Uses and Statistical Discrepancies
Crops							
Temporary							
Grains							
Wheat	2,289,995	115,000	80,000	500,000	1,824,995	1,166,306	658,689
Other Grain	230,004	6,651,000	16,000	95,000	6,770,004	339,000	6,431,004
Vegetables							
Tomatoes	326,754	110,301	4,143		432,912	437,158	-4,246
Cucumbers	70,417				70,417	70,417	
Onion	11,492	95,708	1,842		105,358	110,636	-5,278
Watermelon	374,246	16,798	30,514		360,530	352,388	8,142
Melon	162,613	10,727	2,059		171,281	199,651	-28,370
Squash	45,045				45,045	38,000	7,045
Okra	17,448				17,448	14,008	3,440
Eggplant	39,420	7,292	176		46,536	44,187	2,349
Carrots	17,380				17,380	19,546	-2,166
Other Vegetables	282,024	136,000	2,424		415,600	415,600	
Permanent							
Fodders	2,781,000	4,368	809		2,784,559		2,784,559
Fruits							
Dates	457,443	1,234	24,732		433,945	429,532	4,413
Citrus	11,141	279,667			290,808	290,808	
Other Fruit	72,406	294,566			366,972	366,972	

Source: FAO Statistical Printouts about Saudi Arabia. Rome 1988. Grain data on production were obtained from Statistical Yearbook MOAW 1987, the rest of grain data are extracted from USDA Data Base about Saudi Arabia.

TABLE XXVIII

AGRICULTURAL LABOR BY FARM SIZE IN SAUDI ARABIA, 1981 AND 1985

Farm Size	Permanent[a] Labor 1981 (No.)	Temporary Labor 1981		Occasional Labor 1981		Total Labor 1981		Person Year Equivalents 1985[d] (No.)
		Persons (No.)	Person Year Equivalent[b] 37% (No.)	Persons (No.)	Person Year Equivalent[c] 12.5% (No.)	Persons (No.)	Person Year Equivalents (No.)	
Small (< 20 Ha)	235,202	78,241	29,340	261,508	32,688	574,950	297,230 (81.7%)	251,013
Large (≥ 20 Ha)	57,891	11,537	4,326	35,926	4,491	105,354	66,708 (18.3%)	56,224
Total	293,093	89,777	33,666	297,434	37,179	680,304	363,938	307,237

Source: Census of Agriculture, MOAW 1985. Riyadh.

Definitions and Assumptions:

[a]Permanent labor works 6 months or more. The assumption is that permanent is equivalent to one person year.

[b]Temporary labor works more than 3 but less than 6 months. Therefore, the assumption is that temporary labor is an average of 4.5 months or the equivalent of 37.5% of a person year.

[c]Occasional labor works less than 3 months. Therefore, the assumption is that occasional labor is an average of 1.5 months a year or the equivalent of 12.5% of a person year.

[d]The total agricultural employment in 1985 is available from the Ministry of Planning (MOP) Fourth Development Plan 1985-1990. The reported 1980 employment is 545,600 and the reported 1985 employment is 617,400. An interpolation of the MOP data is made to give a corresponding level for 1981 to compare with the 1981 census data. Using the 1981 census data, proportional means were used to estimate 1985 person year equivalents and a distribution between small and large farms.

in Table XXVIII and equals 307,237. The person year equivalent for 1985 by small and large farms is 251,013 and 56,224, respectively.

Compensation to labor on an average basis per full-time equivalent is calculated by dividing the estimated total compensation for labor in 1985 (SR4,456.4 million) by the estimated full-time equivalents in 1985 (307,237). This gives an estimated annual wage per full-time equivalent of SR14,505. The assumption is that labor compensation per full-time equivalent is the same for manual labor used on small and large farms.

Capital. The remaining portion of value added after accounting for the compensation to employees is capital rents and operating surplus. The capital rents and operating surplus share of GDP for the period 1979-1982 was 60 percent. If the same share holds for 1985, capital rents and operating surplus is SR6,685 million.

The SAM indicates this portion of value added is the return to land, capital, other rents, and profits. A further assumption is made that the distribution between compensation to (1) land and water and (2) other rents and profits is on a 50-50 basis. That is, land and water rents receive 50 percent of the compensation and other (capital) rents and profits (including returns to management) receive 50 percent of the compensation.

CHAPTER V

DATA SPECIFICATION AND MODEL VALIDATION

Introduction

The Saudi Agricultural Sector Model contains a total of 32 crop production activities divided equally between traditional and commercial farms. Each crop production activity defines a given yield per hectare together with fixed proportions of the following factors and purchased inputs: land, labor, fertilizer, other capital, and purchased inputs. Livestock activities for traditional and commercial producers were defined for purposes of identifying sector resource use control totals for the crop activities.

The commodities produced are distributed between national level consumption and export for certain commodities. Domestic final demand activities are segmented in the model. Intermediate demands are defined for livestock production. Each final demand activity defines the area under the demand curve together with a quantity range and convex combination constraint set.

Aggregate Sector Control Totals

The Saudi agricultural sector control totals for 1985 are presented in Table XXIX. Gross revenue in agriculture is disaggregated to agriculture GDP and purchased inputs. Agriculture GDP is from Table III. Labor and capital are the

TABLE XXIX

CONTROL TOTALS FOR THE SAUDI AGRICULTURAL SECTOR, 1985 (MILLION SR)

Category	Traditional			Commercial			Total		
	Crops	Livestock	Total	Crops	Livestock	Total	Crops	Livestock	Total
Gross Revenue	4,529.02	2,554.67	7,083.69	9,203.54	2,454.49	11,658.03	13,732.56	5,009.16	18,741.72
Gross Domestic Product	3,859.56	1,479.32	5,338.88	4,768.64	1,033.89	5,802.53	8,628.20	2,513.21	11,141.40
Labor	2,876.30	764.60	3,640.90	725.80	89.70	815.50	3,602.10	854.30	4,456.40
Capital	983.26	714.72	1,697.98	4,042.82	944.19	4,987.03	5,026.10	1,658.91	6,685.00
Land & Water	587.62	--	587.62	1,235.67	--	1,235.67	1,823.29	--	1,823.29
Other Capital & Surplus	395.64	714.72	1,110.36	2,807.17	944.19	3,751.36	3,202.81	1,658.91	4,861.72
Purchased Inputs	669.46	1,075.35	1,744.81	4,434.91	1,420.60	5,855.51	5,104.37	2,495.95	7,600.32
Fertilizers	74.20	--	74.20	211.30	--	211.30	285.50	--	285.50
Other inputs	595.26	1,075.35	1,670.61	4,223.61	1,420.60	5,644.21	4,818.87	2,495.95	7,314.82

component parts of GDP. Capital, in turn, is allocated to land and water and other capital and surpluses. Purchased inputs include fertilizers and other inputs.

The GDP in agriculture for 1985 of SR11,141.4 million is allocated as follows; (i) labor returns of SR4,456.4 million and (ii) capital returns of SR6,685 million of which SR1,823.29 million is for land and water rents and the remaining SR4,861.71 million is attributed to other capital and surpluses. Land and water rents are determined on a per hectare basis as explained below. Other capital and surplus is computed as a GDP residual.

Purchased inputs of SR7,600.32 million is the difference between gross revenue and GDP. Purchased fertilizers SR285.5 million is discussed in Table XXXIV. Other purchased inputs are a residual.

Gross Revenue for Crops and Livestock

Estimated gross revenue from crops is obtained by multiplying prices of commodities by level of production. Results are presented in Table XXX. Other grains is calculated on the basis of revenue per hectare for barley. Other vegetables and other permanent crops are calculated on the basis of revenue per hectare for all vegetables and citrus, respectively. Gross revenue for traditional farms amounted to SR4,529.024 million while that for commercial farms amounted to about twice as much or SR9,203.543 million.

Gross revenue for livestock products is provided in Table XXXI. Gross revenue for traditional farms from producing livestock products amounted to SR2,554.67 million and for the commercial farms amounted to SR2,454.49 million.

TABLE XXX

ESTIMATED GROSS REVENUE FROM CROP PRODUCTION IN SAUDI ARABIA, 1985

		Traditional		Commercial		Total
	Prices SR/MT	Production MT	Revenue SR1000	Production MT	Revenue SR1000	Revenue SR1000
Temporary Crops						
Grains						
Wheat	2,000	227,098	454,196	2,062,897	4,125,794	4,579,990
Barley	1,600	12,519	20,030	108,000	172,800	192,830
Other Grains			160,265		14,912	175,177
Total Grains			634,491		4,313,506	4,947,997
Vegetables						
Tomatoes	3,250	146,643	476,590	180,111	585,361	1,061,951
Cucumbers	3,500	19.569	68,492	50,848	177,968	246,460
Onion	2,750	1,259	3,462	10,233	28,141	31,603
Watermelon	2,250	44,193	99,434	330,053	742,619	842,053
Melon	2,500	21,035	52,588	141,578	353,945	406,533
Squash	4,750	9,027	42,878	36,018	171,086	213,964
Okra	9,000	7,561	68,049	9,887	88,983	157,032
Eggplant	3,250	29,698	96,519	9,722	31,597	128,116
Carrots	2,250	6,758	15,206	10,622	23,900	39,106
Other Vegetables			417,488		538,698	956,186
Total Vegetables			1,340,706		2,742,298	4,083,004
Permanent Crops						
Fodders	1,300	1,291,480	1,678,924	1,489,520	1,936,376	3,615,300
Fruits and Dates						
Dates	2,110	373,449	787,977	83,994	177,227	965,204
Citrus	1,449	7,521	10,898	3,620	5,245	16,143
Other fruits			76,028		28,891	104,919
Total Fruits & Dates			874,903		211,363	1,086,266
Total Crops			4,529,024		9,203,543	13,732,567

Source: Prices were obtained from Humaidan (1980) and from FAO printouts about Saudi Arabia. Production levels were obtained from Table XXII.

TABLE XXXI

ESTIMATED GROSS REVENUE FROM LIVESTOCK PRODUCTION IN SAUDIA ARABIA, 1985

	Price Per Unit US $	Quantity	Unit	Value US$(1000)	Value SR(1000)
Beef & Veal (Carcass)	1,831	24,750	Ton	45,317	164,048
Milk (Whole)	806	370,000	Ton	298,220	1,079,556
Mutton & Lamb	61	5,600,000	Head	341,600	1,236,592
Poultry Meat	993	250,000	Ton	248,250	898,665
Eggs	2,183	134,064	Ton	292,662	1,059,436
Camels	546	85,000	Head	46,410	168,004
Sheep milk	403	95,200	Ton	38,366	138,885
Goat meat	30	900,000	Head	27,000	97,740
Goat milk	403	81,950	Ton	33,026	119,554
Camel milk	403	32,000	Ton	12,896	46,684
Total Value				1,383,747	5,009,164

Source: FAO Printouts about Saudi Arabia.
Footnote: According to FAO documents, the livestock principle commodities are indexed according to their proportional contribution as follows;

Commodity	Value($1000)	Percentage
Beef & Milk	343,537	27
Mutton & Lamb	341600	27
Poultry & Eggs	540,912	42
Camels	46,410	4
Total	1,272,459	100

The farm size distribution of the livestock production in Saudi Arabia is obtained from the Census of Agriculture and Water(MOAW).

	Farm Size Percentage share < 20 hectare	≥20 hectare	Value Of output ($1000)
Beef & milk	0.40	0.60	343,537
Mutton & lamb	0.77	0.23	341,600
Poultry	0.42	0.58	540,912
Camel	0.55	0.54	46,410
Total			1,272,459

Index of output	<20 ha	≥20 ha	Total
	51%	49%	100%

Accordingly ,the total Gross Revenue of SR5,009.164 million is distributed to small and large farms by the same percentages. Therefore, gross revenue from traditional farms is SR2,554.67 million and for commercial farms is SR2,454.49 million.

Land and Water Rents

Information on actual or imputed land and water rents is not available. Per hectare land and water rents is assumed at SR1,764 for temporary crop land and SR2,464 for permanent crop land. Originally, the study hypothesized that total capital rents of SR6,685 million were distributed equally to land and water and to other capital and surplus. This would assign a land and water rent of SR3,528 per hectare. For some crops, gross revenue would not cover such a high land and water rent.

Crop area by traditional and commercial producers is from Table XXII. Land and water rents for traditional producers are calculated as SR587.62 million and for commercial producers as SR1,235.67 million (Table XXXII).

Labor Returns

The labor intensity ratio between crops and livestock in the U.S. is 2.13 to 1.0 for 1985. This is obtained by the following steps: (i) divide crop labor hours by crop cash receipts in the U.S. Agriculture for 1985, i.e (2,170 million hours/$74,413 million = 0.029162); (ii) divide livestock labor hours by livestock cash receipts in the U.S. Agriculture for 1985, i.e (955 million hours/$69,780 million = 0.013686); (iii) obtain the crop-livestock labor intensity ratio by dividing (i) by (ii) as follows, (0.029162/0.013686=2.13); (iv) apply these ratios to gross revenues in Saudi Arabia (Table XXXIII); and (v) allocate labor returns on basis of labor intensities calculated in (iv).

Returns to labor are SR4,456.4 million in the agricultural sector (Table XXIX). This is allocated to traditional and commercial farms according to the percentage of person year equivalents obtained in Table XXVIII of 81.7 percent

TABLE XXXII

DISTRIBUTION OF LAND AND WATER RENTS, SAUDI ARABIA, 1985

	Traditional			Commercial			Total		
	Temporary	Permanent	Total	Temporary	Permanent	Total	Temporary	Permanent	Total
Ha	171,228	115,896	287,124	558,868	101,391	660,259	730,096	217,287	947,383
Value SR million	302.05	285.57	587.62	985.84	249.83	1,235.67	1,287.89	535.40	1,823.29

Crop area is from Table XXII. Assumed land and water rents is SR1,764/ha for temporary crops and SR2,464/ha for permanent crops.

TABLE XXXIII

LABOR RETURNS BY FARM SIZE AND MAJOR ACTIVITY, SAUDI ARABIA, 1985

Category	Traditional			Commercial		
	Crops	Livestock	Total	Crops	Livestock	Total
Gross Revenue (SR million)	4,529.02	2,554.67	7,083.69	9,203.54	2,454.49	11,658.03
Labor Intensity Ratio	2.13	1		2.13	1	
Labor Intensity	9,646.82	2,554.67	12,201.49	19,603.55	2,454.49	22,058.04
(Percent)	79%	21%	100%	89%	11%	100%
Labor Returns (SR Million)	2,876.30	764.60	3,640.90	725.80	89.70	815.50

and 18.3 percent, respectively. This gives labor returns of SR3,640.9 million and SR815.5 million for traditional and commercial farms, respectively.

The allocation of labor returns between crop and livestock activities is based on relative labor intensities for the same activities in the U.S. (U.S. Agricultural Statistics, 1987a) provided in Table XXXIII.

Fertilizer Purchases

Information on total fertilizer application for traditional and commercial farms is provided in Table XXXIV (FAO 1987). It amounted to 89,440 tons and 254,560 tons for traditional and commercial farms, respectively. Battal (1986) reported fertilizer price in Saudi Arabia of SR830 per ton. Thus fertilizer expenditures for 1985 amounted to SR74.2 million and SR211.3 million for traditional and commercial farms, respectively. Estimated total purchased fertilizers is SR285.5 million for the agriculture sector (Table XXIX).

Capital and Other Purchased Inputs

Capital accounts for 60 percent of GDP in agriculture as presented in the last column of Table XXIX. After accounting for land and water rents, the remaining capital rents of GDP is SR4,861.71 million in 1985. Other capital and surpluses includes items such as machinery and equipment and profits.

Other purchased inputs shown in Table XXIX equal SR7,600.32 million for the Saudi agricultural sector in 1985. This includes intermediate purchased inputs apart from fertilizers for the base year production activities.

TABLE XXXIV

PURCHASED FERTILIZER BY FARM SIZE, SAUDI ARABIA, 1985

Size	Total Fertilizer Application (MT)	Cultivated Area (Ha)	Fertilizer Application (MT/Ha)
Traditional			
<20 Ha	89,440	287,124	0.30
(percent)	26.0	30.3	
Commercial			
≥ 20 Ha	254,460	660,259	0.39
(percent)	74.0	69.7	
Total	344,000	947,383	0.35
(percent)	100.0	100.0	

Source: Fertilizer Year Book, FAO 1987. Rome.

The sum of other capital rents and surpluses and other purchased inputs is a residual from gross revenue after accounting for returns to labor, returns to land and water, and purchased fertilizers. This residual is divided between other capital rents and surpluses and other purchased inputs in relation to the aggregate proportions. Allocations are then made to activities of traditional and commercial producers as recorded in Table XXIX.

Activity Budgets

The budget data included in this research are assembled and discussed in this section. Sources of budget data are numerous, thus different sources have different definitions. Data reconciliation therefore was inevitable.

The Ministry of Agriculture and Water published cost of production studies for different crops in the middle 1970's and more focused wheat production cost studies in the early 1980's. The Saudi Agricultural Bank published a cost of production study for wheat by farm size in 1981. Extensive budget data are found in the study by Humaidan (1980). Humaidan obtained detailed crop budget information from the agricultural experiment station in the Al-Hasa region. A paper presented at the annual meeting of the American Agricultural Engineers society in Michigan by Nimah et al., (1985a) focused on production cost data for high technology wheat projects of different farm sizes in Saudi Arabia. Another study by Battal (1986) surveyed selected crops and constructed budgets for the Al-Kharj region near the capital city of Riyadh.

Results of synthesizing budget data for traditional and commercial producers are presented in Tables XXXV and XXXVI. The budget data are presented in value terms although physical units could be extracted for labor,

TABLE XXXV

ACTIVITY BUDGETS FOR TRADITIONAL FARMS IN RIYALS PER ACTIVITY UNIT, 1985

CATEGORY	WHEAT	OTHER GRAINS	TOMATO	CUCUMBER	ONION	WATER-MELON	MELON	SQUASH	OKRA	EGG-PLANT	CARROTS	OTHER-VEGE.	FODDERS	DATES	CITRUS	OTHER-FRUIT
Labor	1934	1418	6125	3780	3374	2975	3535	4130	3150	5110	3815	3999	3164	7031	4385	5108
Capital																
Land & Water	1764	1764	1764	1764	1764	1764	1764	1764	1764	1764	1764	1764	2464	2464	2464	2464
Other & Surplus	380	27	23895	45624	37077	22218	49624	51980	32069	15950	22097	28409	17020	7715	315	191
Purchased Inputs																
Fertilizer	542	461	2915	411	2980	3097	897	2980	4600	4015	897	2532	780	1320	1962	1641
Other	520	106	3359	1201	1555	1131	905	1181	1887	1956	722	1544	2572	101	510	232
Gross Revenue	5140	3776	38058	52780	46750	31185	56725	62035	43470	28795	29295	28248	26000	18631	9636	9636

ACTIVITY BUDGETS FOR TRADITIONAL FARMS IN COEFFICIENT BASIS, 1985

CATEGORY	WHEAT	OTHER GRAINS	TOMATO	CUCUMBER	ONION	WATER-MELON	MELON	SQUASH	OKRA	EGG-PLANT	CARROTS	OTHER-VEGE	FODDERS	DATES	CITRUS	OTHER-FRUIT
Labor	0.3763	0 3755	0.1609	0 0716	0 0722	0 0954	0.0623	0 0666	0.0725	0 1775	0 1302	0 1046	0 1217	0 3774	0 4551	0 5300
Capital																
Land & Water	0 3432	0 4672	0 0464	0 0334	0 0377	0 0566	0 0311	0 0284	0 0406	0 0613	0 0602	0 0461	0 0948	0 1323	0 2557	0 2557
Other & Surplus	0 0739	0 0072	0 6279	0 8644	0 7931	0 7125	0 8748	0 8379	0 7377	0 5539	0 7543	0 7428	0 6546	0 4140	0 0327	0 0198
Purchased Inputs																
Fertilizer	0 1054	0 1221	0 0766	0 0078	0 0637	0 0993	0 0158	0 0480	0 1058	0 1394	0 0306	0 0662	0 0300	0 0708	0 2036	0 1703
Other	0 1012	0 0281	0 0883	0 0228	0 0333	0 0363	0 0160	0 0190	0 0434	0 0679	0.0246	0 0404	0 0989	0 0054	0 0529	0 0241
Gross Revenue	1 0000	1 0000	1 0000	1 0000	1 0000	1 0000	1 0000	1 0000	1 0000	1 0000	1 0000	1 0000	1 0000	1 0000	1 0000	1 0000

TABLE XXXVI

ACTIVITY BUDGETS FOR COMMERCIAL FARMS IN RIYALS PER ACTIVITY UNIT, 1985

CATEGORY	WHEAT	OTHER GRAINS	TOMATO	CUCUMBER	ONION	WATER-MELON	MELON	SQUASH	OKRA	EGG-PLANT	CARROTS	OTHER-VEGE	FODDERS	DATES	CITRUS	OTHER-FRUIT
Labor	1460	915	5326	2832	3444	1506	2281	2665	2132	4816	2461	3051	2175	4068	1033	1006
Capital																
Land & Water	1764	1764	1764	1764	1764	1764	1764	1764	1764	1764	1764	1764	2464	2464	2464	2464
Other & Surplus	3483	1540	31063	88578	12035	39679	66707	40509	46671	24167	28500	42280	15063	593	625	528
Purchased Inputs																
Fertilizer	985	838	4893	1420	3236	3986	1631	4418	5465	6644	1631	3703	1715	1320	1304	1309
Other	948	1343	6419	2006	3666	1238	1367	1137	1928	2292	1262	2368	4583	101	95	214
Gross Revenue	8640	6400	49465	96600	24145	48173	73750	50493	57960	39683	35618	53166	26000	8546	5521	5521

ACTIVITY BUDGETS FOR COMMERCIAL FARMS IN COEFFICIENT BASIS, 1985

CATEGORY	WHEAT	OTHER GRAINS	TOMATO	CUCUMBER	ONION	WATER-MELON	MELON	SQUASH	OKRA	EGG-PLANT	CARROTS	OTHER-VEGE	FODDERS	DATES	CITRUS	OTHER-FRUIT
Labor	0.1690	0.1430	0.1077	0.0293	0.1426	0.0313	0.0309	0.0528	0.0368	0.1214	0.0691	0.0574	0.0837	0.4760	0.1871	0.1822
Capital																
Land & Water	0.2042	0.2756	0.0357	0.0183	0.0731	0.0366	0.0239	0.0349	0.0304	0.0444	0.0495	0.0332	0.0948	0.2883	0.4463	0.4463
Other & Surplus	0.4031	0.2406	0.6280	0.9170	0.4984	0.8237	0.9045	0.8023	0.8052	0.6090	0.8000	0.7953	0.5793	0.0694	0.1132	0.0956
Purchased Inputs																
Fertilizer	0.1140	0.1309	0.0989	0.0147	0.1340	0.0827	0.0221	0.0875	0.0943	0.1674	0.0458	0.0697	0.0660	0.1545	0.2362	0.2371
Other	0.1097	0.2098	0.1298	0.0208	0.1518	0.0257	0.0185	0.0225	0.0333	0.0577	0.0354	0.0445	0.1763	0.0118	0.0172	0.0388
Gross Revenue	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

land and water, and fertilizers by applying prices. Other capital and surpluses and other purchased inputs are available only in monetary units. Similarly, crop yields per hectare can be extracted by applying crop prices. These yields are the same as those contained in Table XXII.

A few comparisons between traditional and commercial producers are in order. Yields per hectare are greater for commercial producers except for squash, dates, citrus, and other fruits (see Table XXII). Yield for fodders is the same. In general, traditional producers use more labor and less capital, fertilizer, and other purchased inputs than do commercial producers. Land and water rents per hectare are assumed equal for the two types of producers although the rent per unit of production may vary because yield varies. Rents to other capital and surpluses (profits) are quite significant for some vegetable crops.

To guarantee that all inputs in the aggregate are used up for traditional and commercial farms in the base year production activities, the control totals obtained in Table XXIX are imposed on the aggregation of the per activity unit budgets presented in Tables XXXV and XXXVI. The per activity unit budgets are multiplied by the corresponding crop area reported in Table XXII. For example, the wheat labor coefficient reported in Table XXXV amounted to SR1,934. The corresponding wheat area for traditional farms is 88,433 hectares reported in Table XXII. Thus the aggregate value of labor payment for wheat production by the traditional farms is SR171.03 million. Similarly, the labor payment coefficients for the other crops are multiplied by the hectares of production to arrive at an aggregate estimate of labor payments for traditional and commercial producers. The process is repeated for each input in the activity budget. When the process is completed and the input payments are summed across all crop activities, the aggregate sums of input payments derived from activity budgets are compared with the control totals given in Table XXIX. In all cases except land and water rents, the results from activity budgets are different from the control totals. Therefore, the activity budget data needs to be reconciled to the control total data. The technique used here is the RAS iteration method (Miller and Blair, 1985). The method is carried out for traditional and commercial crop producers separately because control totals exist for each as shown in Table XXIX.

Because land and water rents are defined to be equal for each activity unit of crop production, the first step is to reduce gross returns by the value of land and water rents. These values now become the activity or column control totals. The row or input control totals for labor, fertilizer, other capital and surpluses, and other purchased inputs are from Table XXIX. The activity budget aggregate sums are now forced to be reconciled with these column and row control totals by means of the RAS iteration method. Using the LOTUS 1-2-3 spreadsheet, about a dozen iterations were needed to reconcile the activity budget aggregate input sums to the control totals.

The next step is to put the aggregate input data by activity on a per activity unit basis comparable to the activity budgets given in Tables XXXV and XXXVI. These results are presented in Tables XXXVII and XXXVIII for traditional and commercial farms, respectively.

Domestic Demand

Domestic demand is taken from the commodity balances for the base year (Table XXVII). For most commodities, prices are determined endogenously in

TABLE XXXVII

RECONCILED ACTIVITY BUDGETS FOR TRADITIONAL FARMS IN RIYALS PER ACTIVITY UNIT, 1985

CATEGORY	WHEAT	OTHER GRAINS	TOMATO	CUCUMBER	ONION	WATER-MELON	MELON	SQUASH	OKRA	EGG-PLANT	CARROTS	OTHER-VEGE	FODDERS	DATES	CITRUS	OTHER-FRUIT
Labor	2183	1324	26650	42071	16465	22237	46250	48721	28007	21275	23468	28194	14391	15611	6106	6525
Capital																
Land & Water	1764	1764	1764	1764	1764	1764	1764	1764	1764	1764	1764	1764	2464	2464	2464	2464
Other & Surplus	471	128	2491	2898	24152	1940	2815	3065	3634	1083	1787	2369	3895	248	321	219
Purchased Inputs																
Fertilizer	44	31	905	324	1034	1652	835	2513	2918	1193	397	1274	253	209	195	150
Other	675	530	6244	5710	3376	3607	5060	5988	7159	3480	1873	4649	4997	96	547	279
Gross Revenue	5140	3776	38058	52780	46750	31185	56725	62035	43470	28795	29295	38248	26000	18631	9636	9636

RECONCILED ACTIVITY BUDGETS FOR TRADITIONAL FARMS IN COEFFICIENT BASIS, 1985

CATEGORY	WHEAT	OTHER GRAINS	TOMATO	CUCUMBER	ONION	WATER-MELON	MELON	SQUASH	OKRA	EGG-PLANT	CARROTS	OTHER-VEGE.	FODDERS	DATES	CITRUS	OTHER-FRUIT
Labor	0.4250	0.3505	0.7003	0.7973	0.3519	0.7127	0.8154	0.7852	0.6441	0.7389	0.8012	0.7371	0.5535	0.8380	0.6339	0.6771
Capital																
Land & Water	0.3435	0.4672	0.0464	0.0334	0.0377	0.0565	0.0311	0.0284	0.0406	0.0613	0.0602	0.0461	0.0948	0.1323	0.2558	0.2557
Other & Surplus	0.0917	0.0339	0.0655	0.0549	0.5162	0.0622	0.0496	0.0494	0.0836	0.0376	0.0610	0.0619	0.1498	0.0133	0.0333	0.0227
Purchased Inputs																
Fertilizer	0.0085	0.0081	0.0238	0.0061	0.0221	0.0529	0.0147	0.0405	0.0671	0.0414	0.0136	0.0333	0.0097	0.0112	0.0202	0.0155
Other	0.1313	0.1403	0.1641	0.1082	0.0722	0.1156	0.0892	0.0965	0.1646	0.1209	0.0640	0.1215	0.1922	0.0051	0.0568	0.0289
Gross Revenue	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

TABLE XXXVIII

RECONCILED ACTIVITY BUDGETS FOR COMMERCIAL FARMS IN RIYALS PER ACTIVITY UNIT, 1985

CATEGORY	WHEAT	OTHER GRAINS	TOMATO	CUCUMBER	ONION	WATER-MELON	MELON	SQUASH	OKRA	EGG-PLANT	CARROTS	OTHER-VEGE	FODDERS	DATES	CITRUS	OTHER-FRUIT
Labor	657	292	3803	10,769	1,798	3,948	9,070	8,708	4,308	4,978	4,329	5,246	786	3,579	677	427
Capital																
Land & Water	1764	1764	1764	1764	1764	1764	1764	1764	1764	1764	1764	1764	2464	2464	2464	2464
Other & Surplus	2806	987	7739	24039	5401	14381	19313	7083	18644	12684	11645	13019	9893	1463	1637	1761
Purchased Inputs																
Fertilizers	138	83	1090	1685	527	3261	2024	4506	3447	2144	896	1987	193	362	267	174
Other	3265	3278	35064	58359	14644	24828	41584	28422	29807	18125	16985	31152	12664	680	476	695
Gross Revenue	8640	6400	49465	96600	24145	48173	73750	50493	57960	39683	35618	53166	26000	8546	5521	5521

RECONCILED ACTIVITY BUDGETS FOR COMMERCIAL FARMS IN COEFFICIENT BASIS, 1985

CATEGORY	WHEAT	OTHER GRAINS	TOMATO	CUCUMBER	ONION	WATER-MELON	MELON	SQUASH	OKRA	EGG-PLANT	CARROTS	OTHER-VEGE	FODDERS	DATES	CITRUS	OTHER-FRUIT
Labor	0 0762	0 0456	0 0769	0 1115	0 0745	0.0819	0 1230	0 1725	0.0743	0 1254	0 1215	0 0987	0 0302	0 4187	0 1226	0 0774
Capital																
Land & Water	0 2044	0 2754	0 0357	0 0183	0 0731	0 0366	0 0239	0 0349	0 0304	0 0444	0 0495	0 0332	0 0948	0 2883	0 4463	0 4463
Other & Surplus	0 3251	0 1542	0 1565	0 2488	0 2238	0 2985	0 2619	0 1403	0 3216	0 3195	0 3269	0 2449	0 3805	0 1712	0 2966	0 3189
Purchased Inputs																
Fertilizers	0 0160	0 0130	0 0220	0 0174	0 0219	0 0677	0 0274	0 0893	0 0595	0 0540	0 0251	0 0374	0 0074	0 0424	0 0483	0 0314
Other	0 3783	0 5119	0 7089	0 6040	0 6068	0 5153	0 5638	0 5630	0 5142	0 4566	0 4769	0 5859	0 4871	0 0795	0 0863	0 1260
Gross Revenue	1 0000	1 0000	1 0000	1 0000	1 0000	1.0000	1 0000	1.0000	1 0000	1.0000	1 0000	1 0000	1.0000	1 0000	1 0000	1 0000

the model. Imports and exports for most vegetables are minor except for tomatoes, onions, eggplant, and watermelon. Barley and other grains show large imports as livestock feed. Structure of the wheat market reflects the government wheat policy. Government supports wheat producer prices and subsidizes wheat flour prices.

The segmented demand procedure discussed in Chapter IV is used to model domestic consumption. The grid linearization or the segmented demand procedures are discussed in Hazell and Norton (1986) and Stoecker and Li (1988). It allows direct estimation of the area under the demand curve (ω) and the associated quantities consumed for each demand segment. The starting parameter values needed for each commodity are: (1) the own price elasticity (η), (2) the initial price (P), and (3) the initial quantity (Q). The own price elasticities are reported in Table XXXIX. Initial prices are the farm gate prices reported in Table XXX. Initial quantities are based on domestic consumption in the commodity balances reported in Table XXVII.

Base Model

A discussion of the base period used for the Saudi Agricultural Sector Model is addressed in this section. The 1985 base year data are considered as a benchmark for this research. The main tableau of the Saudi Agricultural Sector Model is presented first then the results of the base solution using the MPSX algorithm are discussed.

A portion of the initial tableau of the Saudi Agricultural Sector Model is presented in Table XL. The rows contain four main elements; the objective function, resource constraints, commodity balances, and the convex

TABLE XXXIX

OWN PRICE ELASTICITIES, INITIAL PRICES, AND INITIAL QUANTITIES FOR AGRICULTURAL CROP COMMODITIES FOR SAUDI ARABIA, 1985

Commodity	Own Price Elasticity	Initial Price SR/MT	Initial Quantity 1000 MT
Wheat Flour	-0.15	2,670	1,166.306
Other Grains	-0.31	1,600	339.000
Tomato	-0.51	3,250	437.158
Cucumber	-0.51	3,500	70.417
Onion	-0.81	2,750	110.636
Watermelon	-0.26	2,250	352.388
Melon	-0.57	2,500	199.651
Squash	-0.41	4,750	38.000
Okra	-0.25	9,000	14.008
Eggplant	-0.34	3,250	44.187
Carrots	-0.04	2,250	19.546
Other vegetables	-0.51	3,250	415.600
Dates	-0.14	2,110	429.532
Citrus	-0.48	1,449	290.808
Other Fruits	-0.48	1,780	366.972

Sources: Own price elasticity for wheat flour, tomato, carrots, eggplant, okra, onion, watermelon, citrus, and dates were obtained from Kahtani (1989). Own price elasticities for barley, melon, and squash were calculated by the author. Barley elasticity is used as a proxy for other grains. Tomato elasticity is used as a proxy for cucumber and for other vegetables. Citrus elasticity is used as a proxy for other fruit.

Initial prices were obtained from Humaidan (1980) and FAO Printouts for Saudi Arabia.

Initial quantities are from TABLE XXVII.

TABLE XL

A PORTION OF THE INITIAL TABLEAU OF THE SAUDI AGRICULTURAL SECTOR MODEL (BASE SOLUTION)

Rows	Agricultural Production Activities WHT1	OTHERGRN1 (Traditional)	TOM1 ..	Agricultural Production Activities WHT2	OTHERGRN2 (Commercial)	TOM2...	Demand Activities DOTHGRN1	DOTHGRN2......	DOTHF11	RHS	
Objective Function							1165 02270	1213 57428	1451 21523	Maximize	
Resource Constraints											
(1) Traditional Farms											
Land	1764	1764	1764							<=	587620
Labor	2183	1324	26650							<=	2876300
Capital	471	128	2491							<=	395640
Fertilizer	44	31	905							<=	74200
Other Purchased Inputs	675	530	6244							<=	595260
(2) Commercial Farms											
Land				1764	1764	1764				<=	1235670
Labor				657	292	3803				<=	725800
Capital				2806	987	7739				<=	2807170
Fertilizer				138	83	1090				<=	211300
Other Purchased Inputs				3265	3278	35064				<=	4223610
Commodity Balances											
Other grains		-2 36			-4 00		233 91	249.67		<=	108 995
Tomatoes			-11 71			-15 22				<=	110 404
Cucumbers										<=	0
Onions										<=	99 144
Watermelon										<=	-21 858
Melon										<=	37 038
Squash										<=	-7 045
Okra										<=	-3 44
Eggplant										<=	4 767
Carrots										<=	2 166
Other vegetables										<=	133 576
Dates										<=	-27 911
Citrus										<=	279 667
Other fruit									455 0458	<=	294 566
Wheat (Traditional)	2 57									>=	227 098
Wheat (Commercial)				4 32						>=	2062 897
Fodder (Traditional)										>=	1291 48
Fodder (Commercial)										>=	1489 53
Cxnvexty Constraint											
CVXOthergrains							1	1		<=	1
CVXTomatoes										<=	1
CVXCucumbers										<=	1
CVXOnions										<=	1
CVXWatermelons										<=	1
CVXMelons										<=	1
CVXSquash										<=	1
CVXOkra										<=	1
CVXEggplant										<=	1
CVXCarrots										<=	1
CVXOthervegetables										<=	1
CVXDates										<=	1
CVXCitrus										<=	1
CVXOtherfruits									1	<=	1

combination constraints. The columns contain production activities, both in traditional and commercial, and the segmented demand or national consumption activities. The RHS are the constraints or sector control totals.

For the base model, two general constraints are identified: resource constraints and commodity constraints.

1. Resource Constraints

The Saudi Agricultural Sector Model constraints are grouped into traditional and commercial resources as follows:

A. Traditional Farm Resources
   (i) Land
   (ii) Labor
   (iii) Capital and Surplus
   (iv) Fertilizer
   (v) Other Purchased Inputs

B. Commercial Farm Resources
   (i) Land
   (ii) Labor
   (iii) Capital and Surplus
   (iv) Fertilizer
   (v) Other Purchased Inputs

The two dichotomy resource groups represent resources available to the crop sector for the traditional and commercial farms. Right hand side values of the specified resources or the upper limits are obtained from Table XXIX and are reported in thousands of units. If factor prices are normalized to one, these constraints can be interpreted as physical units.

2. Commodity Constraints

Commodity balances for all crops except wheat and fodders are expressed as less than or equal to a RHS. The RHS value is calculated as follows:

- Production + Consumer Demand ≤ Imports - Exports

- Change in Stock - Other Uses and Statistical Discrepancies

Note that in this formulation trade, other uses (i.e. livestock feed and seed), and change in stock are not modelled but are held at the base year levels.

The wheat and fodder commodity levels are held at the production levels for the country in 1985. The model is ordered to replicate the minimum levels of wheat and fodder by farm category. Traditional farms are expected to produce a minimum of 227,098 metric tons of wheat, while commercial farms produce 2,062,897 metric tons. Further, traditional and commercial farms are expected to produce 1,291,480 and 1,489,530 metric tons of fodder, respectively.

Results Of The Base Model

Because the model is highly constrained in resource use and production of certain commodities by farm category the results of the base model solution replicate the base year data closely. Results of the base model solution are presented in Table XLI. These results are compared to the original data.

The objective function is maximized at the level of SR19,120.549 million and reflects consumer and producer surpluses. Because wheat and fodder

TABLE XLI

BASE MODEL SOLUTION TO THE SAUDI AGRICULTURAL SECTOR MODEL WITH COMPARISONS TO BASE YEAR DATA, 1985

Variable	Base Year Data	Base Solution	Index of Change
Objective Function (SR million)		19,120 549	
Resource Prices (SR)			
Traditional			
1 Land	1 000	1 030	0 0300
2. Labor	1.000	1.030	0 0300
3 Capital	1 000	1 020	0 0200
4 Fertilizer	1 000	1 090	0 0900
5 Other Purch	1 000	1 000	0 0000
Commercial			
1 Land	1.000	1.030	0 0300
2. Labor	1 000	1 020	0 0200
3 Capital	1 000	1 030	0 0300
4 Fertilizer	1 000	1 070	0 0700
5 Other Purch	1 000	1 020	0 0200
Farm Income (SR million)			
Traditional	3859 560	3971 390	0 0290
Commercial	4768 640	4904.441	0 0285
Commodity Prices (SR 1000/mt)			
Wheat			
Traditional	2.000	2.050	0 0250
Commercial	2.000	2.051	0 0255
Fodder			
Traditional	1 300	1 329	0 0223
Commercial	1 300	1.333	0 0254
Other Grain	1.600	1.643	0 0269
Tomatoes	3 250	3 329	0 0243
Cucumbers	3 500	3 586	0 0246
Onion	2.750	2 818	0 0247
Watermelon	2.250	2 312	0 0276
Melon	2.500	2 563	0 0252
Squash	4 750	4 882	0.0278
Okra	9 000	9 246	0 0273
Eggplant	3 250	3 338	0 0271
Carrots	2 250	2 308	0 0258
Other vegetables	3 250	3.819	0 1751
Dates	2.110	2 172	0 0294
Citrus	1 449	1 485	0 0248
Other fruit	1 449	1 492	0 0297
Activity Levels (1000 ha)			
Wheat			
Traditional	88.433	88 365	-0 0008
Commercial	477 984	477 522	-0 0010
Fodder			
Traditional	64 574	64 574	0 0000
Commercial	74 476	74 477	0 0000
Other Grains			
Traditional	47 743	43.517	-0 0885
Commercial	29.306	29 199	-0 0037
Vegetables			
Traditional	35 052	35 538	0 0139
Commercial	51 578	51.335	-0 0047
Fruits			
Traditional	9.021	12 935	0 4339
Commercial	6.183	5 674	-0 0823
Dates			
Traditional	42 301	41 116	-0 0280
Commercial	20 732	21 821	0 0525
Resource Use (million units)			
Fertilizer			
Traditional	74.200	74 200	0 0000
Commercial	211 300	211 300	0 0000
Other Purchased Inputs			
Traditional	595 260	595 260	0 0000
Commercial	4223 610	4223 610	0 0000
Wheat Production (1000 m t)			
Traditional	227 273	227 098	-0 0008
Commercial	2064 891	2062 897	-0 0010
Total	2292 164	2289 995	-0 0009
Fodder Production (1000 m t)			
Traditional	1291 480	1291 480	0 0000
Commercial	1489 520	1489 540	0 0000
Total	2781.000	2781.020	0.0000

enter as constraints, only producer surplus enters the objective function and not the consumer surplus at the dual (shadow) price.

All resource prices (shadow prices) are slightly higher than base year prices except for other purchased inputs used by traditional farmers. The highest deviation is the fertilizer price for traditional farmers at 1.09 compared to 1.00. Recall that resource prices are normalized to 1.00 for the base year.

Farm income is calculated by multiplying the shadow prices of the fixed resources, i.e. land, labor, and capital by their endowments. In other words, it represents the summation of the multiplication of shadow prices times the RHS values for land, labor and capital by farm size. Hence, farm income is SR3,971,390 thousand and SR4,904,441 thousand for traditional and commercial farms, respectively. These levels of farm income are compared to the base year farm income for crops as presented in the control totals of Table XXIX. Note that even though fertilizer and other purchased inputs are constrained in the base model, returns to these resources are not included in computing farm income.

Commodity prices are marginally higher for the base model results compared to the base year data. Other vegetables price represents the highest deviation at 17.5 percent while the rest of the commodities are in the vicinity of 2.5 percent over base year data.

Activity levels are reported in thousands of hectares. Wheat and other grain area is marginally under estimated by the model results for both traditional and commercial farms. Vegetables and fruits are marginally over estimated for traditional farms and marginally under estimated for commercial farms. Dates, on the other hand, are marginally over estimated for commercial farms and marginally under estimated for traditional farms.

Finally, the resource use section reveals that all resources are fully used with no slack. The model reproduces as specified a priori a fixed amount of wheat of 2,289,995 metric tons. The dual price of wheat is slightly higher than the support price of SR2,000 per metric ton. The dual prices show SR2,050 for traditional producers and SR2,051 for commercial producers.

Comparative Results

The model is gradually adjusted to reflect more realistic market conditions. Results of the adjustments are traced out through the following six scenarios:

1. Combined wheat balance for traditional and commercial farms
2. Combined fodder balance for traditional and commercial farms
3. Combined wheat and fodder balances for traditional and commercial farms
4. Combined wheat and fodder balances and fertilizer buy activity at market price
5. Combined wheat and fodder balances and other purchased inputs buy activity at market price
6. Combined wheat and fodder balances and fertilizer and other purchased inputs buy activities at market price

The following discussion focuses upon these six specified scenarios and their impact on the Saudi Agricultural Sector Model results.

1. Combined wheat balance. In this scenario, the two commodity balances for wheat by farm type are combined to one row. The RHS value becomes the summation of the previous traditional and commercial limits on wheat production. This formulation allows wheat substitution among the two different farm types. Results of this scenario are presented in Table XLII. Results are very similar to the base solution. There is a slight reduction in the fertilizer shadow price for traditional farms. Traditional farms produce 2.41 percent more hectares of wheat and commercial farms produce 0.27 percent fewer hectares of wheat. Traditional farms compensate by cutting back in other grains by 5.13 percent and commercial farms expand by 4.51 percent. All other activities change by less than one percent.

2. Combined fodder balance. Fodder balances specified in the base solution for traditional and commercial producers are combined in one row. This allows fodder substitution among farm types. Results of this specific scenario are shown in Table XLIII and have no significant changes compared to the base solution. Fertilizer prices dropped by 4.6 percent for traditional producers and 1.9 percent for commercial producers. Prices changed by less than one percent for all market determined commodities. Traditional farmers expanded fodder hectares by 1.01 percent and reduced marginally fruits, vegetables, and other grains. Commercial producers reduced fodder hectares by 0.9 percent and increased marginally fruits, vegetables, and other grains. Farm income changed very marginally but increased for traditional producers and decreased for commercial producers.

TABLE XLII

BASE MODEL SOLUTION COMPARED TO COMBINED WHEAT BALANCE

Variable	Base Solution	Current Solution	Index of Change
Objective Function (SR million)	19120 549	19,120 553	0 0000
Resource Prices (SR)			
Traditional			
1 Land	1 030	1 030	0 0000
2. Labor	1 030	1 030	0 0000
3 Capital	1 020	1 020	0 0000
4 Fertilizer	1 090	1 080	-0 0092
5 Other Purch	1 000	1 000	0 0000
Commercial			
1 Land	1 030	1 030	0 0000
2 Labor	1 020	1 020	0 0000
3 Capital	1.030	1 030	0 0000
4 Fertilizer	1 070	1 070	0 0000
5 Other Purch	1 020	1 020	0 0000
Farm Income (SR million)			
Traditional	3971 390	3971 390	0 0000
Commercial	4904 441	4904 441	0 0000
Commodity Prices (SR 1000/mt)			
Wheat		2 051	
Traditional	2.050		0 0005
Commercial	2.051		0 0000
Fodder			
Traditional	1 329	1 330	0 0008
Commercial	1 333	1 333	0 0000
Other Grain	1 643	1 644	0 0006
Tomatoes	3 329	3 330	0 0003
Cucumbers	3.586	3 587	0 0003
Onion	2.818	2 818	0 0000
Watermelon	2.312	2 312	0 0000
Melon	2.563	2 563	0 0000
Squash	4 882	4 881	-0.0002
Okra	9 246	9 243	-0 0003
Eggplant	3 338	3 338	0 0000
Carrots	2.308	2 308	0 0000
Other vegetables	3 819	3 819	0.0000
Dates	2.172	2 171	-0 0005
Citrus	1 485	1 485	0 0000
Other fruit	1 492	1 492	0.0000
Activity Levels (1000 ha)			
Wheat			
Traditional	88 365	90.495	0 0241
Commercial	477 522	476 255	-0 0027
Fodder			
Traditional	64.574	64 574	0 0000
Commercial	74 477	74 477	0 0000
Other Grains			
Traditional	43.517	41.285	-0.0513
Commercial	29.199	30 516	-0 0451
Vegetables			
Traditional	35.538	35 686	0 0042
Commercial	51 335	51 187	-0 0029
Fruits			
Traditional	12 935	12.930	-0.0004
Commercial	5 674	5 683	0 0016
Dates			
Traditional	41.116	41 088	-0 0007
Commercial	21 821	21 883	0 0028
Resource Use (million units)			
Fertilizer			
Traditional	74 200	74 200	0 0000
Commercial	211 300	211 300	0 0000
Other Purchased Inputs			
Traditional	595 260	595 260	0 0000
Commercial	4223 610	4223 610	0 0000
Wheat Production (1000 m t)			
Traditional	227 098	232 573	0 0241
Commercial	2062 897	2057 422	-0 0027
Total	2289 995	2289 995	0 0000
Fodder Production (1000 m t)			
Traditional	1291 480	1291 480	0 0000
Commercial	1489 540	1489 540	0.0000
Total	2781 020	2781 020	0 0000

TABLE XLIII

BASE MODEL SOLUTION COMPARED TO COMBINED FODDER BALANCE

Variable	Base Solution	Current Solution	Index of Change
Objective Function (SR million)	19120 549	19,120 603	0 0000
Resource Prices (SR)			
Traditional			
1 Land	1 030	1 030	0 0000
2 Labor	1.030	1 030	0.0000
3. Capital	1 020	1 030	0 0098
4 Fertilizer	1 090	1 040	-0 0459
5 Other Purch	1 000	1.010	0 0100
Commercial			
1. Land	1 030	1 030	0 0000
2 Labor	1 020	1 020	0 0000
3 Capital	1 030	1.020	-0 0097
4 Fertilizer	1 070	1 050	-0 0187
5 Other Purch.	1 020	1 020	0 0000
Farm Income (SR million)			
Traditional	3971 390	3975 347	0 0010
Commercial	4904 441	4876 370	-0.0057
Commodity Prices (SR 1000/mt)			
Wheat			
Traditional	2.050	2 053	0 0015
Commercial	2.051	2.051	0.0000
Fodder		1 332	
Traditional	1 329		0 0023
Commercial	1 333		-0.0008
Other Grain	1 643	1.644	0 0006
Tomatoes	3 329	3.331	0 0006
Cucumbers	3 586	3 587	0 0003
Onion	2.818	2 819	0 0004
Watermelon	2.312	2 310	-0 0009
Melon	2.563	2.563	0 0000
Squash	4 882	4 878	-0.0008
Okra	9 246	9 235	-0 0012
Eggplant	3 338	3 335	-0 0009
Carrots	2.308	2.307	-0.0004
Other vegetables	3 819	3 818	-0.0003
Dates	2.172	2.170	-0 0009
Citrus	1 485	1.485	0 0000
Other fruit	1.492	1 491	-0 0007
Activity Levels (1000 ha)			
Wheat			
Traditional	88 365	88 365	0 0000
Commercial	477.522	477 521	0.0000
Fodder			
Traditional	64.574	65 226	0 0101
Commercial	74 477	73.825	-0 0088
Other Grains			
Traditional	43 517	43 498	-0 0004
Commercial	29.199	29.210	0 0004
Vegetables			
Traditional	35 538	34.957	-0 0163
Commercial	51 335	51 786	0 0088
Fruits			
Traditional	12 935	12.560	-0 0290
Commercial	5 674	6 328	0 1153
Dates			
Traditional	41.116	41.269	0 0037
Commercial	21.821	21 489	-0 0152
Resource Use (million units)			
Fertilizer			
Traditional	74 200	74 200	0 0000
Commercial	211 300	211.300	0 0000
Other Purchased Inputs			
Traditional	595 260	595 260	0 0000
Commercial	4223.610	4223.610	0 0000
Wheat Production (1000 m t)			
Traditional	227 098	227 098	0.0000
Commercial	2062 897	2062 891	0 0000
Total	2289.995	2289 989	0 0000
Fodder Production (1000 m t)			
Traditional	1291 480	1304 520	0.0101
Commercial	1489 540	1476 500	-0 0088
Total	2781 020	2781 020	0 0000

3. Combined wheat and fodder balances. Significant changes occurred in activity levels when commodity balances were combined for both wheat and fodder but farm incomes changed by less than one percent (Table XLIV). Wheat production was reallocated from traditional producers to commercial producers. Traditional farms gave up about 72 percent of their wheat hectares to increases in hectares of fodder and other grains. Traditional farmers also marginally decreased areas in fruits and vegetables and increased dates. Traditional farms increased area in other grains by 129 percent.

Commercial farms increased area in wheat by 7.9 percent, decreased fodder by 11 percent, and eliminated completely other grains. Commercial producers also increased fruits and decreased vegetables and dates.

Only small changes in resource prices occurred with the exception of decreases of 4.6 percent and 1.9 percent in fertilizer dual prices for traditional and commercial producers, respectively. Commodity prices changed by less than one percent.

4. Combined wheat and fodder balances and fertilizer buy activity. In the process of opening up the model gradually to reflect more realistic situations, this scenario emphasizes the fertilizer input market. A fertilizer buy activity is included at the normalized price of one.

Results of this scenario are relatively similar to the previous scenario (Table XLV). Fertilizer use increases by about 2.1 percent because of the lower

TABLE XLIV

BASE MODEL SOLUTION COMPARED TO COMBINED WHEAT AND FODDER BALANCES

Variable	Base Solution	Current Solution	Index of Change
Objective Function (SR million)	19120 549	19120.967	0 0000
Resource Prices (SR)			
Traditional			
1 Land	1 030	1.030	0 0000
2 Labor	1 030	1 030	0 0000
3 Capital	1 020	1 030	0 0098
4 Fertilizer	1 090	1 040	-0 0459
5 Other Purch	1 000	1.010	0 0100
Commercial			
1. Land	1 030	1 030	0 0000
2 Labor	1 020	1 020	0 0000
3 Capital	1 030	1 020	-0.0097
4 Fertilizer	1.070	1 050	-0 0187
5 Other Purch	1 020	1 020	0 0000
Farm Income (SR million)			
Traditional	3971 390	3975 347	0 0010
Commercial	4904 441	4876 370	-0 0057
Commodity Prices (SR 1000/mt)			
Wheat		2 049	
Traditional	2.050		-0 0005
Commercial	2.051		-0 0010
Fodder		1 332	
Traditional	1 329		0 0023
Commercial	1 333		-0 0008
Other Grain	1.643	1 640	-0.0018
Tomatoes	3 329	3 331	0.0006
Cucumbers	3.586	3.587	0.0003
Onion	2.818	2.818	0 0000
Watermelon	2 312	2.308	-0 0017
Melon	2.563	2.562	-0 0004
Squash	4.882	4.875	-0.0014
Okra	9 246	9 231	-0.0016
Eggplant	3 338	3 334	-0 0012
Carrots	2.308	2.306	-0 0009
Other vegetables	3 819	3.816	-0.0008
Dates	2.172	2.167	-0 0023
Citrus	1 485	1 485	0.0000
Other fruit	1 492	1.488	-0 0027
Activity Levels (1000 ha)			
Wheat			
Traditional	88 365	25 014	-0 7169
Commercial	477 522	515 210	0 0789
Fodder			
Traditional	64 574	72.792	0 1273
Commercial	74 477	66 258	-0 1104
Other Grains			
Traditional	43 517	99 686	1 2907
Commercial	29.199	0.000	-1.0000
Vegetables			
Traditional	35.538	32 471	-0 0863
Commercial	51 335	53 404	0.0403
Fruits			
Traditional	12 935	10 035	-0 2242
Commercial	5.674	10 736	0 8921
Dates			
Traditional	41 116	43.135	0 0491
Commercial	21 821	17.419	-0 2017
Resource Use (million units)			
Fertilizer			
Traditional	74 200	74 200	0 0000
Commercial	211.300	211 300	0 0000
Other Purchased Inputs			
Traditional	595 260	595.260	0 0000
Commercial	4223 610	4223 610	0.0000
Wheat Production (1000 m t)			
Traditional	227 098	64.286	0.1273
Commercial	2062 897	2225.707	0 0789
Total	2289 995	2289 993	0 0000
Fodder Production (1000 m t)			
Traditional	1291 480	1455 840	0.1273
Commercial	1489 540	1476.500	-0 1104
Total	2781 020	2781 020	0 0000

TABLE XLV

BASE MODEL SOLUTION COMPARED TO COMBINED WHEAT AND FODDER BALANCES AND FERTLIZER BUY ACTIVITY

Variable	Base Solution	Current Solution	Index of Change
Objective Function (SR million)	19120 549	18835 604	-0 0149
Resource Prices (SR)			
Traditional			
1 Land	1 030	1 020	-0 00997
2. Labor	1.030	1 030	0 0000
3 Capital	1 020	1 030	0 0098
4 Fertilizer	1 090	1 000	-0 0826
5 Other Purch	1 000	1 020	0 0200
Commercial			
1 Land	1 030	1 030	0 0000
2. Labor	1.020	1 030	0 0098
3. Capital	1 030	1 030	-0 0000
4 Fertilizer	1 070	1 000	-0 0654
5 Other Purch	1 020	1 030	0 0098
Farm Income (SR million)			
Traditional	3971 390	3969 471	-0 0005
Commercial	4904 441	4911 699	-0 0010
Commodity Prices (SR 1000/mt)			
Wheat		2 049	
Traditional	2.050		-0 0005
Commercial	2.051		-0 0000
Fodder		1 333	
Traditional	1 329		0 0030
Commercial	1 333		0 0000
Other Grain	1 643	1 644	-0 0018
Tomatoes	3 329	3.331	0 0006
Cucumbers	3 586	3 589	0 0008
Onion	2.818	2 819	0 0000
Watermelon	2.312	2 304	-0 0035
Melon	2.563	2 563	0 0000
Squash	4 882	4 860	-0 0045
Okra	9 246	9 219	-0 0029
Eggplant	3 338	3 330	-0 0024
Carrots	2.308	2 307	-0.0004
Other vegetables	3 819	3 814	-0.0013
Dates	2.172	2 164	-0 0037
Citrus	1 485	1 485	0 0000
Other fruit	1 492	1 496	-0 0040
Activity Levels (1000 ha)			
Wheat			
Traditional	88 365	30 465	0 6552
Commercial	477 522	511 968	0 0721
Fodder			
Traditional	64 574	70 214	0 0873
Commercial	74 477	68 837	-0 0757
Other Grains			
Traditional	43 517	93 581	1 1504
Commercial	29 199	0 000	-1 000
Vegetables			
Traditional	35 538	32 665	-0 0808
Commercial	51 335	53 890	0 0498
Fruits			
Traditional	12 935	12 286	-0 0502
Commercial	5 674	11 562	1 0377
Dates			
Traditional	41 116	43 792	0.0651
Commercial	21 821	15 988	-0 2673
Resource Use (million units)			
Fertilizer	285 500	291 539	0 0212
Traditional	74 200		
Commercial	211 300		
Other Purchased Inputs			
Traditional	595 260	595 260	0 0000
Commercial	4223 610	4223 610	0 0000
Wheat Production (1000 m t)			
Traditional	227 098	78 295	-0 6552
Commercial	2062 897	2211 702	0 0721
Total	2289 995	2289 994	0 0000
Fodder Production (1000 m t)			
Traditional	1291 480	1404 280	0 0873
Commercial	1489 540	1376 740	-0 0757
Total	2781 020	2781 022	0 0000

price. Traditional wheat activity decreased by 65 percent versus 72 percent in the previous scenario. Commercial wheat activity increased by 7.2 percent versus 7.9 percent in the previous scenario.

Changes in farm income from the base solution are minimal and less than changes in the previous scenario.

5. Combined wheat and fodder balances and other purchased inputs buy activity. The objective function is significantly lower for the current solution compared to the base solution because other purchased inputs enter as a buy activity with a normalized price of one whereas for the base solution other purchased inputs enter as a constraint.

In many respects this scenario is closer to the base year data than is the base solution model (Table XLVI). Prices of resources, farm incomes, and commodity prices are all closer to the base year data. Activity levels in terms of crop areas between traditional and commercial producers are not as close to base year data as the basic model solution but this scenario is much closer to base year data than the previous scenario where fertilizer inputs were purchased through a buy activity.

Because the other purchased inputs' price in this scenario is less than the corresponding price for the base solution, the amount of other purchased inputs used expands by 3.6 percent.

TABLE XLVI

BASE MODEL SOLUTION COMPARED TO COMBINED WHEAT AND FODDER BALANCES AND OTHER PURCHASED INPUTS BUY ACTIVITY

Variable	Base Solution	Current Solution	Index of Change
Objective Function (SR million)	19120.549	14306 1125	-0 2518
Resource Prices (SR)			
Traditional			
1 Land	1 030	1 000	-0 0291
2 Labor	1 030	1 000	-0 0291
3 Capital	1 020	1 000	-0 0196
4 Fertilizer	1 090	1.040	-0 0459
5. Other Purch	1 000	1.000	0.0000
Commercial			
1. Land	1.030	1 000	-0 0291
2. Labor	1.020	1 000	-0 0196
3 Capital	1.030	1 010	-0 0194
4. Fertilizer	1 070	1 040	-0 0280
5 Other Purch	1 020	1 000	-0 0196
Farm Income (SR million)			
Traditional	3971 390	3859 560	-0 0282
Commercial	4904.441	4796 712	-0 0220
Commodity Prices (SR 1000/mt)			
Wheat		2.003	
Traditional	2.050		-0 0229
Commercial	2.051		-0 0234
Fodder		1 303	
Traditional	1.329		-0.0196
Commercial	1.333		-0 0225
Other Grain	1.643	1.603	-0 0243
Tomatoes	3.329	3.255	-0.0222
Cucumbers	3 586	3.508	-0.0218
Onion	2.818	2.755	-0 0224
Watermelon	2.312	2.260	-0 0225
Melon	2.563	2 507	-0.0218
Squash	4 882	4.770	-0.0229
Okra	9 246	9.039	-0.0224
Eggplant	3 338	3 262	-0.0228
Carrots	2.308	2.256	-0.0225
Other vegetables	3 819	3.734	-0.0223
Dates	2.172	2.116	-0 0258
Citrus	1 485	1 453	-0 0215
Other fruit	1.492	1.453	-0.0261
Activity Levels (1000 ha)			
Wheat			
Traditional	88 365	87 967	-0 0045
Commercial	477 522	477.759	0 0005
Fodder			
Traditional	64 574	68.948	0 0677
Commercial	74.477	70.102	-0 0587
Other Grains			
Traditional	43.517	32.801	-0 2462
Commercial	29.199	39.462	0 3515
Vegetables			
Traditional	35.538	29 995	-0 1560
Commercial	51 335	57 217	0.1146
Fruits			
Traditional	12 935	17.821	0 3777
Commercial	5.674	1 902	-0 6649
Dates			
Traditional	41.116	43.780	0 0648
Commercial	21 821	18 240	-0 1641
Resource Use (million units)			
Fertilizer			
Traditional	74.200	74.200	0 0000
Commercial	211 300	211.300	0 0000
Other Purchased Inputs	4818 870	4992.217	0 0360
Traditional	595.260		
Commercial	4223 610		
Wheat Production (1000 m t)			
Traditional	227 098	226 075	-0 0045
Commercial	2062 897	2063 919	0 0005
Total	2289.995	2289.994	0 0000
Fodder Production (1000 m t)			
Traditional	1291 480	1378 960	0 0677
Commercial	1489 540	1402.040	-0.0587
Total	2781 020	2781 000	0 0000

<u>6. Combined wheat and fodder balances and fertilizer and other purchased inputs buying activities.</u> The final model validation scenario is to combine the wheat balances for traditional and commercial producers, combine the fodder balances for the same producer types, and remove fertilizer inputs and other purchased inputs as constraints by adding buy activities at normalized prices. Resource prices, farm incomes, and commodity prices are very close to the base year data (Table XLVII). By removing the wheat and fodder restrictions by type of producer does vary the activity levels of commodity production by type of producer. Hence, in this scenario, wheat production shifts from traditional producers to commercial producers whereas fodder and other grains production shifts in the opposite direction. However, the net effect on farm income is minimal. In this scenario, farm income changes by only 0.1 percent for traditional producers and 0.6 percent for commercial producers when compared to the base year data. Further policy analyses in Chapter VI are based on this scenario as the validated model rather than the base model solution as described earlier.

Base Year Model Validation

Validation of the model is defined as the ability of the model to reproduce actual base year values. In addition, validation can lead to identify possible inconsistencies in data and structure of the model. Finally, the validation process is used to justify the model's predictive ability to simulate any possible exogenous policy changes.

The literature on validation procedures permit three general conclusions: (1) testing and validation are important; (2) validation criterion must depend on

TABLE XLVII

BASE MODEL SOLUTION COMPARED TO COMBINED WHEAT AND FODDER BALANCES AND FERTILIZER AND OTHER PURCHASED INPUTS BUY ACTIVITY

Variable	Base Solution	Current Solution	Index of Change
Objective Function (SR million)	19120 549	18600 811	-0 0272
Resource Prices (SR)			
Traditional			
1 Land	1 030	1 000	-0 0291
2. Labor	1 030	1 000	-0 0291
3. Capital	1 020	1 010	-0 0098
4 Fertilizer	1 090	1 000	-0 0826
5 Other Purch	1 000	1 000	0 0000
Commercial			
1 Land	1 030	1 000	-0.0291
2. Labor	1 020	1 000	-0 0196
3 Capital	1 030	1 010	-0 0194
4 Fertilizer	1.070	1 000	-0 0654
5 Other Purch	1 020	1 000	-0 0196
Farm Income (SR million)			
Traditional	3971 390	3863 516	-0 0272
Commercial	4904 441	4796 712	-0 0220
Commodity Prices (SR 1000/mt)			
Wheat		2 004	
Traditional	2.050		-0 0224
Commercial	2.051		-0 0229
Fodder		1 304	
Traditional	1 329		-0 0188
Commercial	1.333		-0 0218
Other Grain	1 643	1 603	-0 0243
Tomatoes	3 329	3 254	-0 0225
Cucumbers	3.586	3 509	-0.0215
Onion	2.818	2.754	-0 0227
Watermelon	2.312	2 256	-0 0242
Melon	2.563	2.506	-0 0222
Squash	4 882	4 756	-0 0258
Okra	9 246	9 026	-0 0238
Eggplant	3 338	3 259	-0 0237
Carrots	2.308	2 257	-0.0221
Other vegetables	3 819	3.731	-0 0230
Dates	2.172	2.116	-0.0258
Citrus	1 485	1 452	0 0222
Other fruit	1 492	1 453	-0 0261
Activity Levels (1000 ha)			
Wheat			
Traditional	88 365	62.519	-0 2925
Commercial	477.522	492 899	0 0322
Fodder			
Traditional	64 574	71.365	0.1052
Commercial	74.477	67 685	-0 0912
Other Grains			
Traditional	43 517	55 718	0 2804
Commercial	29.199	25 942	-0 1116
Vegetables			
Traditional	35 538	30 748	-0 1348
Commercial	51 335	57 440	0 1189
Fruits			
Traditional	12.935	14 614	0 1298
Commercial	5 674	7 500	0 3218
Dates			
Traditional	41 116	45 844	0 1150
Commercial	21 821	13.739	-0.3704
Resource Use (million units)			
Fertilizer	285 500	290 192	0 0164
Traditional	74 200		
Commercial	211 300		
Other Purchased Inputs	4818 870	4987 329	0 0350
Traditional	595 260		
Commercial	4223 610		
Wheat Production (1000 m t)			
Traditional	227 098	160 673	-0 2925
Commercial	2062.897	2129 322	0 0322
Total	2289 995	2289 995	0 0000
Fodder Production (1000 m t)			
Traditional	1291 480	1427 304	0 1052
Commercial	1489.540	1353.706	-0 0912
Total	2781 020	2781 010	0 0000

the uses of the model; and (3) validation procedures must instill confidence in the model on the part of both the analyst and the user of results (Kutcher and Scandizzo).

Validation begins with a series of comparisons of model results with the reported actual values of the variables. Most often, simple comparisons are made and measures of deviations are calculated. Production, cultivated area, and prices are the comparisons given the most emphasis. There is no consensus on the statistic to be used in evaluating the goodness of fit of sector models. However, most researchers have used measures such as the mean absolute deviation (MAD) or the percentage absolute deviation (PAD). The Theil coefficient also has been employed.

A rule of thumb suggested by Hazell and Norton for evaluating performance of sector models is the following: (1) a PAD below 10 percent is good, (2) a PAD of 5 percent would be exceptional, and (3) a PAD of 15 percent or more indicates the model may need improvement before it can be used.

Validity of the Saudi Agricultural Sector Model is evaluated using the percentage absolute deviation (PAD). Detailed results on the observed and simulated levels of traditional and commercial cultivated land are presented in Table XLVIII. It is evident that the PAD for the specified test falls below 5 percent and reflects an excellent fit.

Production is another variable commonly used in validation tests. For the Saudi Agricultural Sector Model the PAD value for production is 4.1 percent, reflecting a superior goodness of fit (Table XLVIX).

TABLE XLVIII

VALIDATION OF THE SAUDI AGRICULTURAL SECTOR MODEL BY CULTIVATED CROP AREA IN HECTARES.

Commodity	Observed Area	Simulated Area	Absolute Deviation
Wheat			
Commercial	477,984	477,522	462 00
Traditional	88,433	88,365	68.00
Other Grains			
Commercial	29,306	29,199	107 00
Traditional	47,743	'43,517	4,226 00
Tomatoes			
Commercial	11,835	12,981	1,146 00
Traditional	12,524	11,983	541 00
Cucumbers			
Commercial	1,842	2,400	558 00
Traditional	1,298	394	904 00
Onion			
Commercial	1,166	1,630	464 00
Traditional	74	98	24 00
Watermelon			
Commercial	15,413	17,052	1,639 00
Traditional	3,187	0	3,187 00
Melon			
Commercial	4,799	5,127	328.00
Traditional	927	0	927 00
Squash			
Commercial	3,389	3,356	33 00
Traditional	691	598	93 00
Okra			
Commercial	1,535	2,069	534.00
Traditional	1,565	781	784 00
Eggplant			
Commercial	796	0	796 00
Traditional	3,352	4,280	928 00
Carrots			
Commercial	671	1,093	422 00
Traditional	519	0	519 00
Other Vegetables			
Commercial	10,132	5,625	4,507 00
Traditional	10,915	17,404	6489 00
Fodders			
Commercial	74,476	74,477	1 00
Traditional	64,574	64,574	0 00
Dates			
Commercial	20,732	21,821	1,089 00
Traditional	42,301	41,116	1,185 00
Citrus			
Commercial	950	0	950 00
Traditional	1,131	0	1,131 00
Other Fruits			
Commercial	5,233	5,674	441.00
Traditional	7,890	12,935	5,045 00
Total	947,383		39,528

PAD or the percentage absolute deviation is interpreted as

PAD = absolute sum of (observed values - simulated values)/total observed values

$$PAD = \frac{\Sigma_i \left| X_i^o - X_i^s \right|}{\Sigma X_i^o}$$

PAD = 39528/947383 * 100

PAD = 4.17%

where O = observed values of variable X, Product I

S = simulated value of variable X, Product I

TABLE XLVIX

VALIDATION OF THE SAUDI AGRICULTURAL SECTOR MODEL BY PRODUCTION LEVELS IN THOUSAND M.T.

Commodity	Observed Production	Simulated Production	Absolute Deviation
Wheat	2290.00	2289.99	0.01
Other Grains	230.00	219.50	10.50
Tomatoes	326.75	334.77	8.01
Cucumbers	70.42	62.69	7.73
Onion	11.49	160.19	148.69
Watermelon	374.25	343.09	31.16
Melon	162.61	145.61	17.01
Squash	45.05	43.65	1.39
Okra	17.45	16.05	1.40
Eggplant	39.42	40.66	1.24
Carrots	17.38	15.97	1.41
Other Vegetables	282.02	308.59	26.57
Fodders	2781.00	2781.02	0.02
Dates	457.44	456.92	0.52
Citrus	11.14	0	11.14
Other Fruits	72.41	99.56	27.15
Total	7188.83		293.95

PAD or the percentage absolute deviation is interpreted as:
PAD = absolute sum of (observed values - simulated values)/total observed values

$$PAD = \frac{\Sigma_i \left| X_i^o - X_i^s \right|}{\Sigma_i X_i^o}$$

PAD = 293.95/7188.83 * 100
PAD = 4.09%
where O = observed values of variable X, Product i.
S = simulated value of variable X, Product i.

The price test showed even a better goodness of fit of 3.67 percent, (Table L). The simulated prices are the shadow prices of the commodity balances. Simulated prices are generally higher than the observed base year prices, but their total absolute deviation represent only 3.67 percent of the total observed prices.

The validity of scenario 6 can be examined using the PAD values. Scenario 6 shows a superior fit in terms of prices. The total absolute deviation represents only 1.25 percent of total observed prices. Production level recorded under scenario 6 showed also a very good fit reflected by a low value of PAD of 4.6 percent. Cultivated area absolute deviation from observed data represents 14.4 percent of deviation. The rather high magnitude of cultivated area PAD value can be attributed to rounding errors in the yield, hectares, and monetary valuation of land resource. It should be pointed out that no slack variable was reported in the solution.

The performance of several international agricultural sector models are reported in Hazell and Norton. The Saudi Agricultural Sector Model is compared to these models in terms of performance on production, crop area, and commodity prices. Table LI summarizes these comparisons.

The Saudi Agricultural Sector Model has the lowest PAD values for production and crop area variables among the eight models considered. This is evidence of the validity of the Saudi Model to simulate different policy scenarios.

TABLE L

VALIDATION OF THE SAUDI AGRICULTURAL SECTOR MODEL BY PRICE IN SAUDI RIYAL PER M.T.

Commodity	Observed Prices	Simulated Prices	Absolute Deviation
Wheat	2,000	2,050	50
Other Grains	1,600	1,643	43
Tomatoes	3,250	3,329	79
Cucumbers	3,500	3,586	86
Onion	2,750	2,818	68
Watermelon	2,250	2,312	62
Melon	2,500	2,563	63
Squash	4,750	4,882	132
Okra	9,000	9,246	246
Eggplant	3,250	3,338	88
Carrots	2,250	2,308	58
Other Vegetables	3,250	3819	569
Fodders	1,300	1,329	29
Dates	2,110	2,172	62
Citrus	1,449	1,485	36
Other Fruits	1,449	1,492	43
Total	46,658		1,714

PAD or the percentage absolute deviation is interpreted as:

PAD = absolute sum of (observed values - simulated values)/total observed values

$$PAD = \frac{\Sigma_i \left| X_i^o - X_i^s \right|}{\Sigma_i X_i^o}$$

PAD = 1714/46658 * 100

PAD = 3.67%

where O = observed values of variable X, Product i.

S = simulated value of variable X, Product i.

TABLE LI

VALIDATION MEASURES FOR SELECTED AGRICULTURAL SECTOR MODELS

Model Name	Country	Reference	Variable	PAD
CHAC	Mexico	Bassoco and Norton (1983)	Production	13.4
MAAGAP	Philippines	Kunkel et.al (1978)	Acreage	9.4
TASM	Turkey	Le-Si, Scandizzo, and Kasnakoglu (1982)	Production	7.2
TARP	Turkey	Cakmak (1987)	Acreage	4.6
			Production	4.7
--	N.E. Brazil	Kutcher and Scandizzo (1981)	Production	8.2
MOCA	CostaRica	Cappie et.al (1978)	Production	7.0
	El Salvador			12.0
	Guatemala			7.1
	Honduras			9.3
	Nicarugua			8.7
TOLLAN	Region of Mexico	Howell (1983)	Acreage	13.9
--	Saudi Arabia	Current Study	Production	4.1
			Acreage	4.2
			Price	3.7

CHAPTER VI

ANALYSIS OF WHEAT PRICE SUPPORT POLICY

Introduction

Saudi Arabia's push for wheat production began in the 1980's. The Government's decision to move toward self-sufficiency in wheat has three main objectives: First, increased wheat output reduces the nation's dependence on imports. Second is a desire to distribute petroleum wealth to rural areas including small farmers. And third, a thriving wheat growing sector provides profits and incentives for new crop land development thus representing a stable agricultural base for Saudi Arabia.

The Government initiated a wheat price support program in 1979 of SR3500 ($ 1000) per ton. Generous input subsidies of 50 percent of cost and interest free loans preceded the output price support program and encouraged investors to establish commercial wheat farms. The wheat production results are impressive but costly. Desert dunes have turned into fertile lands, and wheat belts are becoming familiar scenes in certain regions of Saudi Arabia.

Wheat production increased from 150 thousand tons in 1975 to 2.5 million tons in 1986 and is expected to reach 3 million tons in 1990. International experts forecast Saudi wheat output to reach 5 million tons by 1995 (Parker, 1989). Wheat consumption is estimated to be 1.3 to 1.5 million tons per annum (USDA 1987b, Mohamad 1988, Kahtani 1989).

By 1985 the country reached self-sufficiency in wheat production and lowered the wheat price support to SR2000 ($570) per ton. This policy change is the result of modern agriculture's most persistent problems experienced elsewhere in the World and were inevitable for the Saudi dynamic agricultural sector: increasing agricultural surpluses (wheat most obvious), a growing grain storage problem, increasing government costs, depleting water resources, and benefits accruing disproportionally to large farmers over small farmers.

An additional policy change was initiated to support barley prices in 1986 at SR1000 ($ 265) per ton to encourage large wheat farm projects to allocate part of their land to barley production and thus decrease livestock feed imports.

Results of Decreasing Wheat Price Support

In this section, discussion focuses on the following areas: purpose of comparative static analysis, justification for adjustment of the wheat price support, and simulated results of a gradual reduction of the wheat support price.

Comparative Static Analysis

Comparative static analysis represents a simulation of the sector's behavior to a policy change or a combination of policy changes. The value of the parameters or policy variables are changed, one at a time, and cause and effect relations in the model are traced out.

A comparative static analysis requires at least two solutions, a base solution and the simulated or current solution. The simulated or current solution is obtained by adjusting possible policy instruments (e.g. input-output coefficients, right hand side values, prices) and tracing out the policy outcomes after each change.

It is preferable to address one change at a time and obtain a new solution before making further changes. This allows recognition of the effects of each policy change. However, when it is desired to simulate the impact of more than one instrumental policy variable at the same time, the sector modelling technique provides those results including any results of interdependent policy effects.

Justification of Wheat Price Adjustment Policy

The model is used to reflect the current trend of lowering wheat support price policy. The model should reflect the goal and interest of the decision making body. Since wheat production is above the level of self-sufficiency for consumption, wheat stocks are increasing thus increasing storage costs and reducing economic efficiency. Export is one channel to reduce stocks. However, production costs are high making it difficult for Saudi Arabia to be competitive in the international market for wheat. Therefore, producing up to the self-sufficiency level for wheat saves government costs and preserves a buffer stock for the nation.

In this regard the Saudi Agricultural Sector Model is used by gradually lowering the price support for wheat until the self-sufficiency level of about 1.5 million tons is approached.

Wheat Price Support Policy Simulations

The Saudi Agricultural Sector Model is used to simulate the impact of gradual reductions in the wheat support price. The procedure is to change wheat support price by SR200 per metric ton decrements starting from the current price of SR2000 per metric ton and until the self-sufficiency level of 1.5 million tons is achieved. The simulation results reveal that wheat production of 1.543 million metric tons is approached at the support price of SR1400 per metric ton.

The impact of the simulated wheat support price reductions are evaluated with respect to factor input prices, farm incomes, commodity prices, activity levels of major commodities, and variable resource cost. The policy simulations are the following:

Simulation I: wheat support price of SR1800 per metric ton
Simulation II: wheat support price of SR1600 per metric ton
Simulation III: wheat support price of SR1400 per metric ton

Simulation I. Results of this simulation are presented in Table LII. The first column presents the base model solution represented by scenario 6 of Chapter V. The other solutions simulate the progressive effects of reducing the level of wheat price support in the Saudi Agricultural Sector Model.

Reduction in the wheat price support by about 10 percent or at the level of SR1800 per metric ton caused most factor prices to decline. Prices of land and capital for both traditional and commercial farms decreased reflecting that these factors are less critical as the wheat price support is reduced. This is consistent with the Saudi government policy for initially expanding wheat production by increasing the wheat price support. Land and water development and machinery costs were heavily subsidized by the government thus reducing the constraints to wheat producers for land and capital.

TABLE LII

SAUDI AGRICULTURAL SECTOR MODEL SIMULATION RESULTS FOR REDUCED WHEAT PRICE SUPPORT

Variable	Scenario 6	Simulation I	Index of Change	Simulation II	Index of Change	Simulation III	Index of Change
Objective Function (SR million)	18600 811	18200 326	-0 022	17833 283	-0 041	17513.734	-0 058
Resource Prices (SR)							
Traditional							
1 Land	1 000	0 850	-0.150	0 720	-0 280	0 420	-0 580
2 Labor	1 000	1 000	0 000	0 980	-0 020	0.980	-0 020
3 Capital	1 010	0 460	-0 545	0 000	-1 000	0.000	-1 000
4 Fertilizer	1 000	1 000	0 000	1.000	0 000	1 000	0 000
5 Other Purch	1 000	1.000	0.000	1 000	0 000	1 000	0.000
Commercial							
1 Land	1 000	0 760	-0.240	0 580	-0 420	0 130	-0 870
2 Labor	1 000	1 190	0.190	1 290	0 290	1 540	0 540
3 Capital	1 010	0.800	-0 208	0 580	-0 426	0 500	-0 505
4 Fertilizer	1 000	1 000	0.000	1 000	0 000	1 000	0 000
5 Other Purch	1 000	1 000	0 000	1 000	0 000	1.000	0 000
Farm Income (SR million)							
Traditional	3863 516	3557.771	-0 079	3241 860	-0 161	3065 574	-0 207
Commercial	4796 712	4048.547	-0.156	3281.129	-0 316	2681 954	-0 441
Commodity Prices (SR 1000/mt)							
Wheat	2 004	1.800	-0.102	1.600	-0 202	1.400	-0 301
Fodder	1.304	1.180	-0 095	1 053	-0 192	0.966	-0 259
Other Grain	1.603	1.461	-0.089	1.324	-0 174	1.102	-0 313
Tomatoes	3 254	3.121	-0.041	2.939	-0.097	2.900	-0 109
Cucumbers	3.509	3 386	-0 035	3.206	-0 086	3.178	-0 094
Onion	2.754	1 979	-0 281	1.279	-0 536	1 251	-0 546
Watermelon	2 256	2.132	-0 055	1 989	-0 118	1 942	-0 139
Melon	2 506	2 414	-0 037	2.290	-0.086	2 286	-0 088
Squash	4 756	4 619	-0 029	4 388	-0 077	4 357	-0 084
Okra	9 026	8 487	-0 060	7 871	-0 128	7.627	-0.155
Eggplant	3 259	3 087	-0 053	2 874	-0 118	2.825	-0 133
Carrots	2 257	2.129	-0 057	1 975	-0 125	1 932	-0 144
Other vegetables	3 731	3.582	-0.040	3 375	-0 095	3 331	-0 107
Dates	2 116	2 059	-0 027	1 961	-0 073	1.882	-0 111
Citrus	1 452	1.242	-0 144	1.051	-0 276	0.769	-0 471
Other fruit	1 453	1.224	-0 158	1 018	-0 299	0.717	-0 507
Activity Levels (1000 ha)							
Wheat							
Traditional	62 519	127 482	1 039	106.086	0 697	123.164	0 970
Commercial	492 899	359.756	-0 270	333.150	-0 324	283 951	-0 424
Fodder							
Traditional	71 365	31.962	-0.552	16 494	-0 769	0 000	-1 000
Commercial	67 685	107 089	0 582	122 556	0 811	139 051	1 054
Other Grains							
Traditional	55 718	63.754	0.144	106 366	0.909	113 045	1 029
Commercial	25 942	21 200	-0.183	0 000	-1.000	0.000	-1 000
Vegetables							
Traditional	30.748	56 943	0.852	65 837	1.141	72 649	1 363
Commercial	57 440	35 529	-0 381	30 608	-0 467	27 891	-0 514
Fruits							
Traditional	14 614	0 000	-1 000	0 000	-1.000	0 000	-1 000
Commercial	7 500	45 437	5 058	54 443	6.259	63 363	7 448
Dates							
Traditional	45 844	28.846	-0 371	22.758	-0.504	17.368	-0 621
Commercial	13.739	50.799	2.697	64.073	3 663	75.825	4 519
Resource Use (million units)							
Fertilizer	290 192	282 685	-0 026	279 697	-0 036	280 324	-0 034
Other Purchased Inputs	4987 329	4322 311	-0.133	4127 754	-0.172	4025 694	-0.193
Wheat Production (1000 m t)							
Traditional	160 673	327 628	1 039	272 641	0 697	316 530	0 970
Commercial	2129 322	1554 144	-0 270	1439 209	-0 324	1226 669	-0 424
Total	2289 995	1881 772	-0 178	1711 850	-0.252	1543.199	-0 326

Labor, however, shows opposite trends. Factor price of labor is the same for traditional farms but increases for commercial farms from 1 to 1.19 (a 19 percent increase). Labor thus is a critical constraint for the commercial farms. Because the model formulation allows purchase at market prices for fertilizer and other purchased inputs the normalized price remains the same.

Farm income is reduced due to the reduction in factor prices (rents). Income of traditional farms decreased from SR3864 million to SR3558 million (a 8 percent reduction), while that of commercial farms decreased from SR4797 million to SR4049 million (a 16 percent reduction). It is evident from this simulation that large farms' income is very sensitive to any change in wheat price support level. A ten percent reduction in wheat support price reduced large farm income by 16 percent but only reduced small farm income by 8 percent. The phenomena under focus can be discussed the other way around. A ten percent increase in wheat support price generated a 16 percent increase in farm income for large farms and half of that amount for small farms. This finding is consistent with the discussion in earlier chapters that output support policies benefit large farms more than small farms because those policies are based on volume of production.

All commodity prices decreased as a result of the wheat support price reduction. Land and other resources are reallocated from wheat to other crops. Apart from wheat, other crop production increases because of lower opportunity costs for land and capital, and hence those commodity prices will decline. This is consistent with economic theory, which suggests that, when resource prices are lowered, supply functions shift to the right and given constant commodity demand functions, commodity prices are reduced.

Resource utilization of fertilizer and other purchased inputs reduces. Fertilizer use decreased from 290 million units to 283 million units (a 2.6 percent reduction). Other purchased inputs reduced from 4,987 million units to 4,332 million units (a 13 percent reduction).

Wheat production declined substantially from 2,289,995 metric ton to 1,881,772 metric ton (a 18 percent reduction). The decreased wheat production came about from commercial farms where wheat output decreased from 2,129,322 metric ton to 1,554,144 metric ton (a 27 percent reduction). Traditional farms, however, increased wheat production from 161,673 metric ton to 327,628 metric ton (a 104 percent increase).

Traditional farms gave up 37 percent and 55 percent of dates and fodders cultivated area, respectively. Fruit production is completely eliminated in small farms. However traditional farms redirected more land to other groups of crops. Other grain production is given more priority as a result of lowering wheat support price. Small farms allocated 14 percent additional land for other grains. Vegetable production increased significantly in the new scenario for small farms. Eighty-five percent additional land is allocated to vegetables from other crops.

The results for traditional farms are in the direction of more production of wheat, other grains, and vegetables and less production of fruits and dates. Commercial farms are directing resources away from wheat, other grains, and vegetables and towards fodder, fruits, and dates.

<u>Simulations II and III</u>. The purpose of these two simulations is to further reduce the wheat support price to SR1600 and SR1400 per metric ton,

respectively, and observe the impact on the Saudi agricultural sector. Results of the simulations are presented in Table LII. The impacts of the two simulations are quite similar, trendwise, therefore discussion focuses more on the last simulation.

The opportunity cost of land and capital significantly decreases for both traditional and commercial farms. In fact, the shadow price on capital is reduced to zero for traditional farms reflecting an excess or unused supply. For Simulation III, land price is reduced by 58 percent for traditional farms and 87 percent for commercial farms. Labor price, however, is slightly reduced for traditional farms but increases significantly for commercial farms. It increased from 1.00 to 1.54 (a 54 percent increase), reflecting a significant shortage of labor for the commercial farms. As discussed below, commercial farms reallocated about 42 percent of their wheat land to other crops including fruits, fodder, and dates.

Farm income is lowered for traditional farms from SR3,864 million to SR3,066 million (a 21 percent reduction). Reduced farm income is greater for commercial farms, however, where it declined from SR4,797 million to SR2,682 million (a 44 percent reduction). The farm income trend is analogous to Simulation I for both small and large farms. A 30 percent reduction in wheat support price - i.e. from SR2000 to SR1400 per metric ton - will hurt large farm income by almost 44 percent, but will reduce small farm income by only 21 percent, a level below the wheat support price reduction rate.

Prices of other commodities continue to decline but with different magnitudes. This is because resources are shifted out of wheat into other crops. Fruits and some vegetable prices are reduced by half. This group includes citrus, other fruits, and onion, followed by other grains, wheat, and fodder. The other commodity prices are reduced by 10 percent or less as a reflection of a 30 percent reduction in wheat prices.

The activity levels change drastically. Most significantly, commercial wheat producers reallocate 42 percent of their land to other crops including fodders, fruits, and dates.

Fertilizer use is reduced marginally from 291 to 280 million units (a 3 percent reduction). Other purchased inputs declined more drastically from 4,987 million units to 4,026 million units (a 19 percent reduction).

Wheat production is lowered to 1,543 thousand metric tons, a target level consistent with self-sufficiency in the Kingdom. The equilibrium quantity of about 1.5 million metric tons of wheat is approached using the Saudi Agricultural Sector Model at the support price of SR1,400 per metric ton.

Wheat Supply Response

Agricultural sector programming models generate implicit supply response functions for commodities (Hazell and Norton). The supply response functions are made explicit by parametric price solutions of the model. In the Saudi Agricultural Sector Model, price of wheat was parameterized to arrive at the self-sufficiency production level. Lower adjustment of wheat price support caused readjustments in the whole sector. Land rents declined by 58 and 87 percent for traditional and commercial farms, respectively. Land used for wheat was reallocated to other crops. The shadow price for capital decreased by 50 percent for commercial farms and became zero for traditional farms where capital appeared as a slack variable. As wheat price declined, production of wheat reduced and resources previously used for wheat were redirected toward other more profitable crops.

The supply response function is not a supply function because prices of inputs and other outputs are not held constant. As discussed under the wheat price simulations, as the wheat support price was reduced, prices of other crops and resource prices changed.

The wheat supply response function generated using the Saudi Agricultural Sector Model is shown in Figure 2. At the support price of SR2,000 per metric ton, wheat production amounted to 2,289,995 metric tons. Gradual reductions in the wheat support price to SR1,400 per metric ton reduced the level of wheat production to 1.54 million metric ton or close to the level of self-sufficiency.

The arc elasticity of supply response is calculated by the following formula between the prices of SR2,000 and SR1,400:

$$\eta = \frac{(Q_u - Q_l)}{(P_u - P_l)} * \frac{(P_u + P_l)}{(Q_u + Q_l)}$$

The result is a supply response elasticity of 1.1. The interpretation of the supply response elasticity for wheat is that for a one percent increase (decrease) in the support price for wheat there is a 1.1 percent increase (decrease) in the supply of wheat.

Welfare Analysis

The welfare analysis is a useful technique, by which supply and demand relationships are used to determine the level and distribution of gains and losses among producers, consumers, and society from changes in economic

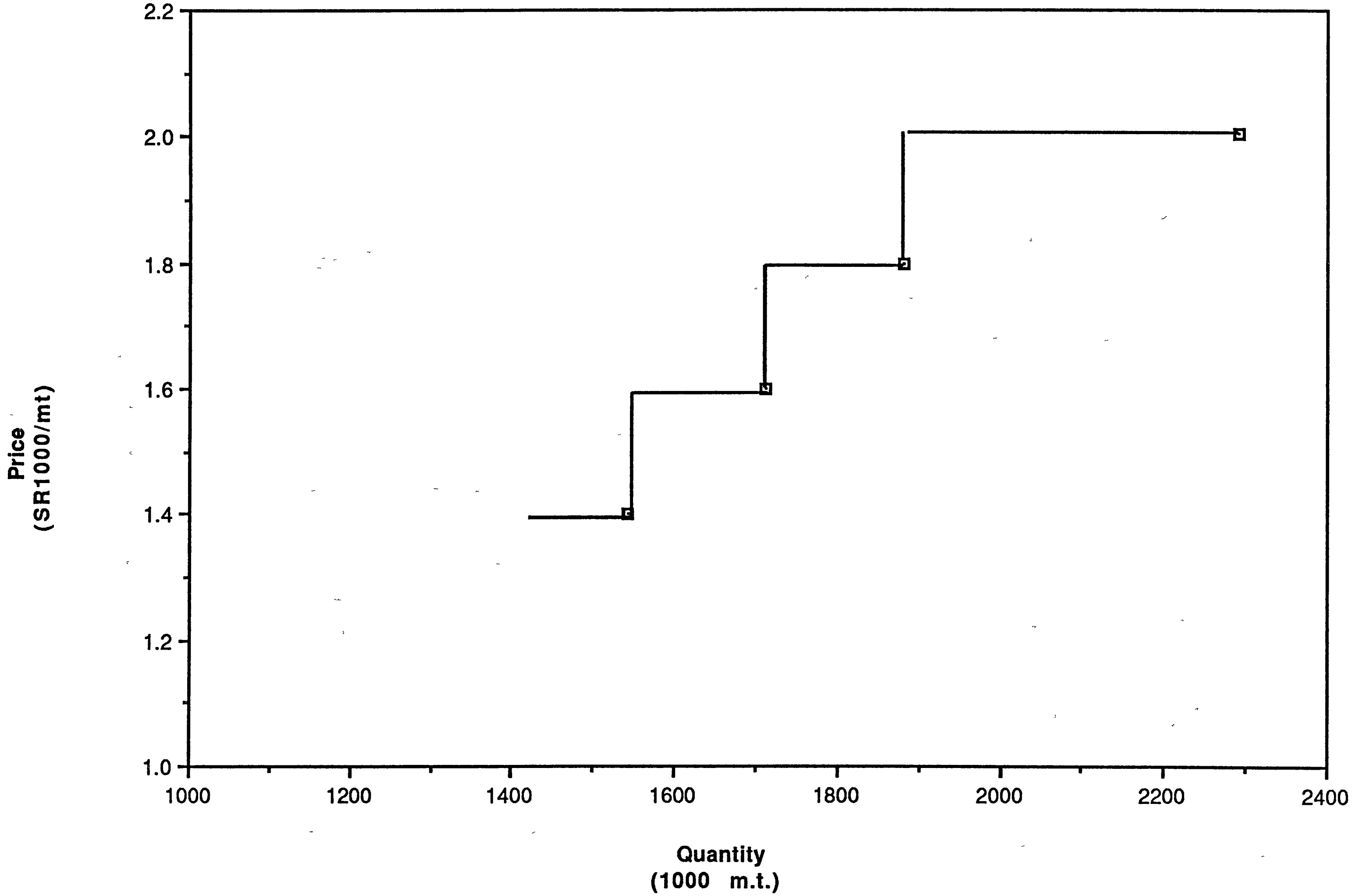


Figure 2: Supply Response for Wheat, Saudi Arabia, 1985.

policy. The technique is a useful tool for policymakers to provide them with information about who gains and who loses from any economic policy. Classical welfare analysis is suited to analyze equity (distribution) issues as well as economic efficiency (Tweeten 1989).

Economic efficiency and equity are difficult tasks to attain simultaneously. Economic efficiency entails allocating resources to uses contributing the most to output. However, efficient allocation is not necessarily an equitable allocation. Markets can be in equilibrium with large sums of benefits absorbed by few producers. On the other hand, economic efficiency and equity do not always conflict.

Thus development plans and decision makers are always emphasizing both goals, efficiency and equity, together as the main strategic objectives. Saudi Arabia Development Plan objectives in the agricultural sector calls for efficiency and upgrading the rural welfare.

The wheat price support is a significant policy instrument in the Saudi agriculture. To measure economic costs, benefits, and redistributions induced by this policy, classical welfare analysis is used to trace out who gains and who loses by lowering price support levels until the self-sufficiency level is achieved. The welfare analysis starts with the current wheat price policy of SR2000 per metric ton. It identifies producer surplus, consumer surplus, government cost and social cost. Then a gradual reduction in wheat price by decrements of SR200 per metric ton is traced out until the self-sufficiency level of about 1.5 million ton of wheat is attained at SR1400 per metric ton.

Key indicators of the levels and distribution of gains and losses for alternative wheat price support levels are presented in Table LIII. At the current price level of SR2000 per metric ton, total producer surplus amounted to SR8,660.23 million. Thirty-three percent of that amount is attributed to wheat production of SR2,866.70 million. The wheat producer surplus represents the value of land, labor, and capital used for the production of wheat by traditional and commercial farms multiplied by their shadow prices generated by the Saudi Agricultural Sector Model in scenario 6. Producer surplus attributed to other crops is the residual difference between total producer surplus and wheat producer surplus.

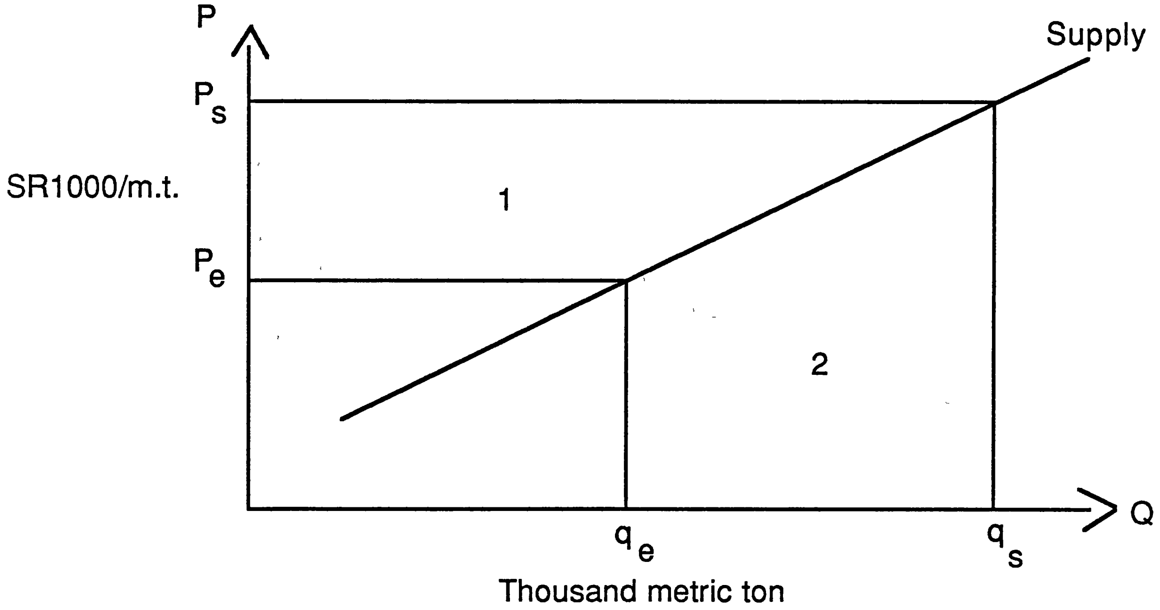
Consumer surplus is obtained also from the Saudi Agricultural Sector Model. It is the shadow prices of the convex combination constraints of all endogenously determined demands in the model. To account for the consumer surplus in fodder, a proxy value is determined for consumer surplus based on demand elasticity of -0.3 (same as barley demand elasticity) and the associated price and quantity of SR1300 per ton and 2781 thousand metric ton demanded by livestock.

Government cost is illustrated in Figure 3 (A) and (B). In Figure 3 (A), government cost is represented by areas 1 and 2. As illustrated in the graph, support price P_s of SR2000 generates production level q_s of 2,289,995 metric tons. Self-sufficiency quantity q_e of 1,543,199 metric ton is approached at price level P_e of SR1400 per metric ton. The difference between production levels $q_s - q_e$ of 746,796 metric ton is the excess wheat and to be stored or exported. According to commodity balances reported in Table XXVII, 500,000 metric tons were stored in 1985. Further, the Saudi government has been donating wheat

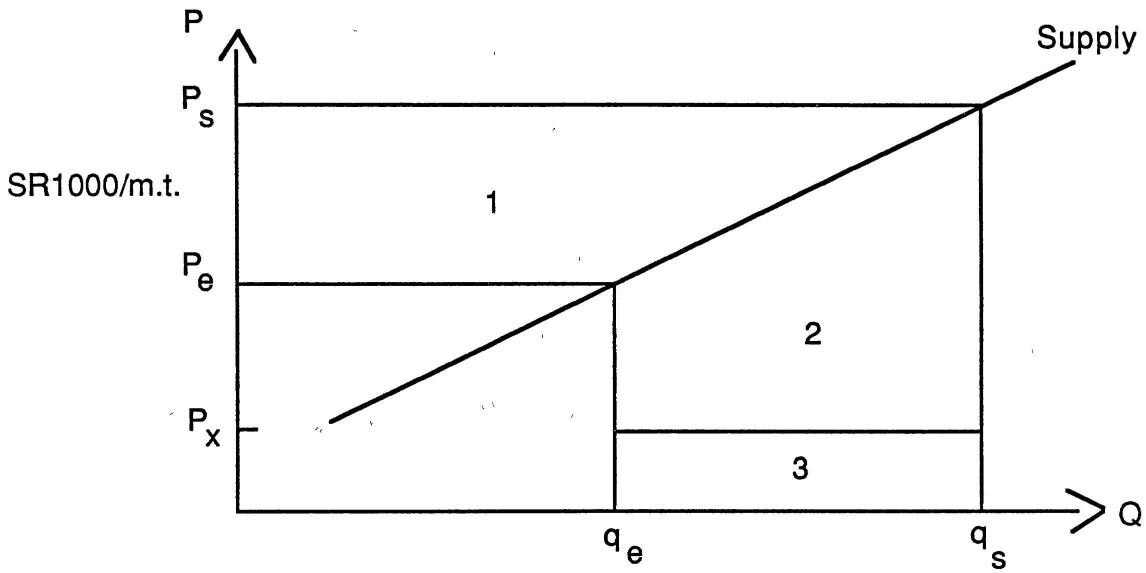
TABLE LIII

WELFARE ANALYSIS FOR ALTERNATIVE GOVERNMENT PRICE SUPPORT LEVELS ON WHEAT, 1985, SAUDI ARABIA

	Wheat Support Price (SR1000/m.t)			
	2.00	1.80	1.60	1.40
Producer Surplus (SR million)				
Wheat	2,866.70	2,068.22	1,527.11	1,107.55
Other Crops	5,793.53	5,538.10	5,000.88	4,639.98
Total	8,660.23	7,606.32	6,527.99	5,747.53
Consumer Surplus (SR million)				
Other Crops	11,490.23	12,030.21	12,656.63	13,072.55
Fodders	6,021.00	6,355.00	6,708.00	6,949.95
Total	17,511.23	18,385.21	19,364.63	20,022.50
Government Cost (SR million)				
1) Assuming zero opportunity cost for excess wheat (no export)	2,419.51	1,226.71	477.29	0.00
Government cost to transfer SR1.00				
a: to wheat producers	1.38	1.28	1.13	0.00
b: to all crop producers	0.83	0.66	0.61	0.00
Welfare Gain (Loss)	(2,018.08)	(1,005.21)	(354.70)	0.00
2) Assuming export value for excess wheat at SR865 per mt	1,773.53	933.85	432.60	0.00
Government cost to transfer SR1.00				
a: to wheat producers	1.01	0.97	1.03	0.00
b: to all crop producers	0.61	0.50	0.55	0.00
Welfare Gain (Loss)	(1,372.10)	(712.35)	(310.00)	0.00
Social Cost (ΔConsumer Surplus + Δ Government Cost) (SR million)				
1) Assuming zero opportunity cost for excess wheat (no export)	4,930.78	2,864.00	1,135.16	0.00
Social cost to transfer SR1.00				
a: to wheat producers	2.80	2.98	2.71	0.00
b: to all crop producers	1.69	1.54	1.45	0.00
2) Assuming export value for excess wheat at SR865 per mt	4,284.80	2,571.14	1,090.47	0.00
Social cost to transfer SR1.00				
a: to wheat producers	2.44	2.68	2.60	0.00
b: to all crop producers	1.47	1.38	1.40	0.00



(A) Government Cost with Food Aid



(B) Government Cost with Stock Sold in International Market

Figure 3. Government Cost Under Different Assumptions for Excess Wheat.

and other products for needy countries as food aid. Therefore, the difference between 1985 production and self-sufficiency is assigned no monetary value. Hence government cost under this assumption is areas 1 and 2 in Figure 3 (A). From Table LIII this amounts to SR2,419.51 million.

Alternatively, the difference between the 1985 production level and self-sufficiency is exported at the FOB price of SR865 per metric ton. This export price is reported in FAO documents for Saudi Arabia. Therefore the government cost is areas 1 and 2 in Figure 3 (B). This amounted to SR1,773.53 million reflecting an export revenue of SR646 million.

The government efficiency of transferring SR1.00 to producers, wheat and total crops, under the no export assumption is SR1.38 and SR0.83, respectively. Government efficiency of transferring SR1.00 under the export revenue assumption is SR1.01 and SR0.61, respectively, to wheat producers and producers to all crops. These values are obtained by dividing the respective government cost figures by the difference in producer surplus at current price policy of SR2000 and the self sufficiency level of SR1400 per metric ton. That is, SR2419.51 divided by (2866.7 - 1107.55). The extent of government cost would be considerably more if input loans and subsidies were included.

Welfare gain or loss under the two assumptions is reported in Table LIII. Under the no export assumption welfare loss amounted to SR2018.08 million in 1985. This represents the gain to producers (8660.23 - 5747.53), the loss to consumers (17511.23 - 20022.5), and the cost to government (2,419.51). If Saudi Arabia wheat stock is exported at SR865 per metric ton then the welfare loss would reduce to SR1372.1 million. Welfare loss decreases as wheat support price reduces. Welfare loss at the support price of SR1600 versus SR1400 is SR354.7 million at zero export value and SR310 million at FOB export price.

Social cost (consumer surplus plus government cost) from the current wheat policy of SR2000 per metric ton amounts to SR4,930.78 million and SR4,284.8 million under the no export and the export assumptions, respectively. These cost figures are obtained by adding government cost to the difference between current consumer surplus and the wheat self-sufficiency level for consumer surplus. The social cost to transfer SR1.00 to wheat producers and total crops producers under the no export assumption is SR2.80 and SR1.69, respectively. If Saudi Arabia exported the excess production, then the social cost to transfer SR1.00 to wheat producers and total crop producers will reduce to SR2.44 and SR1.47, respectively.

The welfare analysis results reported in Table LIII show that at the self-sufficiency price level of SR1400, government cost, welfare loss, and social cost are zero hence there is no transfer costs to producers. Producer surplus is reduced to SR5,747.53 million and consumer surplus increases to SR20,022.50 million. Compared to the results with a wheat support price of SR2000, wheat producers surplus reduces to SR1,107.55 million. This amount is shared by traditional and commercial farms on a 30 percent and 70 percent basis, respectively (Tables LII). In comparison to the producer level at the current price of SR2,000, producer surplus of SR2,866.70 million is shared by traditional and commercial farms on a 11 percent and 89 percent basis, respectively. The reduction of wheat price to the self-sufficiency level moderates the distributional share of producer surplus between traditional and commercial farms.

CHAPTER VII

SUMMARY, CONCLUSIONS, AND POLICY IMPLICATIONS

Summary

Problem Statement

The agricultural sector in Saudi Arabia entered a period of dynamic growth in the early 1980's. A broad range of policies were used to pursue government goals including interest free loans, subsidies on inputs, and price supports for selected commodities such as wheat, barley, and dates.

Saudi Arabia has chosen the self-sufficiency approach for food security rather than the path of food imports. Decision makers have realized the importance of developing a stable agricultural base for the country. The food import bill averaged $5 billion in the middle 1980's. Population increase, both national and guest labor, together with growth in income are among the major factors for increased food demand in Saudi Arabia.

The four Five Year Development Plans (1970 - 1990) show government policy goals for the agricultural sector of (1) increasing farm output and hence lowering food import and (2) upgrading welfare of the rural population.

The government has allocated massive resources to subsidize the agricultural sector. Part was in the form of infrastructure and research stations but direct payments to farmers amounted to SR57 billion (U.S. $ 15.4 billion) between 1970-1988 (Table XI). These payments represent direct loans, subsidies, and wheat purchase program payments.

The take-off stage in Saudi agricultural development took place in 1979 when the government initiated a price support policy for wheat of $1000 per metric ton. The response by farmers, businessmen, and agricultural companies to this generous policy was substantial.

The results have been a successful transformation of desert dunes to fertile fields. Wheat production increased from 150 thousand metric tons in 1975 to 2.5 million tons in 1986 and is expected to reach 3 million tons in 1990. International experts forecast Saudi wheat output to reach 5 million tons in 1995. The country reached self-sufficiency in wheat by 1985 of 1.5 million tons and an excess of one million tons has been available annually for export. The wheat price support policy was lowered in 1985 from $1000 to $571 per metric ton. This policy change was accompanied by initiating a barley price support price of $265 per metric ton in 1986. Both policies were to encourage the production of barley by reallocating some land originally in wheat to that of barley. At the same time, the Kingdom has become self-sufficient or nearly so in eggs, chicken, milk, and dates.

The remarkable achievements in Saudi agriculture have brought about new policy concerns including over production of wheat, depleting water resources, and imbalance between large and small farms.

To investigate the impacts of the Saudi agricultural policies on the whole agricultural sector as a unit, a formal quantitative sector model is required. The need for formal modelling of the Saudi agricultural sector was realized in the Second Development Plan for 1975-1980. A decade later, the Fourth

Development Plan (1985 - 1990) reinforced the need for a formal framework to collect and update data on production costs, record prices of principal crops, and assess the different policy impacts on the farm sector.

It is argued that large commercial farms dominate agricultural production and enjoy apparent economies of scale over small farms. Since incentives, namely wheat price support, are based on volume of production rather than on income, wheat price supports tend to benefit large farms over small farms. The Development Plans however stress the strategic goals of increasing the well being of traditional farmers.

Objectives

The overall objective of this study was to develop an economic framework to analyze the impact of different agricultural policies on the Saudi agricultural sector with reference to farm size. Specific objectives were to: (1) develop an agricultural sector model for policy analysis, reflecting the unique features of the Saudi agricultural sector; (2) estimate the economic and distributional impacts of reduced wheat price support on large versus small farms; and (3) evaluate alternative policies to improve the welfare of small farmers.

Procedure

Economic research should use the best methods available. Agricultural sector models provide measurements for economic policy analysis and have been developed for different purposes in developed as well as in developing countries. The notion of price endogenous sector models has been developed based on the surplus maximization approach formalized by Samuelson (1952), Takayema and Judge (1964), and Duloy and Norton (1975).

Hazell and Norton have combined the state of the art in the structure, validation, and policy applications of agricultural sector mathematical programming models. They have presented different types of sector models and their policy applications for different countries.

The Saudi Agricultural Sector Model developed in this research follow closely the general guidelines of Hazell and Norton. However, it differs in certain areas where the Saudi model has to reflect the unique features and situations of Saudi agriculture.

The basic structure of the Saudi Agricultural Sector Model includes an objective function, resource constraints, and commodity balances. Extensive use is made of demand segment variables, along with associated convex combination constraints. The production side of the Model includes two sub-models representing small and large size farms. On the demand side, consumer behavior is regarded as prices dependent, and thus market clearing commodity prices are endogenous to the model.

The Saudi Agricultural Sector Model replicates the performance of the agricultural sector in 1985. The model simulates the impact of lowering wheat support price on farm income by farm size, resource prices, commodity prices, and production levels. Experiments show how the model can describe economic behavior of different farm sizes and how resources flow from less profitable to more profitable crops. Policy goals such as self-sufficiency in wheat and improved small farm income are not maximized directly with the model, but instead, the model is used to simulate market behavior under alternative policy instrumental variables.

The Saudi Agricultural Sector Model has undergone a detailed validation procedure. The validation results instill solid confidence in the Model's ability to simulate the impact of different policies. The model can be thus used as a decision making tool for future agricultural policy planning in the Kingdom.

To simulate the impact of different policies on the Saudi agricultural sector, three policy simulations for lowering wheat price support level were selected. The procedure was to reduce the wheat support price by SR200 per ton starting at the current price of SR2000 per metric ton and until the self-sufficiency level of 1.5 million tons was achieved. The policy simulations are the following:

Simulation I: Wheat Support Price of SR1800 per metric ton.

Simulation II: Wheat Support Price of SR1600 per metric ton.

Simulation III: Wheat Support Price of SR1400 per metric ton.

<u>Results</u>

The results of the base model solution replicate the base year data closely. Resource prices, farm incomes, and commodity prices are very similar to the base year data (Table XLI). Validation results of scenario 6 with common balances for wheat and fodder and buy activities for fertilizer and other purchased inputs show a superior fit in terms of prices. The percentage absolute deviation (PAD) for prices is 1.25 percent. This means that the total absolute deviation represents only 1.25 percent of total observed prices. Commodity production levels recorded under scenario 6 also show a very good fit reflected by a low value of PAD of 4.6 percent.

Policy Simulation I with a reduction of the wheat price support by 10 percent caused most factor prices to decline. All commodity prices and farm incomes declined. Resource use of fertilizer and other purchased inputs declined. The response in wheat production was significant. Total wheat production declined by about 18 percent as a result of a 10 percent reduction in wheat price. Prices of land and capital for both traditional and commercial farms decreased reflecting that these factors are less critical as the wheat price support is reduced. This is consistent with the Saudi government policy for expanding wheat production by increasing the wheat price support. Land and water development and machinery costs were heavily subsidized by the government thus reducing the constraints to producers for land and capital.

Labor, however, shows opposite trends. Factor price for labor was the same for traditional farms but increased for commercial farms from 1 to 1.19 (a 19 percent increase). Labor thus is a critical constraint for commercial farms.

Incomes for large farms is very sensitive to any change in wheat price support. A ten percent reduction in wheat price caused a 16 percent reduction in income for large farms but only a 8 percent reduction in income for small farms.

All commodity prices decreased as a result of the wheat support price reduction. Land resources were reallocated from wheat to other crops. Apart from wheat, other crop production increased because of lower opportunity costs for land and capital, and hence those commodity prices declined. This is consistent with economic theory, which suggests that when resource prices are lowered, supply functions will shift to the right and given constant commodity demand, commodity prices will decrease.

In terms of activity levels, traditional farms are expanding in wheat, other grains, and vegetables. On the other hand, commercial farms are expanding into fodder, fruits, and dates.

Policy Simulations II and III reduce further the wheat support price to SR1600 and SR1400 per metric ton, respectively. Results of the simulations are quite similar trendwise, therefore discussion addresses the last simulation. Reduction of wheat price by 30 percent from SR2000 to SR1400 per metric ton caused most factor prices to decline substantially. Commodity prices, farm incomes, resource use, and wheat production decreased. The opportunity cost of land and capital significantly decreases for both traditional and commercial farms. In fact, the shadow price on capital is reduced to zero for traditional farms reflecting an excess or unused supply. Because the model does not allow flow of capital out of the agricultural sector, the price of capital is reduced to zero. The assumption of this model is that capital can flow between activities within agriculture but not between agriculture and other industries. Labor price is slightly reduced for traditional farms but increases significantly for commercial farms. It increased from 1.00 to 1.54 (a 54 percent increase), reflecting a significant shortage of labor for the commercial farms. Again, labor is allowed to move between activities within a farm size category but not between farm size categories or into and out of agriculture.

Reduction of wheat price support by 30 percent reduced large farm income by 44 percent, and less than half of this amount for traditional farms or about 21 percent. This phenomenon can be analyzed in the other direction. A 30 percent increase in wheat price support raises large farm income by 44 percent, but only increases small farm income by 21 percent. This reflects the effects of price supports favoring large farm volume production. Small farms benefit more from direct income payments.

Commodity prices decline with different magnitudes. This is because resources are shifted out of wheat into other crops. Fruits and some vegetable prices are reduced by half. This group includes citrus, other fruits, and onion, followed by other grains, wheat, and fodder. The other commodity prices are reduced by 10 percent or less as a reflection of 30 percent reduction in wheat prices.

Reduced wheat support price by 30 percent reduced wheat production by 33 percent. The calculated supply response for wheat is 1.1. The wheat production level is reduced to 1,543,199 metric ton which represents the wheat self-sufficiency level for the Kingdom.

Results of the welfare analysis showed that the producer surplus for wheat production is lowered from SR2866.7 million to SR1107.55 million as a result of wheat price support reduction to the self-sufficiency level. The original producer surplus of SR2866.7 is shared by traditional and commercial wheat producers on the basis of 11 percent and 89 percent respectively. On the other hand, the producer surplus at the lower support price is shared more moderately by traditional and commercial wheat producers at 30 percent and 70 percent, respectively. Consumer surplus increases from SR17,511.23 million to SR20,022.90 as a result of reducing wheat price support to the self-sufficiency level of SR1400. This is because all commodity prices are reduced as a result of lower wheat price. Land and capital are shifted out of wheat and into other crops. Therefore, other crops production increases and prices decrease given a constant demand, and consumer surplus increases.

The welfare gain of reducing wheat production to the self-sufficiency level is SR2018.08 million, given that the excess wheat of 1985 production is reserved as a buffer stock or donated as food aid. However, if the excess wheat is sold or valued at the international market price of SR865 per metric ton, then the welfare gain of reducing wheat price support to self-sufficiency level is SR1372.1 million.

Social cost (change in consumer surplus + government cost) of the current wheat price support of SR2000 per metric ton is SR4930.78 given that the excess wheat is valued at a zero opportunity cost. This amount decreases to SR4284.4 million if the excess wheat is valued at an FOB price of SR865 per metric ton.

Conclusions

Agricultural development in Saudi Arabia is the result of a deliberate policy strategy to increase food production and improve rural welfare. The government has allocated massive resources to subsidize the agricultural sector. The results have been impressive. According to USDA sources, the annual compound growth rate of agricultural production in Saudi Arabia from 1977-1986 was 16.9 percent, the highest level in the world. Not only wheat but other commodities have experienced dramatic increases in output and changes in the structure of production. The emergence of factory-style production units for poultry and eggs, large integrated meat and dairy farms, and greenhouses for vegetables over the last decade are part of the new agricultural era.

The wheat price support is a significant policy in the Kingdom. Thus it was selected as the policy to evaluate in the context of Saudi development objectives. The agricultural sector model approach made it possible to replicate the performance of Saudi agriculture in 1985 and to simulate the impact of reducing wheat price support to the self-sufficiency level of 1.5 million ton. The following conclusions can be drawn from this analysis.

1. A ten percent reduction in wheat price support causes the whole agricultural sector to adjust. This reflects the importance of wheat price support policy in the country. Reduction of wheat price support by 10 percent causes reduction on most factor prices, all commodity prices, farm incomes, resource use, and wheat production.

2. Large farm income is more sensitive to change in wheat price support than small farm income. A 10 percent decrease in wheat support price reduces large farm income by 16 percent versus small farm income reduction of 8 percent. Interpreted in the other direction, wheat price supports have increased large farm incomes substantially more than small farm incomes.

3. Reduction of wheat price support to the self-sufficiency level has significant effects on agriculture. The wheat self-sufficiency level of 1.5 million tons can be attained at a price support level of SR1400 per metric ton. This implies a reduction of wheat price support by 30 percent. This substantially reduces factor prices, commodity prices, farm incomes, resource use, and wheat production. The opportunity cost of land and capital significantly decreases. In fact, the shadow price on capital is reduced to zero for traditional farms reflecting an excess supply. Part of the excess supply of capital could be moved out of agriculture into other sectors but part is in fixed supplies such as

irrigation facilities, machinery and equipment, and fruit and date palm orchards. Because the agricultural sector model does not allow movement of resources out of agriculture, then slack resources appear in different policy simulations.

4. An interpretation of the relative shadow prices would indicate that farm incomes could be increased by a movement of labor from small farms to large farms or a movement of land from large farms to small farms. In both cases this should result in improved use of capital. With significant reductions in wheat support prices, there should be a significant softening of land prices thus allowing small farmers to expand their land bases and thus allow higher utilization of their labor and capital resources. With a reduction in wheat price support, however, large farms may tend to hire more labor from outside of agriculture to more intensely use their land and capital resources. This will tend to reduce the comparative advantage small farms have with their apparent large labor pool and decrease further small farm incomes.

5. The welfare analysis shows that all agricultural producers benefit from the wheat price supports. However, consumers will gain by reducing wheat price support to the self-sufficiency level. Excluding government input subsidies, it costs government less than one SR to transfer one SR to agricultural producers through the wheat price support policy. However, when losses in consumer surpluses are included, it costs society SR1.40 to SR1.70 to transfer one SR to producers depending on the level of price support and the value attributed to excess wheat production.

Policy Implications

1. Wheat price support policy has expanded agricultural output in Saudi Arabia. Farmers have benefitted but at high government cost and still higher

social cost. In the absence of other policies, reducing wheat price supports will leave considerable excess capacity in agriculture, decrease farm incomes, and lower prices of other commodities thus somewhat benefiting consumers. Even though prices of other commodities (vegetables and fruits) will tend to decrease as resources are shifted out of wheat, Saudi Arabia will not in the near future become sufficiently competitive to export these commodities at a producer profit, particularly if input subsidies are also lowered or removed. However, Saudi Arabia is a major importer of feed grains and these feed grains are highly subsidized to poultry and livestock producers. It would seem logical for Saudi Arabia to utilize its excess capacity in wheat production to produce feed grains even if feed grain price supports replace wheat price supports. Most capital equipment is easily transferable from wheat production to feedgrain production. As resource productivities continue to increase in agriculture there will be need for fewer input subsidies including feed grain subsidies to poultry and livestock producers. This should tend to bring about more realistic relative prices between wheat, feed grains, and other crops.

2. Reducing wheat price supports should tend to reduce income disparities between large producers and small producers. In tight labor markets, small producers are more efficient utilizers of marginal land resources than are large producers. With a competitive land market some large producers may be willing to sell land because of higher returns to capital invested in other sectors. Some small and intermediate size producers may be willing to buy land, particularly at zero real interest rates, and thus more fully employ their labor and capital resources.

Limitations of the Study

Model building inevitably is contingent upon the limitations of data availability. Thus results, conclusions, and policy implications are limited by the accuracy of data and assumptions used.

Limitations are experienced both in the quantity and quality of data for the Saudi agricultural sector. According to the Third Development Plan published by the Ministry of Planning (MOP 1980), "the data base for agriculture remains inadequate, and all estimates must be taken as indicative rather than firm." Al-Hamoudi proposed an agricultural information system framework developed at Michigan State University to fulfill the need for more accurate data in Saudi Arabia. The information system is composed of three subsystems, data, inquiry, and decision making.

In this research, data were gathered from different sources, hence different sources have different definitions. Reconciliation of differences in data to arrive at what is thought to be logical and consistent estimates requires value judgement. A technical procedure (the RAS method) was used in some cases to force data to sum up to agricultural sector control totals. Labor intensity ratios for crops and livestock were borrowed from U.S. agricultural statistics. Production cost data were the most difficult pieces of information to obtain. There is, therefore, a need to continuously update farm level budgets by the Ministry of Agriculture and university research centers in Saudi Arabia. An enterprise Budget Generator similar to that developed at Oklahoma State University's Department of Agricultural Economics would be of great use to implement as part of the Saudi agricultural data base.

Assumptions in the Saudi Agricultural Sector Model are numerous. Capital is assumed fixed in the aggregate, but not across production activities. In other words, machinery and equipment can be used for different crops and not restricted to one type of crop. Resource movement out of agriculture is not allowed in this modelling effort. Therefore there was an excess supply of capital in some of the policy simulations. If resources were allowed to leave the agricultural sector to other industries the shadow price of capital may not have approached zero.

The livestock subsector is assumed exogenous to the model. However, fodder and other grain activities were included in the Saudi Agricultural Sector Model with demand determined exogenously. The modelling effort for future research would be better off by integrating the crop sector with the livestock sector.

Regional disaggregation in this research was sacrificed in favor of a simpler model focusing on national markets. Regional data on production costs were available but only for some regions. Future modeling would be improved by surveying farms in different regions of the country and establishing solid budgetary information on a regional basis.

Nevertheless, the Saudi Agricultural Sector Model in present form can be used to simulate the impact of different policies on the structure of agriculture and the distributional impacts of policy benefits.

Further Research

The results of the Saudi Agricultural Sector Model were useful in replicating the performance of the agricultural sector in the base year and in simulating the impacts of reducing wheat price support to the self-sufficiency level. A future research agenda for the Saudi Agricultural Sector Model should focus on the following areas:

1. Integration of the livestock sector with the crop sector. The Saudi Agricultural Sector Model assumed fodder demand as exogenous. It would be more appropriate to include livestock production and consumption activities, allowing fodder and other grains production to be utilized fully by livestock. Data shortage of the livestock input-output coefficients, productivity, and prices need to be collected and integrated into the Saudi Agricultural Sector Model.

2. Disaggregation of the Kingdom into the five 5 regions of Western, Central, Eastern, Northern, and Southern. By disaggregating the model to different regions comparative advantage of regions to produce certain commodities are readily identified. Therefore, agricultural policy planning can focus on regional specific policies and incentives.

3. A more complete model of the Saudi economy emphasizing imports and exports and resource flows between agriculture and other sectors. Flow of resources between competing sectors would more realistically explain factor markets for labor and capital. Linkages between the agricultural sector and other sectors such as food processing and input markets such as fertilizers would give more insights to overall potential of agricultural development.

4. Continuing change in the dynamic agricultural sector. A continuous chain of research pertaining to the changing conditions in the sector

is very important. The Ministry of Agriculture and Water, the Saudi Arabian Agricultural Bank, private and public agricultural companies, and agricultural colleges should expand and integrate research efforts for continuous improvements in growth and efficiency. Agricultural policy studies are of great importance for continuing development of the Saudi agricultural sector. An agricultural economic research center should be established in Saudi Arabia to implement research related to farm management, marketing, and agricultural policy analysis. The research center could be affiliated with the College of Agriculture, King Saud University in Riyadh in conjunction with a graduate program on agricultural management and policy analysis.

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