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Number 24

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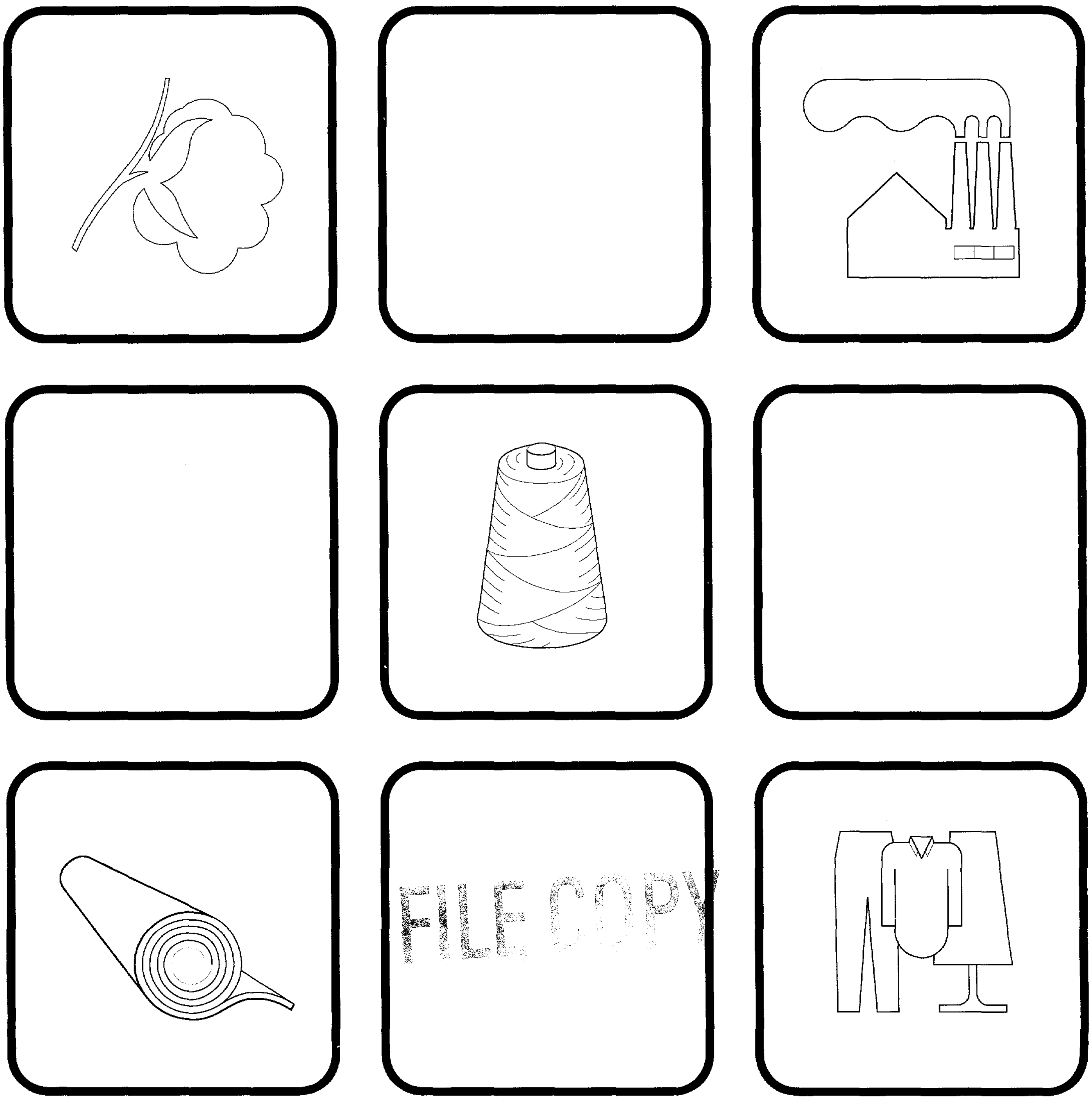
An Econometric Model of the World Cotton and Non-Cellulosic Fibers Markets

Jonathan Coleman
M. Elton Thigpen



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ABSTRACT

The main purpose of this study was to specify and estimate an econometric model of the world fiber market, with emphasis on the cotton sector, and following testing and validation of the model, to forecast prices, production and consumption for the major world fiber market participants. In addition to forecasting, the model is used to estimate the impact of some important market and policy developments. Analysis of these developments provides timely and relevant information for many groups and individuals with interest in the fiber market.

The nature of the fiber market is described along with recent trends and market developments. This description provides the basis for the model specifications (e.g., world price determination, choice of model production and consumption regions, and treatment of textile demand). The demand component of the model is composed of two equations for each demand region in the model. These explain consumer demand for total fiber use and the cotton share of total fiber use. The econometric results are satisfactory and provide price elasticities that conform closely to price elasticity estimates reported in previous studies. The production of cotton is derived from equations explaining the area planted and average yields. The model is closed by formulating a pricing equation as an inverted world stocks demand equation. A non-cellulosic fibers model is also presented. Non-cellulosic share of total fiber use equations are estimated for each consumption region, which are then combined with total fiber use to determine non-cellulosic fibers consumption. The supply of non-cellulosic fibers is estimated for the world. The polyester price is determined in an inverted demand equation for non-cellulosic fibers. A number of validation statistics are presented that cover various aspects of the model's ability to reproduce actual data. In general, the model stands up well under these testing procedures and predicts actual market values accurately enough to be used for policy experiments and forecasting.

Six sets of simulation results are presented. These are for (i) a forecast of price, production and consumption for the period 1990-2005; (ii) a 10% decrease in cotton production in the USSR; (iii) a 10% increase in cotton production in China; (iv) a 10% decline in domestic cotton price in the United States; (v) a 10% increase in the price of oil; and, (vi) an evaluation of the impact of the Multi-Fiber Agreement (MFA) on the cotton and non-cellulosic fibers sectors.

The model forecasts that between 1990 and 2005 the real world price of cotton will fall approximately 25%, while a 10% price increase is forecast for polyester. This suggests that cotton should maintain, or even expand, its share of the total fiber market in the coming decade. The forecast simulation results also show that the individual countries' shares of both production and consumption of cotton and non-cellulosic fibers change very little up to 2005.

Three model simulations involve shocking key variables in major producing regions (i.e., the USSR, China and the United States). In each case, the effect on the world market is significant. For example, given a permanent 10% decrease in production in the USSR, the world price rises by about 9%. This indicates that forecasts of price, both near and long term, should include information on USSR cotton policy and producer incentive structures. Over an 11-year simulation of the model, for every 1% increase in China's production the world price of cotton falls, on average, about 1% and the price of polyester falls 0.35%. The impact of a 10% decline in the US cotton price during the early 1990s would reduce US production, on average, less than 3%, and increase world prices an average of 3.7%. In contrast, the model finds that the impact of an oil price change on the fiber market is small. The conclusion emerging from the MFA simulation is that the MFAs have had an important impact on world prices of fibers. The simulation finds that, as a result of the agreements, world prices of cotton and polyester are reduced by, on average, about 5% between 1979 and 1986 (within a range between 3% and 7%).

ACKNOWLEDGEMENTS

The authors would like to thank a number of individuals whose input into this study was invaluable. An early draft of this paper was reviewed by Tom Bell (ContiCotton), Don Etheridge (Texas Tech University), Jack Ferris (Michigan State University), Terry Townsend and Carlos Valderama (International Cotton Advisory Committee), and Carolyn Whitton (Economic Research Service, United States Department of Agriculture). Their criticisms and suggestions are greatly appreciated. From inside the International Trade Division much helpful guidance was provided by Takamasa Akiyama, especially in formulating the model. Also many useful comments and editorial assistance were provided by Ron Duncan.

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I. INTRODUCTION

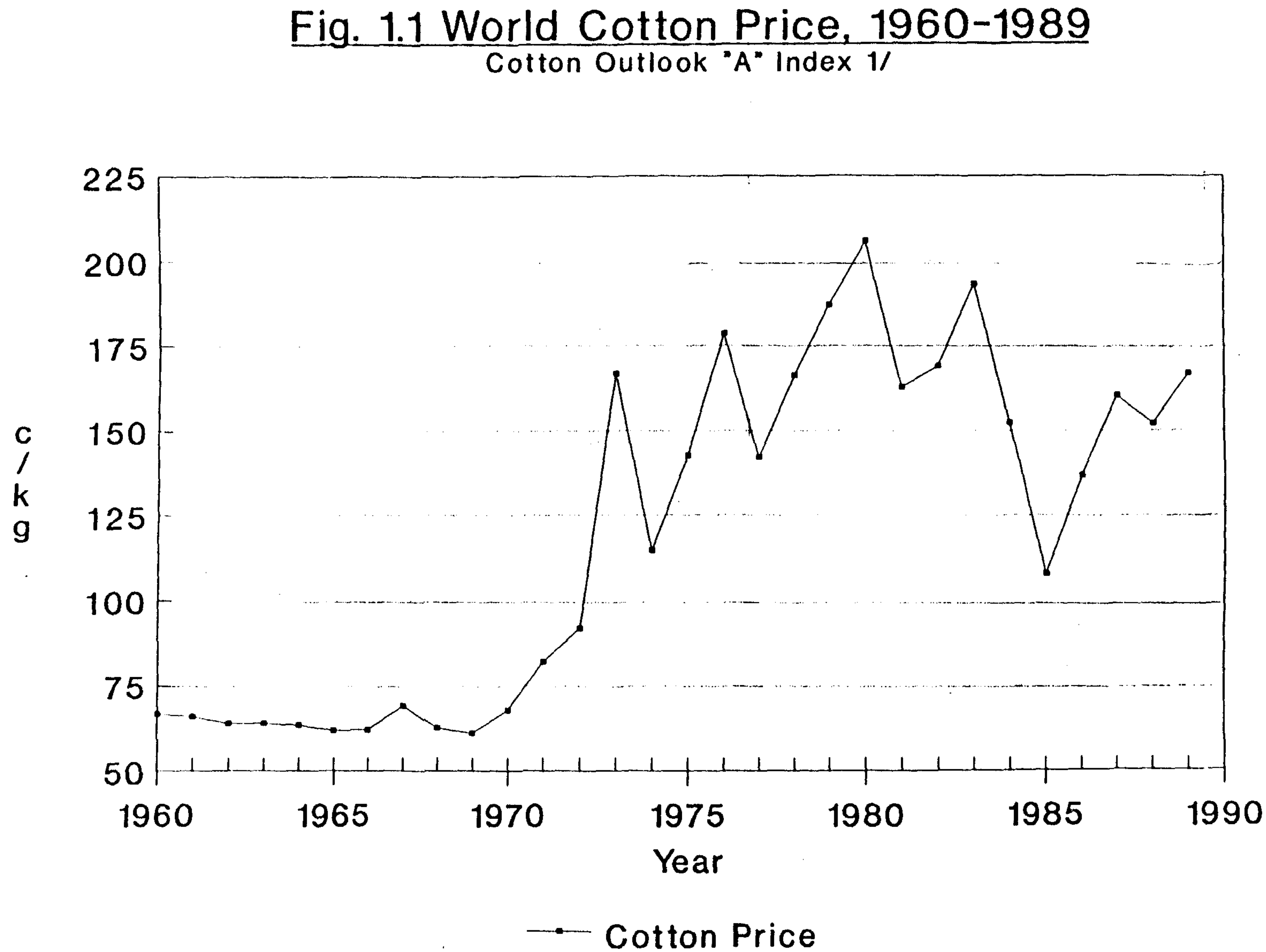
1.1 The Importance of Cotton in Global Agriculture

In many countries, particularly developing countries, cotton is an important agricultural commodity, providing a significant contribution to farm income and export earnings. For example, Table 1.1 shows the export earnings from cotton for selected African and Asian countries. In 1987, more than $1 billion was earned by African countries from cotton exports, representing about 9.5% of total export earnings from agriculture. In Asia, cotton is relatively less important but still generated $3.3 billion in export revenues in 1987. In some low-income countries cotton is the principal export crop and foreign exchange earner. For example, 84.3% of the agricultural export earnings of Burkina Faso in 1987 were derived from cotton sales, representing almost 70% of its merchandise trade; while in Sudan and Egypt cotton revenues contributed more than one-half of total export revenues from agriculture. Cotton is also an important agricultural commodity and/or industrial raw material in many industrial countries (e.g., Australia, the United States) and centrally planned economies (e.g., the USSR).

The world cotton market has undergone substantial change since the early 1960s. There has also been substantial price volatility (Figure 1.1). Prices tend to be cyclical with peaks every three or four years (such as in 1973, 1976, 1980, 1983 and 1990). This instability has led to economic hardship in some countries, especially in those deriving a large proportion of export revenues from cotton. A description of recent price movements and discussion of their causes is presented in section II.

1.2 Research Needs

There is a need for greater analytical insight into various areas of the fiber market. For example, since the introduction of its domestic market incentives in the late 1970s, China has become the most important producer and stockholder of cotton in the world market. No quantitative analysis has been undertaken to measure the degree to which these changes have affected the world fiber market. Such analysis would be useful in assessing the impact of future changes in China's cotton policy on world prices and supply and demand conditions in other countries. The USSR is also a large producer of cotton whose supply is determined administratively. There are no studies which measure the impact of changes in USSR cotton supplies on the world market. In forecasting fiber consumption it is important to assess the impact of substitutability and competition from other fibers. In this regard, another important development in the fiber market has been the rapid growth of non-cellulosic (mainly polyester, acrylic, nylon) fibers (increasing from about 11% of total fiber use in 1965 to over 35% currently, at the expense of cotton and other cellulosic fibers). Another important issue concerns how



1/ Middling 1-3/32", c.i.f North Europe

Table 1.1 Export Earnings from Cotton Production for Selected Countries, 1987

Regions and Countries	Cotton Export Earnings ($ million)	Percent of Agricultural Export Earnings	Percent of of Merchandise Trade
Burkina Faso	43.0	84.3	69.6
Chad	31.7	24.9	19.8
Egypt	388.9	56.2	13.2
Mali	46.3	30.6	22.3
Sudan	185.1	59.5	55.5
Tanzania	43.2	12.6	10.4
Togo	34.3	33.1	14.5
AFRICA	1,069.3	9.5	NA
China	756.1	8.9	NA
India	175.0	7.5	NA
Pakistan	445.2	42.3	NA
ASIA	3,319.6	1.9	NA

Source: FAO Trade Yearbook, 1987.

changes in US cotton programs (such as those in the 1985 Food Security Act) affect US producers and world fiber prices. Finally, while some research has been completed on the impact of the Multi-Fiber Agreement (MFA) on the developing countries and the cost of the distortions created (Goto, 1990), its effect on cotton demand and prices has not been evaluated. This issue is important as the MFA is under discussion in the Uruguay Round of negotiations under the GATT. Measuring the impact of the MFA on cotton and polyester producer prices will provide valuable input into the debate over the how the MFA has distorted the world fiber market.

1.3 Research Method

In order to explain and predict cotton price movements and to assess the impact of the abovementioned and other market developments and policy issues, an econometric model of the world cotton and non-cellulosic fibers markets has been developed, with emphasis on the cotton fiber sector. 1/

1/ The other major fiber categories, namely cellulosic fibers and wool, will be added to the model later.

An overview of the model is presented in Figure 1.2. As shown there, the price of cotton is determined by the level of world cotton stocks, which is derived as the residual of world production plus ending stocks, less consumption. Cotton production in each region defined in the model is derived from behavioral equations for yield and area levels. Regional cotton consumption is derived as the product of cotton's share of total fiber consumption and total fiber consumption. Similarly, the consumption of non-cellulosic fibers is derived as the product of non-cellulosic fibers' share of total fiber consumption and total fiber consumption. The cotton and non-cellulosic fibers' share equations are estimated behaviorally as functions of cotton and polyester prices; and total fiber consumption is determined by income, population and general price levels. The supply of non-cellulosic fibers is estimated at the world level as a function of polyester and crude oil prices, while the polyester price is estimated using an inverted demand equation for the Rest-of-the-World region (there are assumed to be no non-cellulosic fibers stocks).

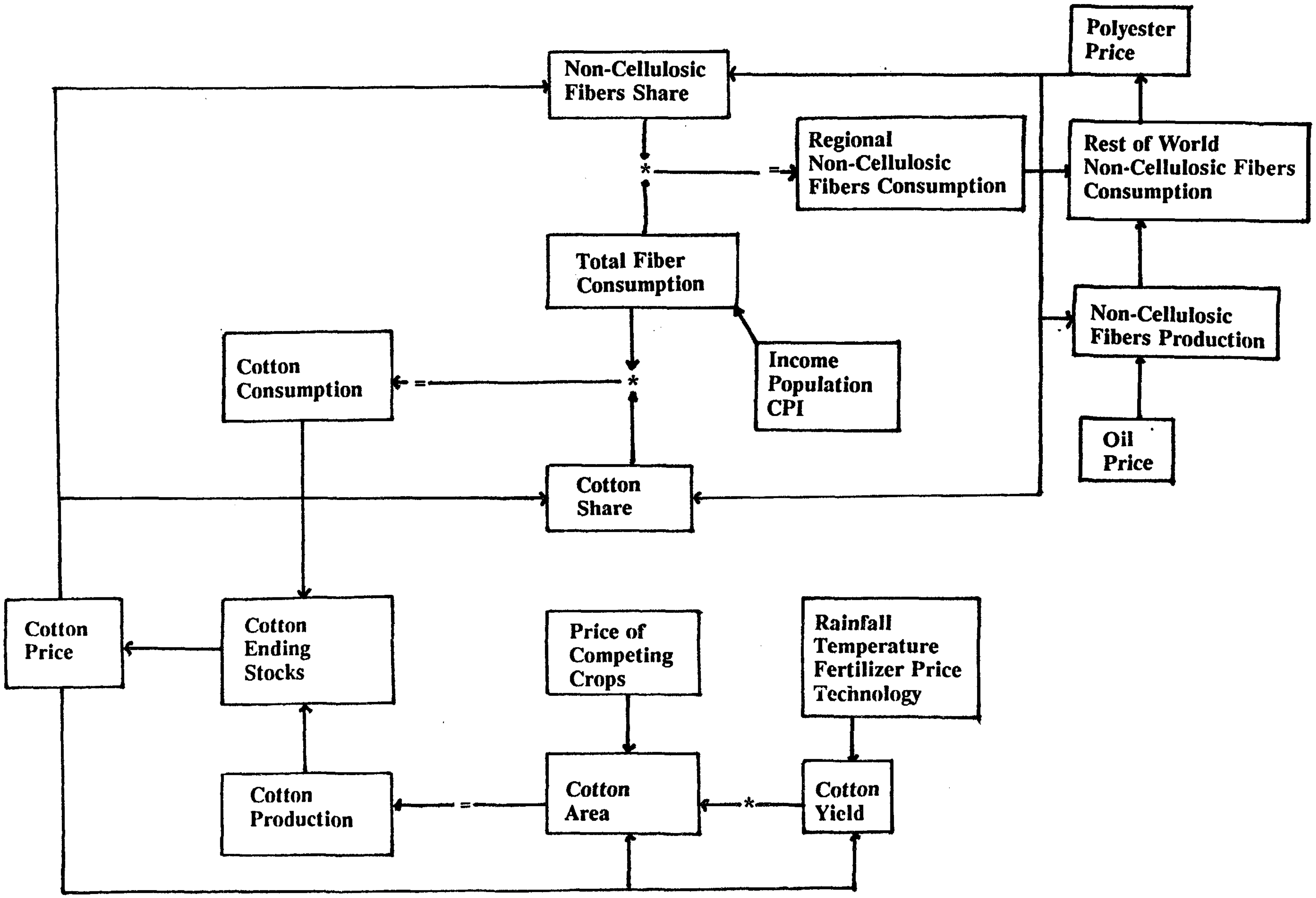
As far as the authors are aware, there are no econometric models of the world fiber market of the detail and country coverage presented below. 1/ Therefore, in addition to analyzing the questions posed above, this study is unique in modeling of the world fiber market, and should be of interest to other research institutions involved in analyzing the world textile and fiber industry.

1.4 Organization of the Paper

This paper is organized into nine sections. The structure of the world fiber market is summarized in section II. The cotton demand, cotton supply and cotton price determination components of the model are presented in sections III, IV and V, respectively. In each of these sections a review of the relevant literature, a discussion of theoretical issues and the regression results are presented. In section VI, the non-cellulosic fibers component of the model is presented. Section VII presents some validation results. In section VIII, price projections from the model up to the year 2005 are reported and discussed. Also presented are model simulation results which address the policy issues outlined in section 1.2. Finally, in section IX a summary and conclusions of the study are provided, along with some proposals for further analysis using the model.

1/ Countries/regions included in the model are Argentina, Australia, Brazil, Central Africa, EEC, Egypt, India, Japan, Korea, Mexico, Pakistan, People's Republic of China, USSR, United States.

Figure 1.2 Diagram of the World Cotton and Non-Cellulosic Fibers Model



II. **THE COTTON MARKET**

2.1 Production

Cotton fiber is produced commercially as an annual cash crop on farms in at least 80 countries located in the tropic and temperate climatic zones. Farms producing cotton vary greatly in size, ownership structure, soil types and technology use. Cotton growing competes with other crops for agricultural land and other production inputs, giving special importance to the relative prices and productivity increases for cotton and competing crops. Its past success in intercrop competition was made possible by a trend of increasing yields and expanded use of labor-substituting capital to offset rising wage rates. Increasing yields have aided in the control of long-run costs of producing cotton, while permitting the expansion of world production with only a small increase in cotton acreage. Cotton production is widely spread between 40 degrees north and 40 degrees south of the equator. However, as shown in Table 2.1, the ten largest cotton-producing countries accounted for over 85% of world output in the 1986/87 crop year--a season of cyclically low production. Five of those large producers are in Asia--China, India, Pakistan, Turkey and the USSR. Together, these large Asian producers accounted for nearly 63% of world production in 1986/87. The United States has alternated with the USSR as the world's third largest cotton producer; in 1986/87 it produced nearly 14% of the world total. Shares of other major cotton producers were as follows: Brazil (4.1%), Egypt (2.6%), Australia (1.4%) and Greece (1.3%).

Cotton is harvested from the plant in the form of seedcotton and requires processing (ginning) to separate the seeds from the fiber (lint). In many African and Asian countries the gins are owned and operated by governmental parastatals and farmers typically sell their seedcotton to government or private agents before ginning. In other cases, for example in North America, the cotton gins are owned privately or by cooperatives and farmers maintain ownership of their cotton while paying a fee for ginning services. In this case, farmers are responsible for merchandising their lint cotton, through cotton merchants or cooperatives, or directly to textile mills.

2.2 Varieties

Cotton is produced with a wide range of fiber quality characteristics, largely depending on its genetic variety and the conditions under which it is produced, harvested, and ginned. Most of the world's commercially produced cotton is of the upland type. Various upland varieties produce a wide range of staple lengths that are broadly characterized as coarse count cottons--suitable for producing coarse count yarns-- and medium count cottons. The coarse count cottons account for a relatively small share of the upland cotton supply. Representative coarse count cottons are the Texas plains varieties, Pakistan Afzal, Argentine C-1/2, Brazilian Type 5/6 and Chinese type 527. The medium count upland cottons account for the bulk of the world cotton supply and are used in a very wide range of textile products.

Table 2.1: Cotton Production, Mill Consumption and Apparent Consumption by Major Countries and Regions in 1986

Regions/ Countries	Production	Mill Consumption	Apparent Consumption
	('000 tons)		
Industrial	5,294	6,438	8,544
N. America	2,119	1,525	2,362
United States	2,119	1,477	2,218
Europe	2,962	4,174	5,054
EEC	290	1,289	2,027
Eastern Europe	12	736	503
USSR	2,660	2,052	2,173
Asia/Oceania	213	739	1,129
Japan	0	717	985
Australia	213	22	122
Developing	10,126	11,023	8,417
Africa	1,340	708	594
Egypt	403	305	210
Asia	7,498	9,011	6,678
China	3,504	4,717	3,704
India	1,615	1,644	1,425
Korea, Rep. of	1	402	233
Pakistan	1,320	630	133
Turkey	518	476	236
America	1,288	1,304	1,145
Brazil	633	731	597
World	15,420	17,461	16,961

Sources: International Cotton Advisory Committee (Production and Mill Consumption); FAO (Apparent Consumption).

The highest valued cottons per unit of weight are the gossypium barbadense type, commonly known for their fine, long, strong fibers. They, and some of the longest and finest gossypium hirsutum cottons--American upland type--are designated by the International Cotton Advisory Committee as extra-fine cotton. These cottons are usually used for spinning 40s count and finer yarns. During 1986/87 they accounted for about 7% of world cotton production. Traditionally, Egypt has been the leading producer and exporter of extra-fine cotton, followed by Sudan and Peru. The limited export supply of Egyptian cotton in recent years has usually been committed to the world's traditional fine yarn spinners within a few weeks of its initial offering each season. Indeed, the limited supply of Egyptian and Sudanese extra fine cottons in recent years has encouraged other producers to sharply increase their acreage of substitute cotton varieties. These producers include China, India, Israel, the United States and the USSR. In these countries, the extra fine cottons account for a relatively small proportion of total cotton production.

2.3 Pricing

Determining the quality of a specific lot of cotton is crucial for correct pricing and for its selection to make specific products. Price determination based on well-understood quality factors at all stages of the marketing system is necessary for transmitting the correct incentives to producers and handlers to encourage the production and preservation of the best quality fibers. For a particular lot of cotton, the uniformity of its quality is also important.

Traditionally, grade and staple length, as determined by an expert classer, have been the most commonly used quality factors for determining cotton's trading price or for selecting the bales to be included in a mill mix. More recently, other fiber quality factors that influence processing performance have been identified, and instruments have been developed to measure these properties. This has made it possible to consider additional factors when selecting cotton for more uniform processing on high-speed, automated textile machinery. A modern high-volume instrument testing line can quickly provide information on fiber strength, fiber fineness and maturity and fiber length uniformity in addition to color and staple length for each bale of cotton. Thus, cotton pricing has become a more complex undertaking as mill requirements have become more stringent.

2.4 Manufacturing

Cotton fiber is used primarily as a raw material for the textile industry. Its properties are quite varied, making it an ideal raw material for a wide range of clothing, household furnishing and industrial products. Cotton is commonly used as the sole fiber in a textile fabric, but it is also blended with other natural or man-made fibers to give special performance characteristics to a particular fabric or for cost considerations.

The textile and clothing industries perform many complex operations in the process of converting cotton fibers into final products for consumption. Specialized machinery and many skills are employed in producing a multitude of intermediate products that make up cotton goods. Fibers are spun into yarns, yarns are woven or knitted into fabrics, fabrics are finished and then converted into consumer products.

Textile manufacturers usually have a choice of fibers that can be used to make their products. Their ultimate choice usually involves the technical performance of each fiber in the specific product, relative prices of the competitive fibers and the preferences of their customers. Cotton's most direct competitors are polyester and rayon fibers. Polyester is a synthetic fiber that is commonly blended with cotton, in varying proportions, to add to the fabric's strength, abrasion resistance, durability and ease of care. Rayon is a cellulosic fiber that is sometimes substituted for cotton in a blend with synthetic fibers.

Cotton is particularly well suited for making apparel items due to its moisture absorbency, its ease and flexibility in dyeing and its pleasant feel. In the United States during recent years about 61% of all cotton used by textile mills was made into apparel products, another 30% was used in home furnishing products and about 9% was used in industrial products.

Textile manufacturing is widely distributed and encompasses both cotton-producing and non-producing countries. Mill consumption of cotton (measured at the spinning stage) can be compared to apparent consumption (cotton textiles available for consumers in raw fiber equivalents) in the main cotton-producing, manufacturing and consuming countries and regions (Table 2.1). In 1986 apparent consumption of cotton in the industrial countries exceeded their mill consumption by over 2 million tons. Their deficit in manufactured cotton goods, which amounted to about 13% of world consumption, was filled by imports from the developing countries. Asian developing countries, which accounted for more than one-half of world mill consumption of cotton, were the main suppliers. Some cotton-producing countries that formerly exported most of their lint production to mills in Europe or Asia have developed substantial textile capacities and now process a major part of their output for local use or for export as textiles. Examples of this development include Brazil, Greece, Pakistan and Turkey. This practice has slowed the growth of cotton trade to well below the growth of cotton production and consumption. Nevertheless, some of the most rapid expansion in cotton manufacturing has occurred in Asian cotton-importing countries, giving a lift to raw cotton trade. Prominent examples include Indonesia, Malaysia, the Republic of Korea, Singapore and Thailand. Overall, exports of raw cotton from developing countries have been unchanged since 1960 while imports into developing countries have increased at an average rate of 4.6% annually. World cotton exports in recent years have been equal to 26% to 31% of world consumption.

III. COTTON DEMAND

In this section the method used to explain the demand for cotton in terms of econometrically-estimated equations is presented. Previous attempts have shown that modeling cotton demand is a formidable task. Empirical analysis has often led to widely differing results--especially in the estimation of income and price elasticities--and seems sensitive to model construction and specification. Monke (1981) associates these difficulties with (i) the development of manufactured fibers, (ii) cotton's role as an input into textile and apparel manufacturing, (iii) variations in cotton quality, and (iv) widespread government intervention in cotton production and trade (e.g., input subsidies, price determination, MFA).

3.1 Features of Cotton Demand

There are a number of features of cotton demand that make the estimation task different from modeling the demand for many other agricultural products. There is no theoretical rationale for directly estimating consumer demand for raw cotton. Raw cotton is demanded by the processors in response to final consumer demand for apparel items and other manufactured textile products. This feature of cotton demand is complicated by the fact that manufactured textile and apparel items are often mixtures of fibers (e.g., blends of cotton and polyester), and individuals tend to be relatively insensitive to the fiber composition. Further, it appears that consumers are insensitive to the prices of individual fibers (e.g., cotton prices relative to polyester prices) because, in general, the fiber component represents only a small proportion of the final purchase price and, within a fairly wide range of blends, consumers are relatively insensitive to different textile mixtures. Therefore, consumer demand can be expected to be highly inelastic and this has been supported empirically in a number of recent studies [Dudley (1974), Magleby and Missaien (1971), Thigpen (1978)].

Textile and apparel manufacturers who purchase raw cotton tend to be much more sensitive than consumers to the relative prices of individual fiber types. Most processing plant technology enables manufactures to substitute fibers quickly but at some cost. 1/ Thus, demand by manufacturers tends to be much more price elastic than at the consumer level.

Another complicating factor is that there is substantial world trade in raw cotton and world trade in apparel and other textile products has grown dramatically since the early 1970s. As a result, the quantities of cotton produced and consumed in any one country may differ significantly.

1/ Although it is now easier to vary the fiber content than in the past, some difficulties remain. The cost of substituting fibers differs widely depending upon the age and design of the machinery and skill of plant managers. A whole assembly line has to be shut down and the machinery recalibrated. This process can take up to a week if switching from all cotton to a blend. In addition, the resulting product has different physical attributes and therefore cannot be marketed as the original product.

An appropriate measure of consumer demand is the quantity available for home use, which is measured by domestic mill consumption plus imported textile products less exports. Some previous studies have used domestic mill consumption as the demand variable [e.g., Mues and Simmons (1988)]. However, this variable does not accurately represent consumer consumption.

3.2 Previous Studies

Several earlier studies attempted to model the demand for cotton and a wide range of approaches have been taken. Because the demand for cotton is derived from the demand for textile products and apparel, some studies have estimated total fiber demand rather than cotton directly.

In an early study by Donald et al. (1963) fiber consumption for the United States was estimated as a function of real income, the change in real income and an index of fiber prices. Dudley (1974) used a similar specification in which total fiber depended on current real income and lagged prices. Magleby and Missaien (1977) and Thigpen (1978) estimated the global demand for all fibers using time series data pooled over a large number of countries. In these studies per capita income was the only regressor and a variety of functional forms was tested, including the double-log, semi-log and log-inverse functions. Overall, the semi-log form performed best, which supports the hypothesis that income elasticity for fibers falls as consumption rises.

Many researchers have used adaptive expectations models to specify their equations. Monke (1981) argues that:

Color, fabric coarseness and fiber mix are important characteristics of textile end-products, and at each level of textile fabrication and distribution, orders are placed and/or received for the delivery of goods in a future period. The current demand for cotton thus depends on textile production decisions made in some previous time period. These decisions, particularly with respect to fiber mix, are presumably influenced by expected prices of cotton and other inputs. The assumption of perfect forecast of income and population changes allows an expression of per capita demand for cotton based on expected prices for fibers.

Studies that have used this approach include Adams and Behrman (1976), Ecevit (1978), Monke and Taylor (1983), and Mues and Simmons (1988). Using world data for 1958 to 1975, Ecevit estimated world cotton consumption as a function of lagged world consumption, lagged real prices of cotton and polyester staple and a time trend. Adams and Behrman estimated per capita cotton consumption equations for industrial and developing countries and centrally planned economies (CPEs). A double-log functional form was used to constrain elasticities to be constant over all price and income ranges. Consumption in industrial countries was specified to depend on lagged consumption, the lagged price ratio of cotton to polyester, per capita income and time. A similar specification was employed for the equations for the CPEs except that the income variable was replaced by per capita production. The equation for the CPEs employed real per capita income and a four-period distributed lag of the cotton to polyester price ratio as regressors.

Mues and Simmons estimated mill consumption for the United States, West Europe and the Rest-of-the-World. The lagged ratio of cotton to polyester prices was used rather than current prices. The authors argued that lagged prices are more appropriate because mills accept orders for their goods up to 12 months in advance and hence need to secure raw cotton supplies by buying forward to ensure that they meet their contracts. The equations included a lagged dependent variable, "since mills are not expected to be able to adjust production levels instantaneously."

Another class of model that has been used to estimate textile demand is based on the work of Chow (1960). These models explicitly recognize the durable nature of textile and apparel products which depreciate over a number of time periods. The model assumes that individuals have a desired level of stocks of these items and that purchases are some fraction of the difference between the desired stocks at the end of the time period and the depreciated old stock from the previous year. Assuming that the desired stock level also depends on prices and income, demand equations can be derived as functions of lagged and current prices, lagged and current income, and lagged consumption. Using this framework, equations for per capita textile demand were estimated by Houthakker and Taylor (1966, 1970) and by Thigpen and Mitchell (1988).

3.3 Theoretical Issues

The two-stage budgeting approach has often provided the theoretical structure for modeling the demand for agricultural commodities. The approach is discussed by Deaton and Muellbauer (1980) and is based on the assumption that preferences are separable across broad groups of consumer goods. The model can be described algebraically as follows. Let the consumer's utility function be given by,

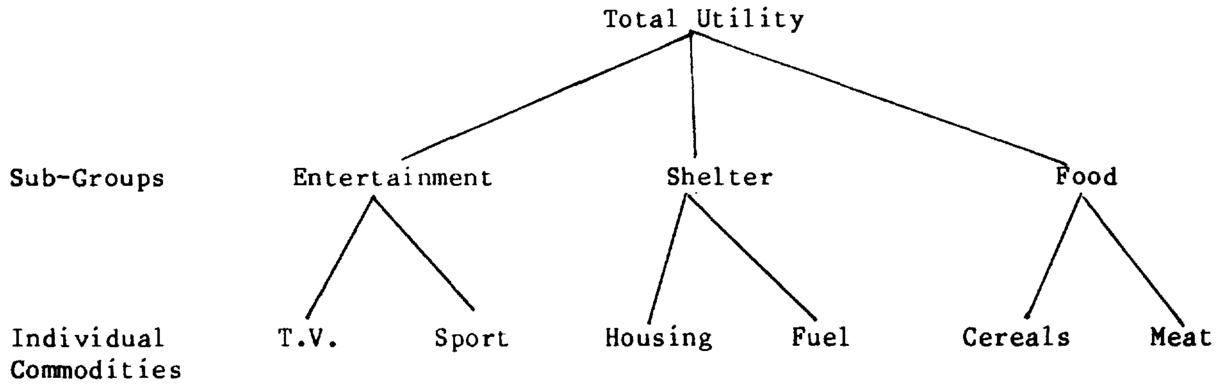
$$U = u(X),$$

where X is a vector of all consumption goods. If preferences are separable then the utility function can be partitioned into a set of sub-utility functions, such that

$$U = u[\ V_1(X_1),\ V_2(X_2),\ \ldots\ ,\ V_n(X_n)\ ]$$

where X_i, $i = 1,\ldots,n$ are partitions of X. Each $V_i(X_i)$ can be regarded as a utility function for broad commodity groupings, such as food, clothing or housing, while the elements of X_i are the quantities of individual goods consumed within the group. The elements of X are allocated among the X_i partitions such that the preference structure within any sub-utility function can be determined independently of the quantities of goods consumed in other sub-utility functions. This is known as weak separability.

Separability is often illustrated with a utility tree. An example is taken from Deaton and Muellbauer (p. 123).



These assumptions about the utility function lead to the idea of two-stage budgeting. In the first stage of this process consumers allocate expenditures to the commodity groups. This is achieved by maximizing the utility function

$$U = [\ V_1(X_1),\ V_2(X_2),\ \ldots\ ,\ V_n(X_n)\ ]$$

subject to $\quad \Sigma_i P_i . X_i = I$

where P_i = a price index for commodity group i,

I = total consumer income.

This problem is solved to determine I_i , the proportion of I allocated to each commodity group i.

In the second stage consumers maximize the sub-utility function for each group, subject to the amount of expenditure determined in the first stage. That is,

$$\text{Max } V_i(X_i)$$

subject to $\quad \Sigma_i p_i . X_i = I_i$

where p_i = a vector of individual commodity prices corresponding to X_i. The solution to this problem gives a demand function for each element of X_i,

$$x_i = x_i(p_i\ , I_i\ ).$$

Note that, the 'direct' cross-price effects of individual commodities in different commodity groups are zero. However, price changes in commodities of one group can impact indirectly on the demand for commodities in another group. This occurs because price changes affect the income allocations in the first stage, which, in turn, alter the budget constraints in the second. The main advantage of this approach in empirical estimation is that it provides a justification for omitting the prices of all commodities considered in the consumer's budget and focusing only on those prices considered most relevant to consumption of the commodity being modeled.

3.4 A Model of World Cotton Demand

While it is not possible to apply the two-stage budgeting approach in its purest form, the features of cotton demand discussed in section 3.1 suggest that cotton demand is derived from a two-step process. Textile and apparel products seem a plausible commodity group, being comprised of individual commodities such as cotton, wool and synthetics. From the discussion of manufacturers' behavior, the consumption of these individual items depends on their relative prices. This is captured by the second stage of the two-stage budgeting process. Consumption of all fibers is constrained by total fiber expenditures which can be proxied by total fiber demand; which, in turn, is determined by total consumer income.

To capture these characteristics of textile demand a two-step approach was taken. Demand in each specified model region was estimated using two behavioral equations and an identity. The first behavioral equation explains total fiber use, which is a measure of the consumption of all fiber types in the form of apparel and textile products. Total fiber use was estimated as a function of current real income. Income elasticities are derived from these equations which express changes in total fiber demand in response to changes in income. This specification forces the income elasticities for individual fibers (cotton, wool, cellulosic fibers, and non-cellulosic fibers) to be the same since the shares are constant with respect to income changes. This restriction may not be important since, as argued earlier, the fiber content of most textile items is generally small. An increase in income may lead consumers to purchase higher valued items. However, typically the higher value can be associated with higher quality products, brand named items, better styling and so on, rather than because of changes in the raw fiber composition.

The price of textiles was not included in the total fiber use equations because of the lack of data on textile prices. Indexes of prices of textiles and apparel do exist as a component of the overall consumer price index for some countries (e.g., the United States and EEC countries) but use of these was econometrically unsuccessful. The lack of statistical significance may result from the fact that the fiber component of the total cost of textile manufacturing is often small (e.g., the cost of cotton delivered to US mills in 1976 was estimated to account for 10.8% of the retail price of a pair of dungarees made from it). Variations in fiber prices therefore account for only a small proportion of the variation in the prices of finished textile products. 1/

1/ The fact that prices were not included in the total fiber use equations weakens the argument in favor of the two-stage budgeting approach.

The second behavioral equation attempts to capture the behavior of textile processors as they respond to changing relative prices of fiber types. This equation estimates the proportion of each fiber type (i.e., cotton, non-cellulosic fibers, cellulosic fibers and wool) that makes up total fiber use. Thus the cotton share of total fiber use was estimated as a function of the prices of cotton and polyester staple. In most of the equations the ratio of these prices was used as the explanatory variable, while in a few equations these prices appeared as separate regressors. The major difference between these approaches is that in the ratio form, the elasticities of the two prices are constrained to be the same. While this specification leads to a reduction in flexibility, it was found that equations in which prices appeared in their ratio form tended to perform better.

To complete the demand system, cotton use was derived through an identity equating the product of the cotton share of total fibers use (given by per capita total fiber use multiplied by population). To summarize, the demand for cotton in each region was derived from:

$$\begin{aligned} CTU &= CTSH * PCTFU * POP, \\ CTSH &= f(CTP, PSP), \\ PCTFU &= f(GDP). \end{aligned}$$

where,

CTU = Cotton for home use;
CTSH = Cotton share of total fibers for home use;
GDP = Gross Domestic Product;
CTP = Price of cotton;
POP = Population;
PSP = Price of polyester staple; and
PCTFU = Per capita total fibers for home use.

An identical structure was used to estimate the use of non-cellulosic fibers and is discussed in detail in section VI. That is, the proportion of non-cellulosic fibers making up total fiber use was estimated as a function of the prices of cotton and non-cellulosic fibers. The non-cellulosic fibers share was then multiplied by total fiber use to obtain the consumer consumption of non-cellulosic fibers.

3.5 Empirical Results

3.5.1 Cotton Share Equations

The equations were estimated from 1964 to 1986 for developing countries and from 1964 to 1987 for industrial countries. These periods were chosen on the basis of data availability. The quantity data used in the demand side of the model was obtained from the World Apparel Fiber Consumption Survey conducted by the FAO. Reasonably comparable data from this survey were available from 1964 to the most recently published survey results (FAO, 1989 issue) up to 1986 for developing countries and 1987 for industrial countries.

Given that the cotton share equations contain current endogenous variables on the right-hand side the model is simultaneous. Consequently, the two-stage least squares estimator (2SLS) was used to avoid the inconsistency of OLS. In the first stage of the 2SLS procedure, instrumental variables are created by regressing current endogenous variables on all exogenous variables within the system. For many models (including the one developed in this study) the number of exogenous variables exceeds the number of observations and the degrees of freedom problem prevents the use of 2SLS. To overcome this problem a subset of exogenous variables can be selected and used as regressors in the first stage. No hard and fast rules exist on how to choose the set of exogenous variables used in the first stage. Intriligator (1978) suggests one criterion:

> ...is to select only those exogenous variables that are most closely related to the endogenous variable in the equation, excluding from each equation those exogenous variables believed to be unimportant on the basis of *a priori* considerations.

This approach was taken in this study with the set of instruments chosen based on knowledge of the relationship between variables within the cotton and non-cellulosic fibers markets. 1/

The price variables used in the cotton share were the prices of cotton 2/ and the price of non-cellulosic fibers. 3/ These prices were denominated in US cents per kilogram. Domestic prices for each region were obtained by applying the US dollar exchange rate to these world prices and

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1/ Alternatively, principle components can be created which are themselves instrumental variables and which capture a specified amount of the variability in the set of exogenous variables. The principle components are then used as regressors in the first stage. For this technique to be consistent the exogenous regressors on the right-hand side of the equations must be included explicitly in the regression of the first stage.

2/ Cotton Outlook A Index, Middling 1-3/32 Inch, CIF Europe.

3/ The price of non-cellulosic fibers was represented by the polyester staple price, f.o.b., US plants.

deflating by a domestic consumer price index. The exchange rates and consumer price indexes were obtained from the IMF. 1/

Based on the framework described above, the cotton share of total fiber use for each region was estimated initially as a function of the deflated price of cotton and the deflated price of polyester. This specification was not successful in most cases with either one or both of these price variables not significant or else did not explain a large amount of the variability of the left-hand side variable. Only in the equations for the United States and Brazil were the price variables included as separate regressors significant and signed correctly (equations 3.3 and 3.14). The poor results of this specification in other regions may have been due to multicollinearity between cotton and polyester prices, despite the deflating of both price series. In light of this possibility, equations explaining the cotton share of total fiber use in other regions were estimated as a function of the ratio of cotton and polyester prices. This specification performed much better and was used in the equations of Argentina, Australia, Central Africa, 2/ China, the EEC-12, Egypt, India, Japan, the Republic of Korea, Mexico and Pakistan.

In the modeling process other variables were tried. For example, to test whether income elasticities differed across fiber types, an income variable was included in the share equations. This variable was not

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1/ IMF, International Financial Statistics. This method of deriving domestic cotton and polyester prices was somewhat crude since it ignored transportation costs, differences in cotton qualities, the impact of trade restrictions on domestic prices in many countries, problems associated with deflating cotton prices and issues over how to obtain exchange rates and deflators for aggregate regions (e.g., the EEC and Central Africa). However, an important requirement of the model was to solve for the Outlook "A" Index price and therefore it was necessary to link domestic prices in cotton producing and consuming regions to this price in some way. Given limited resources and the lack of reliable and consistent domestic cotton price series for individual countries, it was infeasible to take a more sophisticated approach. However, for those countries where price data were available (e.g., China, India and the United States) domestic prices were used in the share equations. This meant that equations linking the domestic price and the Outlook "A" Index price had to be estimated (section V). In the equations with the prices of cotton and polyester appearing as a ratio, the exchange rate and deflation conversions became irrelevant, since identical exchange rates and deflators were included in both the numerator and denominator of the ratio.

2/ The Central Africa region included the following countries: Angola, Benin, Burkina Faso, Cameroon, Central African Republic, Chad, Ethiopia, Ghana, Côte d'Ivoire, Kenya, Malawi, Mali, Mozambique, Niger, Senegal, Somalia, Sudan, Tanzania, Togo, Uganda, Zaire, Zimbabwe.

significant across all regions of the model, as expected, and was pursued no further. A possible explanation for this finding is that attention by consumers to fiber content is a fairly recent phenomenon which was not captured in the regression period.

While the price variables were significant generally, the variability of cotton share in total fiber use was not explained entirely by price relationships. In many equations the specifications were modified to improve the "goodness-of-fit". For example, it was found that estimating the cotton share equations with variables converted into logarithms gave a better fit than in the linear form. In these cases the elasticities were unchanged over all price and consumption levels and were given by the coefficients of the price variables. In many of the equations a zero-one dummy variable was added to the specification to capture abnormal behavior in the data series, while many of the equations contained a time variable. This variable was added because much of the competition between cotton and non-cellulosic fibers is not directly price-related. In all the equations in which it was used, the time variable was negatively signed. This captured the substitution of cotton by non-cellulosic fibers that has taken place following advances in manufactured fiber technology. For example, many important fiber characteristics demanded by manufacturers, such as strength and uniformity of length, are much easier to control by using manufactured fibers. Further, it has been argued (e.g., Monke) that much of the substitution for cotton in the 1950s and 1960s depended on manufactured fiber use rather than price.

The estimated cotton share equations are presented in equations 3.1-3.14, along with selected diagnostics (i.e., t-values, corrected R-squared, standard error of the estimate, Durbin Watson statistic or H-statistic). Reported are the final equation specifications used in the model simulation.

<u>Cotton share of total fiber use in Argentina</u>

$$\text{LN CTSHARG} = -\,0.22 - \underset{(-2.65)}{0.07}\ \text{LN DFCTPARG/DFPSPARG} + \underset{(1.85)}{0.07}\ \text{D76} \quad (3.1)$$

$$+ \underset{(5.48)}{0.606}\ \text{LN CTSHARG}\ (-1)$$

R-SQUARED (CORR.): 0.89 SEE: 0.021 H-STAT: 0.64 PERIOD OF FIT: 1964-86

Where: CTSHARG = Cotton share of total fiber use, Argentina,
DFCTPARG = Deflated cotton price, Argentina,
DFPSPARG = Deflated polyester price, Argentina,
D76 = Zero-one variable, equal 1 to 1976, 0 otherwise,
LN = Indicates variable transformed into logarithms.

The cotton share equation for Argentina was specified with variables converted into logarithms. The ratio of cotton and polyester prices was significant and gave an elasticity estimate of 0.07. A zero-one variable for 1976 was found to be important and captured the high levels of domestic fiber use following a sudden run-down of stocks which had been at very high levels during the early 1970s. A lagged dependent variable was also included in the equation.

Cotton share of total fiber use in Australia

$$CTSHAUS = 0.544 - \underset{(-2.42)}{0.03}\ DFCTPAUS/DFPSPAUS - \underset{(-10.06)}{0.01}\ TIME \qquad (3.2)$$

R-SQUARED (CORR.): 0.92 SEE:0.005 DW:2.32 PERIOD OF FIT: 1964-1987

Where: CTSHAUS = Cotton share of total fiber use, Australia,
DFCTPAUS = Deflated cotton price, Australia,
DFPSPAUS = Deflated polyester price, Australia,
TIME = Time variable.

The cotton share for Australia was a function of the ratio of cotton and polyester prices and a time variable. The price ratio was included after finding the cotton price not to be significant when entered in the equation as a separate regressor. The own- and cross-price elasticities were estimated to be -/+ 0.06 (when measured at the mean prices and quantity) which was smaller than expected. A time variable was found to be highly significant, capturing the non-price related substitution of cotton with manufactured fibers in Australia throughout most of the estimation period. The strength of this trend is indicated by the size of the t-value (-10.06) and corrected R-squared (0.92) which might explain why the estimated price elasticities were small.

Cotton share of total fiber use in Brazil

$$LN\ CTSHBRA = -\ 0.39 - \underset{(-6.15)}{0.18}\ LN\ DFCTPBRA + \underset{(10.84)}{0.17}\ LN\ DFPSPBRA + \underset{(1.92)}{0.06}\ D83 \qquad (3.3)$$

R-SQUARED (CORR.): 0.91 SEE: 0.012 DW: 1.79 PERIOD OF FIT: 1964-86

Where: CTSHBRA = Cotton share of total fiber use, Brazil,
DFCTPBRA = Deflated cotton price, Brazil,
DFPSPBRA = Deflated polyester price, Brazil,
D83 = Zero-one variable, equal 1 in 1983, 0 otherwise,
LN = Indicates variable transformed into logarithms.

The equation explaining the cotton share of total fiber use in Brazil fitted the data better with variables converted into logarithms. The share was explained by the price of cotton and price of polyester which entered the equation as separate regressors, and resulted in elasticity estimates of 0.18 and 0.17, respectively. A dummy variable for 1983 accounted for the effect of the debt crisis in Brazil. The recession caused manufacturers to switch to cotton at the expense of other fibers, although, overall, cotton demand declined sharply.

Cotton share of total fiber use in Central Africa

$$\text{LN CTSHCAF} = -0.14 - \underset{(-3.91)}{0.04}\ \text{LN DFCTPCAF/DFPSPCAF} - \underset{(-10.8)}{0.08}\ \text{TIME} \qquad (3.4)$$

R-SQUARED (CORR.): 0.87 SEE: 0.006 DW: 1.42 PERIOD OF FIT: 1964-86

Where: CTSHCAF = Cotton share of total fiber use, Central Africa,
DFCTPCAF = Deflated cotton price, Central Africa,
DFPSPCAF = Deflated polyester price, Central Africa,
TIME = Time variable,
LN = Indicates variable transformed into logarithms.

The logarithm of the cotton share is explained by the logarithm of the ratio of cotton and polyester prices and a time variable. The results were similar to those reported for Australia (equation 3.2) with small estimates of own- and cross-price elasticities of demand (-/+ 0.04) and a highly significant, negatively-signed time trend variable. The strength of the time trend variable in explaining the share was the result of the sharp upswing in consumption of cheaper textile and apparel items which occurred throughout Africa in the 1970s and 1980s period.

Cotton share of total fiber use in China. 1/

$$\text{CTSHCHI} = 1.08 - \underset{(-8.31)}{0.001}\ \text{DFCTPCHI/DFPSPCHI} + \underset{(3.08)}{0.11}\ \text{D74} \qquad (3.5)$$

R-SQUARED (CORR.): 0.83 SEE: 0.007 DW: 1.89 PERIOD OF FIT: 1964-86

Where: CTSHCHI = Cotton share of total fiber use, China,
DFCTPCHI = Deflated cotton price, China,
DFPSPCHI = Deflated polyester price, China,
D74 = Zero-one variable, equal 1 in 1974, 0 otherwise.

The cotton share of total fiber use in China was estimated to depend on the ratio of cotton and polyester prices and a zero-one variable for 1974. The price ratio was highly significant with a t-value of -8.31 and gave an own- and cross-price elasticity of demand estimate of -/ + 0.06. The initial specification with the prices as separate regressors gave coefficient estimates which were not significant. The dummy variable captured the sudden demand shift towards cotton following the oil price shock which was not fully accounted for by price movements.

Cotton share of total fiber use in the EEC-12.

$$\text{LN CTSHEEC} = -1.01 - \underset{(-5.95)}{0.14}\ \text{LN DFCTPEEC/DFPSPEEC} + \underset{(2.44)}{0.12}\ \text{D83} \qquad (3.6)$$

1/ Includes Taiwan Province.

R-SQUARED (CORR.): 0.70 SEE: 0.047 DW: 1.34 PERIOD OF FIT: 1964-87

Where: CTSHEEC = Cotton share of total fiber use, EEC-12,
DFCTPEEC = Deflated cotton price, EEC-12,
DFPSPEEC = Deflated polyester price, EEC-12,
D83 = Zero-one variable, equal 1 in 1983, 0 otherwise,
LN = Indicates variable transformed into logarithms.

The cotton share of total fiber use in the EEC-12 was estimated as a function of the ratio of cotton and polyester prices and a dummy variable for 1983. The equation fitted the data better when the variables were converted into logarithms. The estimate of the own- and cross-price elasticities were -/+ 0.14.

Cotton share of total fiber use in Egypt.

$$LN\ CTSHEGY = 1.26 - \underset{(-2.08)}{0.17}\ LN\ DFCTPEGY/DFPSPEGY - \underset{(4.26)}{0.06}\ TIME \qquad (3.7)$$

R-SQUARED (CORR.): 0.84 SEE: 0.054 DW: 1.33 PERIOD OF FIT: 1964-86

Where: CTSHEGY = Cotton share of total fiber use, Egypt,
DFCTPEGY = Deflated cotton price, Egypt,
DFPSPEGY = Deflated polyester price, Egypt,
TIME = Time variable,
LN = Indicates variable transformed into logarithms.

The cotton share equation for Egypt estimated with variables converted into logarithms was found to fit the data better than when estimated in the linear form. The cotton share declined consistently throughout the estimation period which was captured by a time variable and found to be highly significant. Also statistically significant was the ratio of cotton and polyester prices with elasticity estimates of -/+ 0.17.

Cotton share of total fiber use in India.

$$LN\ CTSHIND = -0.04 - \underset{(-1.98)}{0.02}\ LN\ DFCTPIND/DFPSPIND + \underset{(13.12)}{0.83}\ LN\ CTSHIND(-1) \qquad (3.8)$$

R-SQUARED (CORR.): 0.95 SEE: 0.004 H-STAT: 0.73 PERIOD OF FIT: 1964-86

Where: CTSHIND = Cotton share of total fiber use, India,
DFCTPIND = Deflated cotton price, India,
DFPSPIND = Deflated polyester price, India,
LN = Indicates variable transformed into logarithms.

The cotton share of total fiber use in India was estimated as a function of the cotton and polyester price ratio and a lagged dependent variable. A double-log functional form was found to fit the data better than the linear form. The price elasticities of demand were estimated to be -/+ 0.016 indicating that consumption of cotton in India was not responsive to price changes. The lagged cotton consumption captured the strong trend in consumption. This result casts doubt on the accuracy of the price elasticity estimates.

Cotton share of total fiber use in Japan.

$$CTSHJPN = 0.25 + \underset{(2.21)}{0.47\ CTSHJPN(-1)} + \underset{(2.31}{0.04\ D74} - \underset{(-1.47)}{0.02\ DFCTPJPN/DFPSPJPN} \qquad (3.9)$$

R-SQUARED (CORR.): 0.61 SEE: 0.004 DW: 1.88 PERIOD OF FIT: 1964-87

Where: CTSHJPN = Cotton share of total fiber use, Japan,
DFCTPJPN = Deflated cotton price, Japan,
DFPSPJPN = Deflated polyester price, Japan,
D74 = Zero-one variable, equal 1 in 1974, 0 otherwise.

The cotton share of total fiber consumption in Japan was estimated to depend on the ratio of cotton and polyester prices, a zero-one dummy variable for 1974, and cotton's share of total fiber use lagged one year. The price variable was not significant but kept in the equation because it had the correct sign. The dummy variable for 1974 captured the sudden increase in cotton imports in that year not explained by price movements.

Cotton share of total fiber use in the Republic of Korea.

$$LN\ CTSHKOR = -\ 0.40 - \underset{(-4.37)}{0.33\ LN\ DFCTPKOR/DFPSPKOR} - \underset{(-2.64)}{0.19\ LN\ TIME} \qquad (3.10)$$

$$+ \underset{(3.63)}{0.38\ D73}$$

R-SQUARED (CORR.): 0.89 SEE: 0.132 DW: 2.22 PERIOD OF FIT: 1964-86

Where: CTSHKOR = Cotton share of total fiber use, Korea,
DFCTPKOR = Deflated cotton price, Korea,
DFPSPKOR = Deflated polyester price, Korea,
D73 = Zero-one variable, 1 in 1973, 0 otherwise,
TIME = Time variable,
LN = Indicates variable transformed into logarithms.

The variables best able to explain the variability in cotton's share of total fiber use in Korea were the ratio of cotton and polyester prices, a time variable, and a zero-one dummy variable for 1973. As with many of the equations reported above, a double-logarithmic functional form provided the best fit to the data. The estimated price elasticities of demand were -/+ 0.33 which indicated that Korean cotton manufacturers are more responsive to price movements than in most other regions studied. The time variable captured the non-price related trend away from cotton during the regression period. However, a zero-one dummy variable for 1973 was needed to account for the sudden demand shift towards cotton following the oil price shock which was not fully accounted for by price movements.

<u>Cotton share of total fiber use in Mexico.</u>

$$CTSHMEX = 0.09 - \underset{(-4.77)}{0.04}\ DFCTPMEX/DFPSPMEX + \underset{(37.69)}{0.86}\ CTSHMEX(-1) \tag{3.11}$$

R-SQUARED (CORR.): 0.99   SEE: 0.002   H-STAT: 1.71   PERIOD OF FIT: 1964-86

Where: CTSHMEX = Cotton share of total fiber use, Mexico,
DFCTPMEX = Deflated cotton price, Mexico,
DFPSPMEX = Deflated polyester price, Mexico.

The cotton share of total use in Mexico declined steadily throughout the regression period with the result that more than 90% of the variation of the cotton share could be explained by the dependent variable lagged one year. The ratio of cotton and polyester prices was found to be significant, however, and gave own- and cross-price elasticity estimates of -/+ 0.09 when calculated at the mean price and quantity.

<u>Cotton share of total fiber use in Pakistan.</u>

$$CTSHPAK = 0.16 - \underset{(-1.72)}{0.03}\ DFCTPPAK/DFPSPPAK + \underset{(10.72)}{0.84}\ CTSHPAK(-1) \tag{3.12}$$

R-SQUARED (CORR.): 0.91   SEE: 0.014   H-STAT: -1.86   PERIOD OF FIT 1964-86

Where: CTSHPAK = Cotton share of total fiber use, Pakistan,
DFCTPPAK = Deflated cotton price, Pakistan,
DFPSPPAK = Deflated polyester price, Pakistan.

The downward trend in cotton's share of total fiber use in Pakistan was captured by a lagged dependent variable which appeared in the equation with a coefficient of 0.84. In addition to this variable, the ratio of cotton and polyester prices was included in the final specification. While this variable was not statistically significant, it was kept in the equation because it had the correct sign.

<u>Cotton share of total fiber use in Turkey.</u>

$$CTSHTUR = 0.24 - \underset{(-2.46)}{0.000007}\ DFCTPTUR + \underset{(2.93)}{0.09}\ D73 + \underset{(8.07)}{0.75}\ CTSHTUR(-1) \tag{3.13}$$

R-SQUARED (CORR.): 0.92   SEE: 0.011   H-STAT: -0.68   PERIOD OF FIT: 1964-86

Where: CTSHTUR = Cotton share of total fiber use, Turkey,
DFCTPTUR = Deflated cotton price, Turkey,
D73 = Zero-one variable, equal 1 in 1973 0 otherwise.

The cotton share of fiber use in Turkey was estimated to depend on the deflated price of cotton in Turkey, a zero-one dummy variable for 1973, and the cotton share lagged one year. The coefficient on the cotton price gave an elasticity of -0.13 when estimated at the mean price and quantity. The zero-one dummy variable captured the sudden demand shift towards cotton following the oil price shock which was not fully accounted for by price movements. The trend away from cotton consumption throughout the regression period was captured by the lagged dependent variable.

Cotton share of total fiber use in the United States.

$$\text{CTSHUSA} = 0.49 - \underset{(-4.91)}{0.0007}\ \text{DFCTPUSA} + \underset{(4.42)}{0.0004}\ \text{DFPSPUSA} - \underset{(-2.86)}{0.004}\ \text{TIME} \qquad (3.14)$$

R-SQUARED (CORR.): 0.89 SEE: 0.013 DW: 1.40 PERIOD OF FIT: 1964-87

Where: CTSHUSA = Cotton share of total fiber use, United States,
DFCTPUSA = Deflated cotton price, United States,
DFPSPUSA = Deflated polyester price, United States,
TIME = Time variable.

For the United States the cotton share of total fiber use was specified to depend on the variability of deflated cotton and polyester prices and a trend variable. It was found that the fit of the equation improved with prices entering as separate regressors. The own- and cross-price elasticities were estimated to be -0.30 and +0.22, respectively, when calculated at the mean values of price and quantity. This indicated that manufacturers in the United States have been more responsive to fiber price movements than their counterparts in other regions. The time variable captured the trend away from cotton in the United States during the regression period (1964-1987) which could not be explained by economic factors.

The fit of the share equations was satisfactory overall. Out of 14 regions, six had a corrected R-squared value of over 90% and for only two equations was it below 80%. Tests for auto-correlation (by the DW or H statistics) failed to find the presence of auto-correlation in most of the equations. A major concern was the inclusion of variables capturing a trend in the consumption data (e.g., time variable or lagged dependent variable). These variables were included because there has been a steady decline in the share of cotton in total fiber consumption during the regression period (1960s to mid-1980s) which was not price-related. As mentioned above, this trend was due, in most part, to technological improvements in the manufactured fibers industry. Also, in many equations dummy variables were used, perhaps too frequently, to remove outlying observations from the data set. However, what was important for the simulation model was to estimate reliable price elasticities. In most cases these were unreliable (i.e., not significant or incorrectly signed) with the omission of the trend and dummy variables. Their inclusion raises the question of how heavily influenced will the long-run forecasts be. Will the forecasts become mainly projections of past trends? However, many other factors play an important role in the forecasts, such as the assumptions made about the model's exogenous variables (e.g., growth rates of income, general prices, exchange rates and population). It is unlikely that the impact of these factors are outweighed by the trend variables; however, this is an issue which is considered carefully in the consumption forecasts which are reported in section VIII.

3.5.2 Per Capita Total Fiber Use Equations

The estimated equations for per capita total fiber use are presented in equations 3.15 to 3.28 below. Per capita total fiber use was estimated as a function of current per capita deflated gross domestic product. In most cases the income variable entered each equation in terms of logarithms. This was consistent with empirical evidence that shows that as incomes and consumption rise, the income elasticity of demand for textile and apparel products falls. 1/ In many of the equations a trend variable was included to provide more reliable estimates of the elasticity of total fiber use with respect to income. The inclusion of this variable improved the statistical fit of the equations considerably, although it implies using caution when making long-run forecasts to see that the trend variables do not determine the outcome.

Per capita total fiber use in Argentina.

$$\text{PCTFUARG} = \underset{}{6.84} + \underset{(3.26)}{3.96}\ \text{LN PDGDPARG} - \underset{(-2.75)}{1.33}\ \text{D81} - \underset{(-3.23)}{1.56}\ \text{D82} \tag{3.15}$$

R-SQUARED (CORR.): 0.73 SEE: 1.88 DW: 2.42 PERIOD OF FIT: 1964-86

Where: PCTFUARG = Per capita total fiber use, Argentina,
PDGDPARG = Per capita deflated gross domestic product, Argentina,
D81 = Zero-one variable, equals 1 in 1981, 0 otherwise.
D82 = Zero-one variable, equals 1 in 1982, 0 otherwise,
LN = Indicates variable transformed into logarithms.

1/ Let: Q^t = Demand for textiles,
I = Per capita income,
LN = Variable transformed into logarithms,
E_{TI} = Elasticity of textile demand with respect to income $(\delta Q^T/\delta I).(I/Q^T)$.
a,b = Intercept and slope coefficients, respectively, in regression equation.

Using a semi-log functional form, the demand equation is represented by, $Q^T = a + b.LNI$. Therefore $E_{TI} = b/Q^T$. Thus as Q^T increases, E_{TI} falls.

The equation explaining per capita total fiber use in Argentina included the log of per capita deflated gross domestic product and zero-one dummy variables for 1981 and 1982. The income variable was highly significant with an estimated income elasticity of 0.58 calculated at the mean total fiber use level. The dummy variables were significant. This result is explained in terms of capturing the recession caused by the debt crisis, the effect of which was not fully captured by the income variable.

Per capita total fiber use in Australia.

$$PCTFUAUS = -\ 88.14 + \underset{(10.32)}{11.84}\ PDGDPAUS - \underset{(-2.08)}{1.95}\ D83 \qquad (3.16)$$

R-SQUARED (CORR.): 0.88 SEE: 16.55 DW: 1.88 PERIOD OF FIT: 1964-87

Where: PCTFUAUS = Per capita total fiber use, Australia,
PDGDPAUS = Per capita deflated gross domestic product, Australia,
D83 = Zero-one variable, equals 1 in 1983, 0 otherwise,
LN = Indicates variable transformed into logarithms.

The variability of per capita total fiber use in Australia was estimated to depend on per capita deflated income and a zero-one dummy variable for 1983. The dummy variable was included to capture the sharp decline in textile imports in Australia in 1983 not accounted for by the income variable.

Per capita total fiber use in Brazil.

$$PCTFUBRA = -\ 12.35 + \underset{(8.81)}{1.55}\ LN\ PDGDPBRA - \underset{(-6.96)}{2.46}\ D85 - \underset{(-7.19)}{2.86}\ D86 \qquad (3.17)$$

R-SQUARED (CORR.): 0.95 SEE: 1.88 DW: 1.29 PERIOD OF FIT: 1964-86

Where: PCTFUBRA = Per capita total fiber use, Brazil,
PDGDPBRA = Per capita deflated gross domestic product, Brazil,
D85 = Zero-one variable, equals 1 in 1985, 0 otherwise.
D86 = Zero-one variable, equals 1 in 1986, 0 otherwise,
LN = Indicates variable transformed into logarithms.

The equation for Brazil fitted the data very well with an adjusted R-squared of 0.95. The income variable was highly significant (t-value = 8.81) providing an estimate of the income elasticity of total fiber use equal to 0.32.

Per capita total fiber use in Central Africa.

$$LN\ PCTFUCAF = -\ 3.51 + \underset{(2.56)}{0.54}\ LN\ PDGDPCAF + \underset{(6.98)}{0.90}\ LN\ PCTFUCAF\ (-1) \qquad (3.18)$$

R-SQUARED (CORR.): 0.92 SEE: 0.06 H-STAT: 0.46 PERIOD OF FIT: 1964-86

Where: PCTFUCAF = Per capita total fiber use, Central Africa,
PDGDPCAF = Per capita deflated gross domestic product, Central Africa,
LN = Indicates variable transformed into logarithms.

The chosen specification of the equation explaining total fiber use in Central Africa included per capita deflated income and per capita total fiber use lagged one year. It was found that regressing the logarithms of the variables provided a better fit to the data than their linear transformation. The income variable was significant with coefficient (and elasticity estimate) of 0.54. The steady increase in fiber use in Africa throughout the regression period meant that the data contained a very strong upward trend. This was accounted for in the equation by the inclusion of a lagged dependent variable which entered the equation with a coefficient of 0.9 and t-value of 6.98.

Per capita total fiber use in China.

$$PCTFUCHI = 6.07 + \underset{(18.28)}{2.88}\ LN\ PDGDPCHI + \underset{(2.36)}{0.58}\ D81 \tag{3.19}$$

R-SQUARED (CORR.): 0.95 SEE: 0.24 DW: 1.73 PERIOD OF FIT: 1964-86

Where: PCTFUCHI = Per capita total fiber use, China,
PDGDPCHI = Per capita deflated gross domestic product, China,
D81 = Zero-one variable, equals 1 in 1981, 0 otherwise,
LN = Indicates variable, transformed into logarithms.

Total fiber use in China was explained by the logarithm of per capita deflated gross domestic product and a zero-one dummy variable for 1981. The regression results should be treated with caution because both per capita consumption and per capita deflated income trended upwards consistently during the regression period with the result that the income elasticity was estimated at 0.91 with a coefficient t-value of 18.28. This elasticity appears to be unduly large and could have resulted from the income variable capturing a non-income related trend in total fiber use.

Per capita total fiber use in the EEC-12.

$$PCTFUEEC = -\ 116.9 + \underset{(7.84)}{15.0}\ LN\ PDGDPEEC - \underset{(-1.71)}{0.14}\ UNEMPEEC - \underset{(-2.39)}{0.76}\ DMFAI \tag{3.20}$$

$$-\ \underset{(-1.71)}{0.58}\ DMFAII\ -\underset{(-4.90)}{1.77}\ DMFAIII$$

R-SQUARED (CORR.): 0.93 SEE: 0.44 DW: 1.62 PERIOD OF FIT: 1964-87

Where: PCTFUEEC = Per capita total fiber use, EEC-12,
PDGDPEEC = Per capita deflated gross domestic product, EEC-12,
UNEMPEEC = Unemployment rate (%), EEC-12,
DMFAI = Zero-one variable for MFAI period, equal 1 1974 to 1977 else 0,

DMFAII = Zero-one variable for MFAII period, equal 1 1978 to 1981 else 0,
DMFAIII = Zero-one variable for MFAIII period, equal 1 1982 to 1985 else 0,
LN = Indicates variable transformed into logarithms.

In the equation for the EEC-12, in addition to the per capita income variable, an unemploment variable was added to the specification. The hypothesis behind the inclusion of this variable was that textile products tend to be durable and purchases are infrequent. In periods of general recession the sales of textile products fall significantly. This is especially the case for lower income households which tend to be most affected by recessions. Although not significant, the variable was kept in the equation because it was signed correctly. Also included in this per capita total fiber use equation were three zero-one dummy variables, accounting for the three Multi-Fiber Agreements (MFA) which operated during the estimation period. The variables captured the decline in consumption which resulted from restrictions placed on the importation of textile products into the EEC-12 from developing countries. An index of prices of textile and apparel products was tried in an initial specification of this equation. However, the variable had a very low t-value (i.e., less than unity) and was dropped from the specification.

Per capita total fiber use in Egypt.

$$\text{PCTFUEGY} = -\ 14.87 + \underset{(12.10)}{3.55}\ \text{LN PDGDPEGY} + \underset{(3.93)}{1.22}\ \text{D81} \qquad (3.21)$$

R-SQUARED (CORR.): 0.91 SEE: 1.66 DW: 1.84 PERIOD OF FIT: 1964-86

Where: PCTFUEGY = Per capita total fiber use, Egypt,
PDGDPEGY = Per capita deflated gross domestic product, Egypt,
D81 = Zero-one variable, equals 1 in 1981, 0 otherwise,
LN = Indicates variable transformed into logarithsm.

The per capita use of fibers in Egypt was estimated to depend on the logarithm of per capita gross domestic product and a zero-one dummy variable for 1981. The income variable was highly significant, and gave an elasticity estimate of 0.68 when calculated at mean fiber use. The dummy variable for 1981 in the equation accounted for the sudden increase in yarn output and weak demand in its export markets.

Per capita total fiber use in India.

$$\text{LN PCTFUIND} = -\ 1.00 + \underset{(2.81)}{0.28}\ \text{LN PDGDPIND} - \underset{(-3.46)}{0.104}\ \text{LN TIME} - \underset{(-2.62)}{0.08}\ \text{D82} \qquad (3.22)$$

R-SQUARED (CORR.): 0.62 SEE: 0.013 DW: 2.08 PERIOD OF FIT: 1964-86

Where: PCTFUIND = Per capita total fiber use, India,
PDGDPIND = Per capita deflated gross domestic product, India,
TIME = Time variable,
D82 = Zero-one variable, equals 1 in 1982, 0 otherwise,
LN = Indicates variable transformed into logarithms.

The variability of per capita total fiber use in India was explained by variability in per capita gross domestic product, a time trend and a zero-one dummy variable for 1982. The equation performed better with variables converted into logarithms rather than in the linear form.

Per capita total fiber use in Japan.

$$\text{PCTFUJPN} = -\ 110.0 + \underset{(2.45)}{8.68}\ \text{LN PDGDPJPN} + \underset{(3.30)}{4.21}\ \text{D73} \qquad (3.23)$$

R-SQUARED (CORR.): 0.81 SEE: 32.47 DW: 1.23 PERIOD OF FIT: 1964-87

Where: PCTFUJPN = Per capita total fiber use, Japan,
PDGDPJPN = Per capita deflated gross domestic product, Japan,
D73 = Zero-one variable, equals 1 in 1978, 0 otherwise,
LN = Indicates variable transformed into logarithms.

Per capita total fiber use in Japan was explained by per capita deflated gross domestic product and a zero-one dummy variable for 1973. The estimated coefficient on the income variable gave an income elasticity of 0.58 when calculated at the mean of total fiber use. The dummy variable for 1973 captured the increase in consumption due to the sudden increase in imports in that year.

Per capita total fiber use in Korea.

$$\text{PCTFUKOR} = -\ 20.85 + \underset{(2.49)}{1.75}\ \text{LN PDGDPKOR} + \underset{(5.83)}{0.71}\ \text{PCTFUKOR}(-1) - \underset{(-3.48)}{2.57}\ \text{D72} \qquad (3.24)$$

R-SQUARED (CORR.): 0.97 SEE: 9.13 H-STAT: 2.01 PERIOD OF FIT: 1964-86

Where: PCTFUKOR = Per capita total fiber use, Korea,
PDGDPKOR = Per capita deflated gross domestic product, Korea,
D72 = Zero-one variable, equals 1 in 1972, 0 otherwise,
LN = Indicates variable transformed into logarithms.

The upward trend in per capita use of fibers in Korea was very strong during the regression period. Because of this, lagged per capita fiber use was included in the final equation specification along with the logarithm of per capita deflated gross domestic product and a zero-one dummy variable for 1972. The statistical significance of a dummy variable in the equation for the Republic of Korea in 1972 captured the substantial economic disruption due to political unrest during the early 1970s.

<u>Per capita total fiber use in Mexico.</u>

$$\text{PCTFUMEX} = -\,15.98 + \underset{(2.49)}{1.77}\ \text{LN PDGDPMEX} + \underset{(2.07)}{0.43}\ \text{PCTFUMEX}\ (-1) - \underset{(-2.17)}{0.82}\ \text{D82} \qquad (3.25)$$

R-SQUARED (CORR.): 0.84   SEE: 2.01   H-STAT: 2.86   PERIOD OF FIT: 1964-86

Where: PCTFUMEX = Per capita total fiber use, Mexico,
PDGDPMEX = Per capita deflated gross product, Mexico,
D82 = Zero-one variable, equals 1 in 1982, 0 otherwise,
LN = Indicates variable transformed into logarithms.

The variables used to explain per capita total fiber use in Mexico were the logarithm of per capita gross domestic product, a zero-one dummy variable for 1982, and per capita fiber use lagged one year. The coefficient on the income variable was significant and resulted in an income elasticity estimate of 0.33. The lagged per capita fiber use variable was needed in the equation to capture the rising trend in use throughout the regression period. The dummy variable for 1982 was included to account for the decline in fiber use as a result of the debt crisis in the early 1980s.

<u>Per capita total fiber use in Pakistan.</u>

$$\text{PCTFUPAK} = 0.44 + \underset{(8.40)}{0.84}\ \text{PCTFUPAK}\ (-1) + \underset{(2.51)}{0.94}\ \text{D72} - \underset{(-2.17)}{0.82}\ \text{D82} \qquad (3.26)$$

R-SQUARED (CORR.): 0.83   SEE: 2.40   H-STAT: 0.78   PERIOD OF FIT: 1964-86

Where: PCTFUPAK = Per capita total fiber use, Pakistan
PDGDPPAK = Per capita deflated gross domestic product, Pakistan,
D72 = Zero-one variable, equals 1 in 1972, 0 otherwise,
D82 = Zero-one variable, equals 1 in 1982, 0 otherwise,
LN = Indicates variable transformed into logarithms.

Of all the equations explaining per capita fiber use, the income variable performed well in all regions except for Pakistan, where it had the wrong sign (negative). Per capita use fell throughout the regression period while per capita income rose. A lagged dependent variable performed well, reflecting the strong trend in the data throughout the regression period. Zero-one dummy variables were included in the regression for the years 1972 and 1982, when there was an unexplained increase and decrease, respectively, in per capita fiber use. The increase in fiber use in 1972 may have been caused by the disruption of supplies going to Bangladesh soon after its independence.

<u>Per capita total fiber use in Turkey.</u>

$$\text{PCTFUTUR} = -\,7.20 + \underset{(2.20)}{0.85}\ \text{LN PDGDPTUR} + \underset{(2.50)}{0.67}\ \text{D74} + \underset{(5.76)}{0.73}\ \text{PCTFUTUR}\ (-1) \qquad (3.27)$$

R-SQUARED (CORR.): 0.95   SEE: 1.02   H-STAT: 1.48   PERIOD OF FIT: 1964-86

Where: PCTFUTUR = Per capita total fiber use, Turkey,
PDGDPTUR = Per capita deflated gross domestic product, Turkey,
D74 = Zero-one variable, equals 1 in 1974, 0 otherwise,
LN = Indicates variable transformed into logarithms.

The equation explaining per capita total fiber use in Turkey contained the logarithm of per capita gross domestic product, a zero-one dummy variable for 1974 and per capita total fiber use lagged one year. The large coefficient on the lagged fiber use variable was caused by the strong upward trend in per capita fiber use during the regression period. The dummy variable accounted for a large increase in fiber availability for domestic consumption in 1974, resulting from sharply lower exports of textiles to other countries which were experiencing a recesson.

Per capita total fiber use in the United States.

$$\underset{}{\mathrm{PCTFUUSA}} = -\,191.0 + \underset{(7.79)}{23.1}\ \mathrm{LN\ PDGDPUSA} - \underset{(-1.32)}{0.28}\ \mathrm{UNEMPUSA} - \underset{(-1.65)}{1.21}\ \mathrm{DMFAI} \quad (3.28)$$

$$-\underset{(-3.42)}{2.30}\ \mathrm{DMFAII} - \underset{(-3.12)}{2.74}\ \mathrm{DMFAII}$$

R-SQUARED (CORR.): 0.82 SEE: 0.77 DW: 1.51 PERIOD OF FIT: 1964-87

Where: PCTFUUSA = Per capita total fiber use, United States,
PDGDPUSA = Per capita deflated gross domestic product, United States,
UNEMPUSA = Unemployment rate (%), United States,
DMFAI = Zero-one variable for MFAI period, equal 1 1974 to 1977 else 0,
DMFAII = Zero-one variable for MFAII period, equal 1 1978 to 1981 else 0,
DMFAIII = Zero-one variable for MFAIII period, equal 1 1982 to 1985 else 0,
LN = Indicates variable transformed into logarithms.

The specification used to explain the variability of fiber use in the United States was the same as used for the EEC-12. An unemployment variable was added to the specification to account for declining textile sales during periods of recession. Although not significant, the variable was kept in the equation because it was signed correctly. Also included in the per capita total fiber use equations were the three zero-one dummy variables accounting for the three MFAs which operated during the estimation period. An index of prices of textile and apparel products was tried in an initial specification of this equation. However, the variable had a very low t-value (i.e., less than unity) and was dropped from the specification.

Overall, the equations fitted the data reasonably well. Of the 14 equations estimated, seven had a corrected R-squared above 0.9, five equations had a corrected R-squared of between 0.8 and 0.9, and for only two equations was it less than 0.8. Some equations were auto-correlated as evidenced by the

DW and H-statistics. 1/ Initially this problem was corrected using the Cochrane-Orcutt transformation. However, using this technique required that a lagged dependent variable appear on the right-hand side of the equation. In most cases, the coefficient on this variable was very large and resulted in unsatisfactory simulation performance. Therefore, the equations were left uncorrected. As was the case in the cotton share equations, it was necessary to use time and lagged dependent variables. While improving the fit of the equations considerably, their inclusion means that caution is needed in deriving model forecasts. Nonetheless, the equations provided plausible income elasticity estimates, which together with the assumptions about future population, income and general prices, as well as the trend components, were used to make consumption forecasts.

3.6 Demand Elasticity Estimates

3.6.1 Price Elasticities

The price elasticities for cotton use are presented in Table 3.1. The demand elasticities are highly inelastic, ranging from -0.02 for India to -0.33 in the Republic of Korea. With the exception of Australia, the elasticities are higher for the industrialized and newly-industrialized countries (e.g., the United States -0.3, the Republic of Korea -0.33, the EEC -0.14) and lower in the developing countries (e.g., Central Africa -0.02, Argentina -0.07, China -0.08). The higher elasticities in the industrialized countries most likely reflect the use of more modern processing facilities in these countries, which enables manufacturers to quickly change the mix of fibers processed in response to changes in relative prices.

The low elasticity for Australia may reflect the fact that, on average, over the past ten years less than 20% of cotton goods sold to consumers has been provided by domestic mills, with 80% coming from imports. Given that the domestic consumption response to price changes in the model is through the milling sector and not through the price of traded goods, it is expected that the elasticity will be small. This may explain also why the price variable was not significant in the case of Japan, where about one-third of cotton consumed is imported.

1/ Autocorrelation may have arisen from model misspecification. The most important source of measurement error in any textile consumption model is measurement error in the dependent variable. There are standard procedures used by statisticians collecting the raw data in estimations of end use cotton consumption (especially conversion factors used to estimate the raw fiber equivalent of textile trade). These methods rest on data and assumptions that are periodically revised and known to contain errors. Since these errors are unlikely to be random from period to period, the vector that denotes the dependent variable may contain an autocorrelation structure.

Table 3.1: Price Elasticities of Cotton Use a/

Region	Elasticity of Cotton Use with Respect to: Cotton Price	Polyester Staple Price b/
Argentina	-0.07	+0.07
Australia	-0.06	+0.06
Brazil	-0.18	+0.17
Central Africa	-0.04	+0.04
China	-0.08	+0.08
Egypt	-0.17	+0.17
EEC	-0.14	+0.14
India	-0.02	+0.02
Japan	-0.04	+0.04
Korea, Rep. of	-0.33	+0.33
Mexico	-0.09	+0.09
Pakistan	-0.04	+0.04
Turkey c/	-0.13	
United States	-0.30	+0.22

a/ Based on the regression period 1964-86 for developing countries, and 1964-87 for industrial countries.

The elasticities of cotton use with respect to price ($E_{CTU/P}$) were derived from the cotton share equations.

$E_{CTU/P}$ = $(\partial CTU/\partial P)*(P/CTU)$. Recall CTU = CTSH * TFU and, in the linear form, that CTSH = a + bP. $(\partial CTU/\partial P) = b * TFU$ and $E_{CTU/P} = b * TFU*P/CTU$.

In the double log form $CTSH = a*P^b$. Therefore, $\left(\frac{\partial CTU}{\partial P}\right) = b*a*P^{b-1}*TFU$ and

$E_{CTU/P} = b$.

Values for CTU, P and TFU were taken as their historical means.

b/ Where polyester price elasticities equal cotton elasticities, a ratio of these prices was used in the share equation.

c/ The price of polyester was dropped from the share equation for Turkey because it had the wrong sign. Hence, no elasticity could be reported.

Table 3.2: Estimates of Price Elasticities of Cotton Use Obtained from Previous Studies

Author	Region	Dependent Variable	Period of Estimation	Elasticity
Donald *et al.*	United States	Fiber Demand	1948-60	-0.14
Dudley	World	Fiber Demand	1953-70	-0.25
Thigpen	Industrial countries	Cotton Demand	1955-75	-0.20
	Developing countries	Cotton Demand	1955-75	-0.09
Adams & Behrman	Developing countries	Fiber Demand	1955-73	-0.23
Mues & Simmons	United States	Mill Consumption	1954-86	-0.34
	Western Europe	Mill Consumption	1954-86	-0.26
	Rest of World	Mill Consumption	1954-86	-0.10

A rather surprising result is the low elasticity reported for China. It was expected that it would be larger given that China has recently invested heavily in modern plant capacity. However, the elasticity reflects average relationships over the estimation period--in this case from 1964 to 1986--and therefore encompasses periods of stagnation in China's cotton industry during the mid-1970s and earlier. Another reason for the low elasticity may be that China's wholesale cotton prices are different from world producer prices.

In Table 3.2 the elasticities obtained from previous studies are reported. All estimates are inelastic and range from -0.09 (Thigpen, for developing countries over the period 1955-75) to -0.34 (Mues and Simmons, for the United States over the period 1954-86). Consistent with the results from this study, other researchers have found the price elasticities to be higher for the higher income countries. Elasticities also tend to be more elastic for the more recent time periods. Generally, the elasticities reported in other studies are not dissimilar to the ones found in this study despite major differences in model specification, period of estimation and regional coverage.

3.6.2 Income Elasticities

The income elasticities of total fiber demand are reported in Table 3.3. The results are different from what was expected, ranging from 0.12 in Turkey to 1.08 in the EEC. The most striking feature of the results is that, in general, income elasticities are greater for the higher-income countries (e.g., the United States, Japan and the EEC). These results do not support the hypothesis that income elasticities decline as income and consumption increase.

The elasticities of 1.08 and 1.04 for the EEC and the United States, respectively, seem high. A possible explanation is that the large increases in the use of cotton products in the United States and the EEC are mainly cheap imports, especially from the newly-industrialized countries of Southeast Asia as well as China. Increased consumption may have resulted from lower import prices as well as from income increases. For the reasons discussed in section 3.4, prices do not appear in the per capita total fiber use equations. Therefore, the income variable may be capturing both price and income influences on consumption.

Table 3.3: Income Elasticities of Demand for All Fibers

Region	Income Elasticity
Argentina	0.58
Australia	0.65
Brazil	0.32
Central Africa	0.54
China	0.91
EEC	1.08
Egypt	0.68
India	0.28
Korea, Rep. of	0.24
Japan	0.58
Mexico	0.33
Turkey	0.12
United States	1.04

Based on a regression period 1964-86 for developing countries; 1964-87 for industrial countries.

Elasticities derived from the semi-log functional form PCTFU = a + b LN PCDFGDP are given by b/PCTFA. The historical mean of PCTFA is used for each region.

Where: PCTFU = Per capita total fiber use,
PCDFCDP = Per capital deflated gross domestic product, and
a, b = Intercept and slope coefficients respectively, regression.

Income elasticity estimates from other studies are reported in Table 3.4. In the study by Thigpen, income elasticities for cotton and total fiber are reported for the industrial and developing countries and for the CPEs. His findings show that income elasticities decline as incomes rise. However, using cross-sectional data over a three-year period Thigpen avoids the multicollinearity problems associated with purely time-series estimation. Interestingly, Adams and Behrman found the income elasticity to be larger for

Table 3.4: Estimates of Income Elasticity of Fiber Demand Obtained from Previous Studies

Author	Region	Dependent Variable	Period	Elasticity
Donald *et al.*	United States	Fiber Demand	1948-60	0.80
Dudley	World	Fiber Demand	1953-70	0.27
Magleby & Missaien	World	Fiber Demand	1964	0.62
Thigpen	Industrial countries	Cotton Demand	1970-72	0.07
	Developing countries	Cotton Demand	1970-72	0.50
	CPEs	Cotton Demand	1970-72	0.20
	Industrial countries	Fiber Demand	1970-72	0.30
	Developing countries	Fiber Demand	1970-72	1.40
	CPEs	Fiber Demand	1970-72	0.60
Adams & Behrman	Industrial countries	Fiber Demand	1955-73	0.60
	Developing countries	Fiber Demand	1955-73	0.47

the industrial countries than for the developing countries, although the magnitudes for the industrial countries were much lower than in this study.

3.7 Summary

This section describes the econometrically estimated equations used to explain the demand for cotton. The task of modeling cotton demand is complicated by the fact that there is no direct consumer demand for raw cotton but rather for textile products, in which cotton is a substitutable input. Given that individuals are relatively insensitive to fiber composition and that the fiber component represents only a small proportion of the final purchase price, equations for total fiber demand were estimated as a function of income. The cotton share of total fiber demand was estimated as a function of the relative prices of cotton and manufactured fibers and captures the price sensitivity of manufactures to relative prices. This framework is consistent with the two-stage budgeting model which provided the theoretical basis for the econometric estimation. The regression equations perform well with, in general, high explanatory power and significant coefficients. More important is that the price and income elasticity measures are reasonable and consistent with previous econometric studies of the textile market.

IV: COTTON PRODUCTION

4.1 Introduction

An important feature of world cotton production is that the substantial increase in output since the early 1960s has resulted from yield increases and not from an expansion of area. Since 1963, average world yields have risen from 338 kg/ha to 545 kg/ha in 1988, an increase of over 60%. Over this period the cotton area has remained fairly constant at around 30 million hectares. This suggests that yields and area should be modeled separately as important information may be lost if production is estimated directly as the product of these components.

Cotton production is more straightforward to model than demand. Cotton is an annual crop which has similar production requirements to other annual crops such as cereals and oilseeds. While the specification of models of annual crop supply have become fairly standard over the years and can be used here, it is important not to lose sight of the theoretical rationale behind their specification. A brief overview of the theoretical issues is presented below.

4.2 Theoretical Issues

A theoretical model of agricultural supply assumes that individual farmers attempt to maximize their profits, subject to technological constraints and exogenous prices of inputs and output. Assume farmers produce a number of commodities and are cost minimizers. Then technology can be expressed in terms of a cost function,

$$C(Y,W,Z) = \min_{(x)}(WX : (Y,X,Z \text{ is in } V)\ ) \text{ where,}$$

Y is a vector of i outputs,
X is a vector of j variable inputs,
Z is a vector of k fixed inputs,
W is a vector of input prices, and
V is the production possibility set.

Given a vector of exogenous output prices, P, cost minimization is equivalent to profit maximization, with profit given by,

$$\pi = PY - C(Y,W,Z).$$

The profit maximization for the function G(P,W,Z) is given by,

$$G(P,W,Z) = \max_{(y)}(PY - C(Y,W,Z)\ ).$$

Finally using Hotelling's lemma, the vector of output supply Y(P,W,Z) can be obtained from,

$$Y(P,W,Z) = \partial G(P,W,Z)\ /\ \partial P.$$

Supply of each output is a function of all prices of products within the farmers' opportunity set (i.e., the price of the commodity itself plus the prices of all competing and complementary commodities), all input prices and the levels of fixed inputs.

Most models of annual crop production separate yields from area and estimate these components separately. According to the theory presented above, input and output prices and fixed inputs are determinants of production. Typically, the relationship between the price of the modeled commodity and the prices of competing products is captured in the area equation. The area equation is often specified as a function of lagged prices of the commodity and one or two commodities believed to compete with the commodity for farm resources such as land and labor.

The relationship between the price of inputs and the price of output is captured in the yield equation. The effects of the fixed inputs are felt through the equation coefficients. Exogenous factors affecting supply, such as weather and technology, are often included in the yield equation.

4.3 Literature Review

Compared to cotton demand, relatively few studies have focused on cotton production and of these most have been for the United States. For example, Evans (1977) estimated a United States cotton acreage response equation for the four major producing areas (i.e., the Delta region, the Southeast, the Southwest, and the West). The explanatory variables used included average variable and opportunity costs of producing cotton, which incorporated prices and costs of cotton and competing crops (e.g., corn, barley, sorghum, and soybeans). Also policy variables were used, such as national acreage allotments, diversion payments and direct payments. Of most interest is the division of the United States into four separate producing regions and the use of region-specific data. This is appropriate because US cotton production practices differ significantly across regions and because of differences in the types of crop that compete with cotton for farm resources.

Starbird and Hazera (1983) estimated cotton yield equations for four regions of the United States. These were the Mississippi Delta, Texas High Plains (irrigated), Texas High Plains (non-irrigated) and California. Yields were explained by the number of acres planted and weather variables for rainfall and temperature during crucial periods of the crop year. In addition, a policy dummy variable was used to capture the effect of the skip-row policy rules. 1/ No economic variables were included in the United States equations which explain a high proportion of yield variability.

1/ "During the allotment years of 1954-61, all acreage in fields planted to skip-rowed cotton were counted as cotton acreage, including the rows not planted. During 1962-65, these rules were relaxed, and only the planted rows were counted as acreage planted. Acreage penalties were reimposed in 1966-67. Since 1968, only land actually planted to cotton has been counted as cotton land in determining compliance with program provisions" (Starbird and Hazera, p. 18).

Monke (1981) estimated an equation for the production of all price-responsive countries for the period 1960-80. The world price lagged one period as well as current prices of a number of competing commodities were used as regressors. None of the coefficients on competing commodities were significant, however. A concern about the equation is that a lagged dependent variable was added to the specification which had a coefficient of 0.95 (and t-value of 52.84). This variable drives the model and probably explains the lack of significance of the coefficients on competing crops.

Mues and Simmons (1988) estimated the area planted to cotton for the United States, Australia and the Rest-of-the-World. For the United States equation the lagged world price of cotton, the price received for soybeans and a lagged dependent variable were used as regressors. Various policy instrument variables were added to the specification, including dummy variables for the PIK program and for the soil bank years, the guaranteed price to growers under the farm program, and the acreage-reduction requirement for participation in the program. All the variables, including those capturing policy, were significant. A similar specification was used for Australia and the Rest-of-the-World except that the policy variables were dropped from the equations.

Hamid et al. (1987) estimated cotton area and yield equations for the Punjab and Sind regions of Pakistan. The equations reported did not perform well with most coefficients not significant and some with the wrong sign. None of the economic variables had significant coefficients. The most significant variable was water availability, measured by the number of tubewells in operation. This variable may have also been capturing other factors such as improvements in cotton varieties.

Thigpen and Mitchell (1988) estimated equations for both area and yield. Area was determined by lagged cotton area, lagged cotton revenue and lagged revenue of one or more competing crops such as coarse grains or soybeans. Yields were determined by a linear trend, lagged cotton price and the current fertilizer price. The fertilizer price and the competing crop revenue were exogenous in the model.

4.4 Model of Cotton Supply

As suggested above, cotton supplies were estimated using a fairly standard specification for annual crops. Production in each region was determined by a behavioral equation for yield and area planted, and an identity giving production as the product of these components. That is,

$$\begin{aligned} PD &= CTYD * CTHA, \\ CTYD &= f(CTP,\ PF,\ W\ ), \\ CTHA &= f(CTP(-1),\ PCC(-1)\ ), \end{aligned}$$

where,

PD = Cotton production,
CTYD = Cotton yield per hectare,
CTHA = Number of hectares planted,
PCC = Price of competing crops,
CTP = Price of cotton,
PF = Price of fertilizer, and
W = Weather.

As mentioned in the theoretical review, yields are determined by profitability of the cotton enterprise which depends on the relationship between product and factor prices. To capture these relationships the cotton price and price of fertilizer were used initially as explanatory variables in the yield equations. This specification performed badly for many of the model regions. On careful inspection of the yield data it was observed that rainfall and temperature play a crucial role in determining yields, especially in those countries with little irrigated cotton area. This led to the collection of large amounts of rainfall and temperature data for the major producing countries. When these variables were added to the specification the performance of the equations improved dramatically and in some cases weather data alone explained up to 80% of the variations in yield over the historical period.

Another factor affecting cotton yields is the impact of the rapid growth in the use of high-yielding and drought-resistent cotton varieties. To capture this development, a time variable was added to the specifications. In some regions of the model in which yields trended upwards throughout the estimation period, a time trend explained almost all the variation in yield. In forecasting production up to 2005 the time variable was replaced by the log of time. Perhaps a better variable to capture this historical effect would be to measure the percentage of total crop under high-yielding varieties. This would give an upper-limit (i.e., 100%) to increases in yield from the uptake of new technology. Unfortunately, data on area allocated to high-yielding varieties of cotton are not readily available. However, this variable would raise problems in forecasting as it would not allow for new technology.

Another variable that was successful in some cases was area planted. The rationale for the inclusion of this variable is that as area increases, production is forced onto land of lower quality, forcing average yields to decline.

The number of hectares planted with cotton is specified to depend on the profitability of the cotton enterprise relative to the profitability of crops which have similar farm resource requirements. To capture substitution between crop enterprises in determining cotton area, the lagged prices of cotton and the prices of competing crops such as coarse grains and soybeans were included in the regression equations.

The production equations were estimated using international prices for cotton 1/ and competing commodities. These prices were adjusted by converting into the domestic currency using the US dollar exchange rate and by deflating using the consumer price index for each model region. 2/ The results were unsatisfactory with many prices not significant or wrongly signed. The poor performance of price variables in the equations may be explained by the fact that producers in many of the regions do not face world prices. In many countries government intervention in production and trade results in farmers facing a set of local prices which differ substantially from world price levels. In an attempt to capture farmer response to prices, local price data for cotton and competing crops were collected for some regions (i.e., United States, India, China). These prices were also in local currency and deflated by the consumer price index. Almost without exception local prices were significant and the area equations improved considerably. Next, these local prices were related to world prices using price linkage equations. Only in the equations for the United States were statistically significant relationships found between the local and world cotton prices. Local prices of other countries (e.g., China and India) were treated as policy variables and made exogenous in the model.

In many countries, cotton production takes place in distinct regions. For example, US cotton output is produced in the Delta region, the Southeast, Southwest and West. In each region farmers face different prices and choices with respect to alternative crops (e.g., cotton competes with corn and soybeans in the Southeast, with soybeans in the Delta region, with sorghum and winter wheat in the Southwest and with alfalfa, wheat, corn and barley in the West). Also, yields are affected by rainfall and temperature which differ substantially across regions. US regional production was obtained by the product of yield and area and total US production was obtained by summing the regional production. A regional disaggregation was attempted for India and Pakistan. Equations for area and yield for the Punjab and Sind regions of Pakistan and the North, South and West regions of India were estimated successfully.

4.5 Empirical Results

4.5.1 Yield Equations

The estimated equations for cotton yields were estimated using OLS for the period 1964-1988 and are presented in equations 4.1-4.17 below. Yield equations were difficult to estimate because there was often a lot of randomness contained in the series. However, overall the equations perform well with 14 out of 17 having a corrected R-squared greater than 80%. In many equations the fit was improved by the inclusion of zero-one dummy variables.

1/ Outlook "A" Index Price.

2/ Consumer price indexes were used because, for many regions, more appropriate indexes (e.g., a wholesale or producer price index) were not available. However, consumer price indexes are likely to be highly correlated with other deflators.

In general, these were capturing abnormally good or bad weather conditions for cotton production.

Cotton yields in Argentina.

$$CTYDARG = \underset{(1.88)}{0.26}\ CTYDARG\ (-1) + \underset{(3.73)}{1.09}\ DFCTPARG + \underset{(2.49)}{0.90}\ D81 - \underset{(-1.62)}{0.06}\ D70 + \underset{(3.11)}{0.06}\ LN\ TIME \qquad (4.1)$$

R-SQUARED (CORR.): 0.82 SEE: 0.020 H-STAT: 0.03 PERIOD OF FIT 1964-88

Where: CTYDARG = Cotton yield, Argentina (tons/hectare),
DFCTPARG = Deflated cotton price, Argentina,
TIME = Time variable,
D70 = Zero-one variable, equals 1 in 1970, 0 otherwise,
D81 = Zero-one varaible, equals 1 in 1981, 0 otherwise,
LN = Indicates variable transformed into logarithms.

The cotton yield series for Argentina was explained by the deflated price of cotton, a time trend variable and zero-one dummy variables for 1970 and 1981. The time variable was included to capture the improvements in yields through time as a result of improved technology, such as higher yielding seed varieties, improved fertilizer and chemical responses, and other better farming practices. The rate of increase declined over time and this was accounted for by converting the time variable into logarithms. The high yield in the 1981 crop season was a consequence of the policy change which gave cotton growers access to special credit to purchase inputs. The equation for Argentina was one of the few in which the price of cotton was significant.

Cotton yields in Australia.

$$CTYDAUS = 0.77 + \underset{(5.29)}{0.02}\ TIME - \underset{(-2.03)}{0.27}\ D72 - \underset{(-1.81)}{0.24}\ D75 - \underset{(-2.03)}{0.27}\ D76 \qquad (4.2)$$

R-SQUARED (CORR.): 0.68 SEE: 0.34 DW: 1.82 PERIOD OF FIT: 1964-88

Where: CTYDAUS = Cotton yield, Australia (tons/hectare),
TIME = Time variable,
D72 = Zero-one variable, equals 1 in 1972, 0 otherwise,
D75 = Zero-one variable, equals 1 in 1975, 0 otherwise,
D76 = Zero-one variable, equals 1 in 1976, 0 otherwise.

Cotton yields in Australia were explained by a time trend and zero-one dummy variables for 1972, 1975 and 1976. Prices of cotton and competing crops were found not to be significant. The trend variable was highly significant (t-value of 5.29), reflecting the uptake of improved cotton production technology, especially since the early 1980s. The zero-one dummy variables captured yields substantially below trend, mainly the result of low rainfall in those years.

Cotton yields in Brazil.

$$CTYDBRA = 0.13 + \underset{(1.68)}{0.27}\ CTYDBRA(-1) + \underset{(1.72)}{0.03}\ DFCTPBRA/DFFNPBRA \qquad (4.3)$$

$$+ \underset{(2.21)}{0.003}\ TIME - \underset{(-2.56)}{0.06}\ D70 + \underset{(4.03)}{0.10}\ D84$$

R-SQUARED (CORR.): 0.84   SEE: 0.009   H-STAT: - 0.45   PERIOD OF FIT: 1964-88

Where: CTYDBRA = Cotton yield, Brazil (tons/hectare),
DFCTPBRA = Deflated cotton price, Brazil,
DFFNPBRA = Deflated fertilizer price, Brazil,
TIME = Time variable,
D70 = Zero-one variable, equals 1 in 1970, 0 otherwise,
D84 = Zero-one variable, equals 1 in 1984, 0 otherwise.

Brazilian cotton yields were explained by cotton and fertilizer prices, a time trend variable, zero-one dummy variables for 1970 and 1984, and cotton yield lagged one year. The cotton and fertilizer prices were entered in the equation as a ratio and, although not significant, the variable was kept in the equation because it had the correct sign. The time trend was used in the equation to capture improved technology use in the Brazilian cotton sector, especially in the use of higher-yielding cotton varieties. The dummy variable was included because the near-perfect growing conditions in that year sent yields to record levels.

Cotton yields in Central Africa.

$$CTYDCAF = 0.08 + \underset{(13.31)}{0.87}\ CTYDCAF(-1) - \underset{(-3.77)}{0.05}\ D75 - \underset{(-1.54)}{0.00001}\ CTHACAF \qquad (4.4)$$

R-SQUARED (CORR.): 0.92   SEE: 0.004   H-STAT: - 0.26   PERIOD OF FIT: 1964-88

Where: CTYDCAF = Cotton yield, Central Africa (tons/hectare),
CTHACAF = Cotton area, Central Africa,
D75 = Zero-one variable, equals 1 in 1975, 0 otherwise.

In the equation for the Central Africa region cotton yields were explained by yield lagged one year, the cotton area, and a zero-one dummy variable for 1975. The strong upward trend in yields was captured by lagged yield and the dummy variable for 1975 captured the weather-related yield reduction in many African countries in that year. The cotton area was significant in the equation. The negative sign on this variable showed that as greater area within the region was planted to cotton, production moved onto land of lower quality where yields were lower. While this variable was not significant it was kept in the equation because it had the correct sign.

Cotton yields in China.

$$CTYDCHI = -2.58 + \underset{(1.95)}{0.003\ DFCTPCHI} - \underset{(-3.45)}{0.001\ DFFNPCHI} + \underset{(9.20)}{1.15\ LN\ TIME} \quad (4.5)$$

$$- \underset{(2.67)}{0.16\ D88}$$

R-SQUARED (CORR.): 0.95   SEE: 0.029   DW: 2.31   PERIOD OF FIT: 1977-88

Where: CTYDCHI = Cotton yield, China (tons/hectare),
DFCTPCHI = Deflated cotton price, China,
DFFNPCHI = Deflated ferlizizer price, China,
TIME = Time, variable
D88 = Zero-one variable, equals 1 in 1988, 0 otherwise.
LN = Indicates variable transformed into logarithms.

The variability of cotton yields in China was explained by a regression estimated from 1977 to 1988. This shortened time period was used because prior to the late 1970s, before price incentives were introduced into China, yields were almost unchanged. With the introduction of market incentives Chinese producers became highly responsive to both cotton and fertilizer prices. This was demonstrated in the equation in which cotton and fertilizer prices were statistically significant. The logarithm of time was added to capture technological improvements. Rainfall was found not to be significant in the equation. This result was not surprising given that most of China's cotton growing area is highly irrigated. The zero-one dummy variable for 1988 was included to account for poor weather in China during the crucial months of August and September which resulted in extremely low yields.

Cotton yields in Egypt.

$$CTYDEGY = \underset{(63.26)}{0.99\ CTYDEGY\ (-1)} + \underset{(3.38)}{0.21\ D78} - \underset{(-1.96)}{0.12\ D88} \quad (4.6)$$

R-SQUARED (CORR.): 0.81   SEE: 0.085   H-STAT: 0.02   PERIOD OF FIT: 1964-88

Where: CTYDEGY = Cotton yield, Egypt (tons/hectare),
D78 = Zero-one variable, equals 1 in 1987, 0 otherwise,
D88 = Zero-one variable, equals 1 in 1988, 0 otherwise.

Cotton yields in Egypt were explained by yields lagged one year and zero-one dummy variables for the years 1978 and 1988. The coefficient on the lagged yield variable (0.99) was evidence of a strong trend in Egyptian cotton yields. The price of cotton used in the model (Outlook "A" Index) was not significant. However, most of Egyptian production is of the high-quality extra-long staple (ELS) cotton, with a market quite separate from that of medium staple cotton. Evidence that the markets are distinct is provided by the low price transmission elasticities between the ELS and medium staple cotton prices. 1/

Cotton yields in Northern India.

$$\begin{aligned} CTYDINDN = {} & 0.32 + \underset{(3.49)}{0.06}\ LN\ TIME - \underset{(-2.78)}{0.0002}\ CTHAINDN + \underset{(2.92)}{0.0001}\ RINDN \\ & + \underset{(5.70)}{0.15}\ D71 + \underset{(2.51)}{0.06}\ D73 \end{aligned} \tag{4.7}$$

R-SQUARED (CORR.): 0.86 SEE: 0.008 DW: 1.89 PERIOD OF FIT: 1965-84

Where: CTYDINDN = Cotton yield, Northern India (tons/hectare),
CTHAINDN = Cotton area, Northern India,
TIME = Time variable,
D71 = Zero-one variable, equals 1 in 1971, 0 otherwise,
D73 = Zero-one variable, equals 1 in 1973, 0 otherwise,
RINDN = Annual rainfall, Northern India (mm),
LN = Indicates variable transformed into logarithms.

Cotton yields in Northern India were explained by the area of land planted to cotton in the region, rainfall, time, and zero-one dummy variables for 1971 and 1973. Since the rate of increase declined over the regression period the time variable was converted into logarithms. The area planted variable was significant and captured the decrease in average yields as cotton was grown on land of lower quality. The annual rainfall variable was highly significant. No statistically significant relationships were found between yield and economic variables, even when the local prices of cotton and competing crops were included in the equation.

Cotton yields in Southern India.

$$\begin{aligned} CTYDINDS = {} & 0.10 + \underset{(3.49)}{0.05}\ LN\ TIME - \underset{(-0.76)}{0.00001}\ CTHAINDS + \underset{(2.19)}{0.00009}\ RINDS \\ & - \underset{(8.87)}{0.20}\ D84 \end{aligned} \tag{4.8}$$

R-SQUARED (CORR.): 0.94 SEE: 0.004 DW: 1.64 PERIOD OF FIT: 1965-84

1/ An econometric study of the Egyptian ELS cotton market is being undertaken at the World Bank. In the model the ELS price is used to explain the variability in cotton production. At a later stage the Egyptian ELS model will be incorporated into this model. Therefore, the results reported here should be treated as preliminary.

Where: CTYDINDS = Cotton yield, Southern India (tons/hectare),
CTHAINDS = Cotton area, Southern India,
TIME = Time variable,
D84 = Zero-one variable, equals 1 in 1984, 0 otherwise,
RINDS = Annual rainfall, Southern India (mm),
LN = Indicates variable transformed into logarithms.

The equation explaining cotton yields in Southern India contained time, cotton area, rainfall, and a zero-one dummy variable for 1984. The rationale for the inclusion of these variables was similar to that for the Northern India equation. Again, the prices of cotton and of farm inputs were not found to be significant.

Cotton yields in Western India.

$$\underset{}{CTYDINDW} = \underset{(30.69)}{0.04\ LN\ TIME} + \underset{(6.61)}{0.00006\ RSUINDW} - \underset{(-5.50)}{0.03\ D76} - \underset{(-2.43)}{0.02\ D83} \qquad (4.9)$$

R-SQUARED (CORR.): 0.88 SEE: 0.0006 DW: 2.21 PERIOD OF FIT: 1965-84

Where: CTYDINDW = Cotton yield, Western India (tons/hectare),
TIME = Time variable,
D76 = Zero-one variable, equals 1 in 1976, 0 otherwise,
D83 = Zero-one variable, equals 1 in 1983, 0 otherwise,
RSUINDW = Summer rainfall (mm), Western India,
LN = Indicates variable transformed into logarithms.

The specification of the equation explaining cotton yields in Western India included a logarithmic time trend, rainfall in the summer months, and a zero-one dummy variable for 1983. The yield in 1983 was abnormally low as a result of heavy unseasonal rainfall. This prohibited timely spraying of insecticides and led to severe pest damage. No statistically significant relationships were detected between cotton yields and cotton and inputs prices.

Cotton yields in Mexico.

$$CTYDMEX = 0.34 + \underset{(9.59)}{0.18\ LN\ TIME} + \underset{(3.38)}{0.09\ D78} + \underset{(3.46)}{0.16\ D88} \qquad (4.10)$$

R-SQUARED (CORR.): 0.87 SEE: 0.042 DW: 2.11 PERIOD OF FIT: 1964-88

Where: CTYDMEX = Cotton yield, Mexico (tons/hectare),
TIME = Time variable,
D78 = Zero-one variable, equals 1 in 1978, 0 otherwise,
D88 = Zero-one variable, equals 1 in 1988, 0 otherwise,
LN = Indicates variable transformed into logarithms.

Cotton yields in Mexico increased throughout the regression period and only a time variable converted into logarithms was found to be significant. This variable captured the improvements in yields resulting from improved technology, such as higher yielding seed varieties, improved fetilizer and chemical responses, and better production practices. The prices of cotton and inputs were not statistically significant when included in the equation.

Cotton yields in the Punjab region of Pakistan.

$$CTYDPAKP = 0.27 + \underset{(7.36)}{0.03\ TIME} + \underset{(2.05)}{0.09\ D71} - \underset{(-5.61)}{0.26\ D83} \tag{4.11}$$

R-SQUARED (CORR.): 0.80 SEE: 0.030 DW: 1.00 PERIOD OF FIT: 1965-85

Where: CTYDPAKP = Cotton yield, Punjab region, Pakistan (tons/hectare),
TIME = Time variable,
D71 = Zero-one variable, equals 1 in 1971, 0 otherwise,
D83 = Zero-one variable, equals 1 in 1983, 0 otherwise.

The impact of technology on cotton yields in the Punjab region of Pakistan was very strong. No significant relationships were found between yield and economic or climatic variables. A zero-one dummy variable for 1983 was added to the equation to capture the effect of heavy unseasonal rainfall which prohibited timely spraying of insecticides and led to severe pest damage.

Cotton yields in the Sind region of Pakistan.

$$CTYDPAKS = \underset{(2.69)}{0.00002\ DFCTPPAK} - \underset{(-13.83)}{0.0005\ CTHAPAKS} + \underset{(6.08)}{0.00001\ IRRPAK} \tag{4.12}$$

$$+ \underset{(3.41)}{0.08\ D72} - \underset{(-5.46)}{0.12\ D78} - \underset{(-4.54)}{0.11\ D83}$$

R-SQUARED (CORR.): 0.91 SEE: 0.006 DW: 2.01 PERIOD OF FIT: 1965-85

Where: CTYDPAKS = Cotton yield, Sind region of Pakistan (tons/hectare),
DFCTPPAK = Deflated cotton price, Pakistan,
IRRPAK = Number of tubewells constructed in the Sind region of Pakistan,
CTHAPAKS = Cotton area, Sind region of Pakistan,
TIME = Time variable,
D72 = Zero-one variable, equals 1 in 1972, 0 otherwise,
D78 = Zero-one variable, equals 1 in 1978, 0 otherwise,
D83 = Zero-one variable, equals 1 in 1983, 0 otherwise.

The variables found to best explain variability of cotton yields in the Sind region of Pakistan were the deflated cotton price in Pakistan, the area planted with cotton in the Sind region, a variable for the number of tubewells in the Sind region, and zero-one dummy variables for the years 1972, 1978, and 1983. This equation was one of the few in which the price of cotton was found to be statistically significant. The elasticity of yield with respect to price was estimated to be 0.01 at the mean yield and price levels. The irrigation variable, measured by the number of tubewells constructed, was very significant. This was consistent with the findings of Hamid _et al_. However, since the number of tubewells has been increasing over the last 20 years this variable may, in addition, have captured yield increases from technological change.

Cotton yields in Turkey.

$$CTYDTUR = 0.54 + \underset{(17.27)}{0.81}\ CTYDTUR(-1) - \underset{(-7.05)}{0.0006}\ CTHATUR - \underset{(-1.98)}{0.06}\ D65 \qquad (4.13)$$

R-SQUARED (CORR.): 0.95   SEE: 0.016   DW: 2.23   PERIOD OF FIT: 1964-88

Where: CTYDTUR = Cotton yield, Turkey (tons/hectare),
CTHATUR = Cotton area, Turkey,
D65 = Zero-one variable, equals 1 in 1965, 0 otherwise.

Cotton yields in Turkey were explained by yield lagged one year, area of cotton planted, and a zero-one dummy variable for 1965. The lagged dependent variable captured the strong upward trend in yields throughout the regression period. Yields were also a function of the area planted that captured the decline in yield as cotton was planted on land of lower quality.

Cotton yields in the United States, Delta region.

$$CTYDUS1 = 8.73 - \underset{(-3.17)}{0.0003}\ CTHAUS1 - \underset{(-4.27)}{0.24}\ RSPUS1 - \underset{(-3.18)}{3.13}\ TSMUS1 \qquad (4.14)$$

$$+ \underset{(4.18)}{1.95}\ TFLUS1 - \underset{(-2.72)}{0.30}\ D67 + \underset{(2.21)}{0.20}\ D82$$

R-SQUARED (CORR.): 0.81   SEE: 0.122   DW: 1.68   PERIOD OF FIT: 1964-88

Where: CTYDUS1 = Cotton yield, Delta region of United States (tons/hectare),
CTHAUS1 = Cotton area, Delta region of United States,
D67 = Zero-one variable, equals 1 in 1967, 0 otherwise,
D82 = Zero-one variable, equals 1 in 1982, 0 otherwise,
RSPUS1 = Spring rainfall (inches), Delta region of United States,
TSMUS1 = Summer temperature (degrees C), Delta region of United States,
TFLUS1 = Fall temperature (degrees C), Delta region of United States.

Variation in cotton yields in the Delta region of the United States was explained mainly by weather variables, as well as by planted cotton area and zero-one dummy variables for 1967 and 1982. No economic factors, such as the price of cotton or fertilizer, were found to be significant. In the Delta region, excess spring rainfall and summer temperatures reduced yield, while high temperatures in the fall improved yields. This result is consistent with knowledge of growing conditions for cotton and the results reported by Starbird and Hazera (1983).

Cotton yields in the United States, Southeast region.

$$CTYDUS2 = 1.78 - \underset{(-1.68)}{0.0002}\ CTHAUS2 - \underset{(-2.55)}{0.03}\ TSMUS2 + \underset{(3.48)}{0.03}\ TFLUS2 \qquad (4.15)$$

$$+ \underset{(2.84)}{0.26}\ D82 - \underset{(-1.72)}{0.18}\ D67$$

R-SQUARED (CORR.): 0.67 SEE: 0.132 DW: 2.02 PERIOD OF FIT: 1964-88

Where: CTYDUS2 = Cotton yield, Southeast region of United States (tons/hectare),
CTHAUS2 = Cotton area, Southeast region of United States,
D67 = Zero-one variable, equals 1 in 1967, 0 otherwise,
D82 = Zero-one variable, equals 1 in 1982, 0 otherwise,
TSMUS2 = Summer temperature (degree C), Southeast region of United States,
TFLUS2 = Fall temperature (degrees C), Southeast region of United States.

The selected equation contained the same variables as the Delta region equation, except for the spring rainfall variable which was found not to be significant. The variable for cotton area was also not significant but was kept in the equation because it had the correct sign.

Cotton yields in the United States, Southwest region.

$$\underset{}{CTYDUS3} = -\,63.53 - \underset{(-0.40)}{0.000006\,CTHAUS3} + \underset{(3.14)}{1.58\,TSMUS3} + \underset{(3.19)}{0.04\,SMUS3} \qquad (4.16)$$

$$+ \underset{(4.53)}{0.02\,TFLUS3} - \underset{(-5.09)}{0.01\,D70} - \underset{(-4.81)}{0.12\,D83}$$

R-SQUARED (CORR.): 0.85 SEE: 0.012 DW: 1.40 PERIOD OF FIT: 1964-88

Where: CTYDUS3 = Cotton yield, Southwest region of United States (tons/hectare),
CTHAUS3 = Cotton area, Southwest region of United States,
D70 = Zero-one variable, equals 1 in 1970, 0 otherwise,
D83 = Zero-one variable, equals 1 in 1983, 0 otherwise,
TSMUS3 = Summer temperature (degrees C), Southwest region of United States,
TFLUS3 = Fall temperature (degrees C), Southwest region of United States,
SMUS3 = Soil moisture level, Southwest region United States.

Cotton yields in the Southwest region of the United States were explained by summer and fall temperature, an index of soil moisture, cotton area, and zero-one dummy variables for 1970 and 1983. This specification is similar to that presented by Starbird and Hazera. Consistent with other US regions, prices were found not to be important in explaining the variability of cotton yields.

Cotton yields in the United States, Western region.

$$CTYDUS4 = 2.37 - \underset{(-1.87)}{0.02\,TSMUS4} + \underset{(2.63)}{0.007\,TIME} - \underset{(-2.63)}{0.23\,D71} - \underset{(-3.84)}{0.33\,D78} \qquad (4.17)$$

R-SQUARED (CORR.): 0.67 SEE: 0.126 DW: 1.39 PERIOD OF FIT: 1964-88

Where: CTYDUS4 = Cotton yield, West region of United States (m.tons/hectare),
D71 = Zero-one variable, equals 1 in 1971, 0 otherwise,
D78 = Zero-one variable, equals 1 in 1978, 0 otherwise,
TSMUS4 = Summer temperature (degrees C), West region of United States,
TIME = Time variable.

The variability of cotton yields in the Western region of the United States was explained by summer temperatures, a time trend variable, and zero-one dummy variables for 1971 and 1978. Other variables, such as area planted, fall temperatures and rainfall, and prices gave the wrong signs when entered into initial specifications of this equation and were subsequently excluded.

4.5.2 Area Equations

The equations for cotton area planted are presented in equations 4.18-4.34 below. In general, the equations fitted the data well with ten of the 17 equations having a corrected R-squared of 90% or greater. In many of the equations a lagged dependent variable was added. This was included in order to capture adaptively-formed expectations and to estimate long-run elasticities. In some cases (e.g., Australia, Brazil, and Northern India) the coefficient on the lagged dependent variable was very large and obviously captured a trend in the data series.

Cotton area in Argentina.

$$\underset{}{CTHAARG} = \underset{(3.48)}{0.38\ CTHAARG\ (-1)} + \underset{(4.56)}{5603\ DFCTPARG\ (-1)} - \underset{(-2.56)}{3148\ DFCGPARG\ (-1)} \qquad (4.18)$$

$$- \underset{(-2.13)}{117\ D80} - \underset{(-3.88)}{165.9\ D85} + \underset{(1.30)}{1.83\ TIME}$$

R-SQUARED (CORR.): 0.85 SEE: 35028 H-STAT: -0.23 PERIOD OF FIT: 1964-88

Where: CTHAARG = Cotton area, Argentina,
DFCTPARG = Deflated cotton price, Argentina,
DFCGPARG = Deflated coarse grain price, Argentina,
TIME = Time variable,
D80 = Zero-one variable, equals 1 in 1980, 0 otherwise,
D85 = Zero-one variable, equals 1 in 1985, 0 otherwise.

The area planted to cotton in Argentina was explained by the deflated price of cotton lagged one year, the deflated price of coarse grains lagged one year, a time variable, and zero-one dummy variables for the years 1980 and 1985. Cotton area lagged one year was also included to capture adaptively-formed expectations and to provide long-run elasticities. Both price variable were statistically significant. The derived short-term elasticity estimates for cotton and coarse grains were 0.87 and -0.38, respectively, when estimated at the mean price and area. The dummy variable for 1985 captured the 22% decline in area in the central-south region of Argentina due to bad weather and difficulties in marketing the previous year's crop.

Cotton area in Australia.

$$CTHAAUS = 39.11 + \underset{(11.76)}{0.75}\ CTHAAUS\ (-1) - \underset{(-1.39)}{0.18}\ DFCGPAUS\ (-1) \quad (4.19)$$

$$+ \underset{(3.83)}{44.14}\ D83 + \underset{(8.05)}{96.42}\ D87$$

R-SQUARED (CORR.): 0.98 SEE: 2275 H-STAT: 1.28 PERIOD OF FIT: 1964-88

Where: CTHAAUS = Cotton area, Australia,
DFCGPAUS = Deflated coarse grain price, Australia,
D83 = Zero-one variable, equals 1 in 1983, 0 otherwise,
D87 = Zero-one variable, equals 1 in 1987, 0 otherwise.

Variability in the area placed under cotton in Australia was explained by variability in the deflated price of coarse grains, the cotton area lagged one period, and zero-one dummy variables for 1983 and 1987. The price of cotton was incorrectly signed when included in an initial specification of the equation. However, the coefficient on the coarse grains price was significant and negative and provided an elasticity estimate of 0.35 when calculated at mean price and area. The coefficient on the lagged area variable was very large (0.75) which captured a strong trend in the cotton area series.

Cotton area in Brazil.

$$CTHABRA = 633.4 + \underset{(6.32)}{0.71}\ CTHABRA\ (-1) + \underset{(3.11)}{396.5}\ D68 + \underset{(3.07)}{401.7}\ D84 \quad (4.20)$$

R-SQUARED (CORR.): 0.76 SEE: 310198 H-STAT: 1.77 PERIOD OF FIT: 1964-88

Where: CTHABRA = Cotton area, Brazil,
D68 = Zero-one variable, equals 1 in 1968, 0 otherwise,
D84 = Zero-one variable, equals 1 in 1984, 0 otherwise.

The area planted to cotton in Brazil was explained by cotton area planted lagged one year and zero-one dummy variables for 1968 and 1984. The large coefficient on the lagged area variable was evidence of the strong upward trend in cotton area throughout the regression period. The 1984 dummy variable captured the sudden substitution of cotton for soybeans following changes in relative domestic producer prices. The prices of cotton and competing crops were found not to be significant. The reason for the poor performance of the price variables may be that Brazilian producers face domestic prices which are not determined in the international market. Also, there are two distinct growing regions in Brazil (i.e., South and Northeast) with different characteristics and growing conditions. Lack of data prevented these regions from being separated in the model.

Cotton area in the Central Africa region.

$$CTHACAF = 1261 + \underset{(10.39)}{0.70}\ CTHACAF\ (-1) + \underset{(3.84)}{315.4}\ DFCTPCAF\ (-1) \tag{4.21}$$

$$- \underset{(-4.87)}{265.5}\ LN\ TIME - \underset{(-3.23)}{370.9}\ D80 + \underset{(3.04)}{356.1}\ D88$$

R-SQUARED (CORR.): 0.93 SEE: 215536 H-STAT: -1.48 PERIOD OF FIT: 1964-88

Where: CTHACAF = Cotton area, Central Africa
DFCTPCAF = Deflated cotton price, Central Africa,
TIME = Time variable,
D80 = Zero-one variable, equals 1 in 1980, 0 otherwise,
D88 = Zero-one variable, equals 1 in 1988, 0 otherwise,
LN = Indicates variable transformed into logarithms.

The area of cotton grown in Central Africa was explained by area lagged one period, deflated cotton prices, a time trend variable, and zero-one dummy variables for 1980 and 1988. The cotton price variable was found to be statistically significant and gave an elasticity estimate of 0.12 when calculated at the mean price and area. The price of fertilizer was also added to the specification to account for the fact that fertilizer requirements are higher for cotton than for most other competing crops. The time trend variable was included to capture the trend away from cotton into other more profitable enterprises.

Cotton area in China.

$$CTHACHI = 4705.53 + \underset{(2.63)}{26.21}\ DFCTPCHI\ (-1) + \underset{(3.28)}{1376.7}\ D84 - \underset{(-2.67)}{1087.0}\ D86 \tag{4.22}$$

R-SQUARED (CORR.): 0.82 SEE: 383 DW: 2.32 PERIOD OF FIT: 1977-88

Where: CTHACHI = Cotton area, China,
DFCTPCHI = Deflated cotton price, China,
D84 = Zero-one variable, equals 1 in 1984, 0 otherwise,
D86 = Zero-one variable, equals 1 in 1986, 0 otherwise.

The area equation for China was estimated for the period 1977-88, since prior to 1977 cotton area was largely a policy decision of the government and not dependent on economic factors. A domestic Chinese cotton price lagged one year was found to be statistically significant and provided an elasticity estimate of 0.11 at mean price and area. In addition to price, zero-one dummy variables were added to the specification for 1984 and 1986. The dummy variable for 1984 captured the change in policy which substantially increased producer prices, coupled with significantly more generous fertilizer allocations. Even though the domestic producer price was included in the equation, the actual area response in 1984 was in excess of that predicted by the model. The dummy variable for 1986 was included to account for the fall in area resulting from the experience of the 1985 season when income was reduced by the weather-induced poor cotton quality for roughly 60% of the growing area.

Cotton area in Egypt.

$$CTHAEGY = 1276 - \underset{(-17.02)}{255.1} \; LN\ TIME - \underset{(-5.06)}{188.2} \; D64 - \underset{(-2.96)}{100.3} \; D68 \qquad (4.23)$$

R-SQUARED (CORR.): 0.93 SEE: 21531 DW: 1.86 PERIOD OF FIT: 1964-88

Where: CTHAEGY = Cotton area, Egypt,
TIME = Time variable,
D64 = Zero-one variable, equals 1 in 1964, 0 otherwise,
D68 = Zero-one variable, equals 1 in 1968, 0 otherwise,
LN = Indicates variable transformed into logarithms.

Cotton area in Egypt was explained by a time variable transformed into logarithms and zero-one dummy variables for 1964 and 1968. The decline in cotton area over the estimation period was reflected in the fact that over 90% of the variation of area was explained by the trend variable. Economic variables were found not to be statistically significant in initial specifications of the equation. A reason for this lack of success may be that, as explained in the description of the cotton yield equation for Egypt, the international price used in the equation was for medium staple cotton, while most of Egyptian cotton production is of long and extra-long staple.

Cotton area in Northern, Southern and Western India.

$$CTHAINDN = \underset{(23.14)}{0.95} \; CTHAINDN\ (-1) + \underset{(1.95)}{13.86} \; DFCTPINDN\ (-1) \qquad (4.24)$$

$$+ \underset{(2.66)}{117.4} \; D83 - \underset{(-4.99)}{225.} D85$$

R-SQUARED (CORR.): 0.94 SEE: 29026 H-STAT: 0.46 PERIOD OF FIT: 1966-86

Where: CTHAINDN = Cotton area, Northern India,
DFCTPINDN = Deflated cotton price, Northern India,
D83 = Zero-one variable, equals 1 in 1983, 0 otherwise,
D85 = Zero-one variable, equals 1 in 1985, 0 otherwise.

$$CTHAINDS = 1504 + \underset{(1.92)}{44.65} \; DFCTPINDS\ (-1) - \underset{(-3.08)}{236.9} \; D73 + \underset{(-8.76)}{233.2} \; D76 \qquad (4.25)$$

R-SQUARED (CORR.): 0.87 SEE: 87647 DW: 1.65 PERIOD OF FIT: 1966-86

Where: CTHAINDS = Cotton area, Southern India,
DFCTPINDS = Deflated cotton price, Southern India,
D73 = Zero-one variable, equals 1 in 1973, 0 otherwise,
D76 = Zero-one variable, equals 1 in 1976, 0 otherwise.

$$CTHAINDW = 6231 + \underset{(4.97)}{134.1} \; DFCTPINDW\ (-1) - \underset{(-10.27)}{510.3} \; LN\ TIME - \underset{(-4.26)}{497.1} \; D74 \qquad (4.26)$$

R-SQUARED (CORR.): 0.91 SEE: 95789 DW: 2.03 PERIOD OF FIT: 1966-86

Where: CTHAINDW = Cotton area, Western India,
DFCTPINDW = Deflated cotton price, Western India,
TIME = Time variable,
D74 = Zero-one variable, equals 1 in 1974, 0 otherwise,
LN = Indicates variable transformed into logarithms.

Cotton area in the three regions of India was specified to depend on the local price of cotton, zero-one dummy variables and variables capturing a strong trend in the area data (i.e., lagged area in the Northern India equation and the logarithm of time in the Western India equation). Producer prices in regional markets were used in the equations and these performed well, giving elasticity estimates ranging between 0.07 and 0.17. The prices of competing crops (i.e., corn in the North, sorghum in the South, and millet in the West) were included but no statistically significant relationships were found. The dummy variables included were most likely capturing the effect of the prices of competing commodities, as well as changes in policy in certain years.

Cotton area in Mexico.

$$\begin{aligned} CTHAMEX = {} & 1146 - \underset{(-16.53)}{255.1}\, LN\ TIME + \underset{(4.02)}{0.05}\, DFCTPMEX(-1) + \underset{(2.45)}{131.}\, D68 \\ & - \underset{(-4.03)}{214.1}\, D75 \end{aligned} \tag{4.27}$$

R-SQUARED (CORR.): 0.94 SEE: 52065 DW: 1.51 PERIOD OF FIT: 1964-88

Where: CTHAMEX = Cotton area, Mexico,
DFCTPMEX = Deflated cotton price, Mexico,
TIME = Time variable,
D68 = Zero-one variable, equals 1 in 1968, 0 otherwise,
D75 = Zero-one variable, equals 1 in 1975, 0 otherwise,
LN = Indicates variable transformed into logarithms.

The equation explaining cotton area in Mexico contained a time variable (converted into logarithms), the deflated price of cotton, and zero-one variables for the years 1968 and 1975. The trend variable captured the decline in cotton area in Mexico throughout much of the regression period. The cotton price was statistically significant and provided an elasticity estimate of 0.56 at the mean area and price.

Cotton area in the Punjab and Sind regions of Pakistan.

$$\begin{aligned} CTHAPAKP = {} & \underset{(31.41)}{0.957}\, CTHAPAKP(-1) + \underset{(2.94)}{0.070}\, DFCTPAKP(-1) + \underset{(2.68)}{163.6}\, D71 \\ & - \underset{(-4.33)}{270.1}\, D75 - \underset{(-4.64)}{276.8}\, D76 \end{aligned} \tag{4.28}$$

R-SQUARED (CORR.): 0.90 SEE: 50293 H-STAT: 0.27 PERIOD OF FIT: 1965-85

Where: CTHAPAKP = Cotton area, Punjab region Pakistan,
DFCTPAKP = Deflated cotton price, Punjab region Pakistan,
D71 = Zero-one variable, equals 1 in 1971, 0 otherwise,
D75 = Zero-one variable, equals 1 in 1975, 0 otherwise,
D76 = Zero-one variable, equals 1 in 1976, 0 otherwise.

$$CTHAPAKS = \underset{}{41.48} + \underset{(11.84)}{0.94\ CTHAPAKS\ (-1)} - \underset{(-6.53)}{210.8\ D76} - \underset{(-4.50)}{159.7\ D77} \quad (4.29)$$

R-SQUARED (CORR.): 0.91 SEE: 15664 H-STAT: - 1.45 PERIOD OF FIT: 1965-85

Where: CTHAPAKS = Cotton area, Sind region Pakistan,
D76 = Zero-one variable, 1 in 1976, 0 otherwise,
D77 = Zero-one variable, 1 in 1977, 0 otherwise.

Cotton area in the Punjab and Sind regions trended strongly throughout the regression period. This trend was captured by cotton area lagged one year. The international price of cotton was statistically significant in the equation for the Punjab region. Prices for cotton and competing crops were not available on a regional basis for Pakistan. Use of regional price data may have improved the results considerably and their omission could account for the significance of a number of zero-one variables included in the equations.

<u>Cotton area in Turkey.</u>

$$CTHATUR = 686 + \underset{(3.53)}{0.01\ DFCTPTUR\ (-1)} - \underset{(-3.39)}{80.74\ LN\ TIME} - \underset{(-1.84)}{102\ D70} \quad (4.30)$$

R-SQUARED (CORR.): 0.56 SEE: 54831 DW: 1.83 PERIOD OF FIT: 1964-88

Where: CTHATUR = Cotton area, Turkey,
DFCTPTUR = Deflated cotton price, Turkey,
TIME = Time variable,
D70 = Zero-one variable, equals 1 in 1970, 0 otherwise,
LN = Indicates variable transformed into logarithms.

Variability in cotton area in Turkey was explained by the deflated price of cotton lagged one year, a logarithmic time variable, and a zero-one dummy variable for 1970. The time variable captured the trend away from cotton over the regression period. The deflated cotton price was significant and provided a supply elasticity of 0.33 when calculated at the mean of the price and area series.

<u>Cotton area in the Delta, Southeast, Southwest and Western regions of the United States.</u>

$$CTHAUS1 = 1426 + \underset{(3.02)}{220\ DFCTPUS1\ (-1)} - \underset{(-2.48)}{0.87\ DFFNPUSA\ (-1)} - \underset{(-3.94)}{18.8\ TIME} \quad (4.31)$$

$$- \underset{(-3.94)}{396.1\ SKRWUS1} + \underset{(2.96)}{439.5\ D72} - \underset{(-3.00)}{437.9\ D83}$$

R-SQUARED (CORR.): 0.81 SEE: 350928 DW: 1.02 PERIOD OF FIT: 1964-88

Where:
CTHAUS1 = Cotton area, Delta region, United States,
DFCTPUS1 = Deflated cotton price, Delta region, United States,
DFFNPUSA = Deflated fertilizer price, United States,
TIME = Time variable,
SKRWUS1 = Zero-one variable for Skip-Row policy, equals 1 1966-67, otherwise 0,
D72 = Zero-one variable, equals 1 in 1972, 0 otherwise,
D83 = Zero-one variable, equals 1 in 1983, 0 otherwise.

$$\begin{aligned} CTHAUS2 = {} & 479.5 + \underset{(2.60)}{105.3}\ DFCTPUS2\ (-1) - \underset{(-3.31)}{0.51}\ DFFNPUSA\ (-1) \\ & - \underset{(-3.86)}{11.14}\ TIME - \underset{(-5.09)}{243.6}\ SKRWUS2 + \underset{(6.15)}{0.62}\ CTHAUS2\ (-1) \\ & - \underset{(-2.88)}{0.67}\ DFSBPUSA\ (-1) \end{aligned} \tag{4.32}$$

R-SQUARED (CORR.): 0.94 SEE: 58595 H-STAT: 0.38 PERIOD OF FIT: 1964-88

Where:
CTHAUS2 = Cotton area, Southeast region, United States,
DFCTPUS2 = Deflated cotton price, Southeast region, United States,
DFSBPUSA = Deflated cotton price, Southeast region, United States,
DFFNPUSA = Deflated fertilizer price, United States,
TIME = Time variable,
SKRWUS2 = Zero-one variable for Skip-Row policy, equals 1 1966-67, otherwise 0,

$$\begin{aligned} CTHAUS3 = {} & 596.1 + \underset{(2.25)}{417.4}\ DFCTPUS3\ (-1) - \underset{(-3.09)}{617.2}\ SKRWUS3 \\ & + \underset{(4.88)}{0.55}\ CTHAUS3\ (-1) - \underset{(-0.59)}{89.25}\ DFSGPUSA\ (-1) - \underset{(-3.03)}{650.5}\ (D82 + D83) \end{aligned} \tag{4.33}$$

R-SQUARED (CORR.): 0.76 SEE: 1280438 H-STAT: 0.70 PERIOD OF FIT: 1964-88

Where:
CTHAUS3 = Cotton area, Southwest region, United States,
DFCTPUS3 = Deflated cotton price, Southwest region, United States,
DFSGPUSA = Deflated sorghum price, United States,
SKRWUS3 = Zero-one variable for Skip-Row policy, equals 1 1966-67, otherwise 0,
D82 = Zero-one variable, equals 1 in 1982, 0 otherwise,
D83 = Zero-one variable, equals 1 in 1983, 0 otherwise.

$$\begin{aligned} CTHAUS4 = {} & \underset{(4.02)}{175.4}\ DFCTPUS4\ (-1) + \underset{(3.32)}{10.01}\ TIME + \underset{(3.58)}{0.43}\ CTHAUS4\ (-1) \\ & - \underset{(-1.39)}{16.88}\ DFRIPUSA\ (-1) - \underset{(-2.68)}{223.4}\ D83 \end{aligned} \tag{4.34}$$

R-SQUARED (CORR.): 0.83 SEE: 124078 H-STAT: 2.12 PERIOD OF FIT: 1964-88

Where: CTHAUS4 = Cotton area, West region, United States,
DFCTPUS4 = Deflated cotton price, West region, United States,
DFRIPUSA = Deflated rice price, United States,
TIME = Time variable,
D83 = Zero-one variable, equals 1 in 1983, 0 otherwise.

The equations for the United States were estimated as functions of the price of cotton in each region, the price of a competitive crop, a policy variable to account for different skip-row rules, and a lagged dependent variable. A dummy variable for 1983 was included in the equations for the Delta, Southwest and West regions of the United States to capture the change in farm policy as a result of large stock levels in 1982. For the 1983 crop season the acreage reduction and PIK programs resulted in more than 7 million acres being taken out of cotton production. Since the fertilizer requirements were higher for cotton than for most other competing crops, the price of fertilizer was used in the equation for the Delta region.

4.6 Cotton Area Elasticity Estimates

The elasticities of planted cotton area with respect to price are presented in Table 4.1. All are inelastic in the short-run, ranging from 0.07 for North India to 0.87 for Argentina. In general, the elasticities are larger for the higher-income countries which may reflect greater flexibility and choice in producing alternative crops to cotton.

Of the studies reviewed in section 4.3, only Mues and Simmons reported elasticities. These are also shown in Table 4.1 and are similar in magnitude to the ones obtained in this study. For the United States the short-run elasticities are slightly smaller than those of Mues and Simmons but the long-run ones are larger. The long-run elasticity estimate for Australia (2.46) seems very high and resulted from the large coefficient on the lagged dependent variable in the area equation.

4.7 Summary

In this section the method used to explain the production of cotton in terms of econometrically-estimated equations was presented. Based on theory of individual firm behavior and drawing on earlier models of cotton supply, production was derived from the product of yield and area planted. Both of these supply components were estimated in a separate equation for each region of the model. The econometric equation results were presented along with supply elasticity estimates. Overall, the econometric results were satisfactory although in many cases world price variables for cotton, competing crops and inputs were not significant. However, when local prices were used in some equations the results improved significantly.

Table 4.1: Elasticities of Cotton Area Planted with Respect to Price

Region	Short-run Elasticity	Long-run Elasticity
Argentina	0.87	1.40
Central Africa	0.12	0.40
China	0.11	
India North	0.07	
South	0.17	
West	0.09	
Mexico	0.56	
Pakistan Punjab	0.08	
Turkey	0.33	
US Southeast	0.27	
Southwest	0.36	0.95
Delta	0.27	0.60
West	0.41	0.72
Estimates of Mues & Simmons (1988)		
United States	0.48	0.64
Australia	0.59	2.46
Rest of World	0.06	0.25

V. COTTON PRICE DETERMINATION

5.1 Introduction

In an earlier version of the model, cotton demand, production and stock equations were estimated for each region and combined in an identity equating production and beginning stocks with consumption and ending stocks. When simulating the model, this identity solved for consumption in one region and price solved as a right-hand side endogenous variable in the demand function for the region. This formulation did not perform satisfactorily in that forecasted values of the price did not track the actual value well, even though consumption and production forecasts performed adequately.

The reason for this result is twofold. Firstly, the estimates of stock equations were unsatisfactory; only in a few equations were the price variables significant. This may be because in many regions (e.g., China) stock levels are more a residual between production and consumption, rather than the result of profit-maximizing behavior of stockholders. Second, as seen from Table 3.1, the elasticities of demand for cotton are highly inelastic. Therefore, small errors in quantity variables tend to lead to relatively larger errors in the price variables.

These problems are discussed by Ghosh et al. (1988) who note that most studies employ inverted stock demand functions where price is specified as a function of stocks. They note that otherwise, "in forecasting or model simulation the price is forced to move too much in order to clear the market. This is a consequence of the incompleteness and inaccuracy of stock data which result in poorly fitting demand equations" (p. 35).

As a result of the poor results obtained using the market-clearing approach, a pricing equation was estimated as an inverted world stock demand function.

5.2 Theoretical Issues

Demand for stocks comes from both producers and consumers and evolves from two separate motives. The first is a transactions demand in which stocks are held to ensure that unanticipated changes in demand can be met. The second is derived from a speculative demand. Stocks are held if prices are expected to increase in the future in excess of the cost of storage.

Suppose stock levels are determined by current prices. That is,

$$S_t = s(P_t).$$

Ghosh et al. discuss two simple models in which price dynamics can be introduced. First, one can assume that stocks follow a partial adjustment process in which stock levels adjust each year towards a certain desired stock level S^*_t. The S^*_t is given by,

$$S^*_t = a_0 - a_1 P_t \tag{5.1}$$

with, $$S_t - S_{t-1} = (1 - \lambda)(S^*_t - S_{t-1}) \quad (0 < \lambda < 1). \tag{5.2}$$

Substituting the partial adjustment equation 5.2 into the stocks equation and inverting gives,

$$P_t = b_0 - b_1 S_t + b_2 S_{t-1}. \tag{5.3}$$

Ghosh *et al.* noted that almost all researchers have found a lagged price term necessary in equation 5.3 and that rarely is the coefficient on the S_{t-1} term significantly different from zero. If the S_{t-1} term in equation 5.3 is substituted j times using equation 5.3, the price equation is given by,

$$P_t = c_0 - c_1 S_t - c_2 \sum \lambda^j P_{t-j}. \tag{5.4}$$

This equation is not useful for estimation because it implies an infinite series of past prices and a negative relationship between current and past prices. Therefore investigators have specified equations in which prices adjust to stock levels (instead of stocks adjusting to prices). This gives an estimable equation of the form,

$$P_t = b_0 + b_1 P_{t-1} - b_2 S_t,$$

and has been applied widely. Researchers often find the coefficient on lagged price to be close to one, and that the coefficient on stocks is not significantly different from zero. In this case, the equation provides forecasts that are too smooth and unresponsive to changes in quantity variables.

The second method of incorporating dynamics into the pricing equation relates stock levels to an expected price. This approach was developed by Hwa (1981, 1985) who derived a stocks equation given by,

$$S_t = a_0 + a_1 C_t + a_2(\ln P^e_{t+1/t} - \ln P_t) - a_3 \ln r_t \tag{5.5}$$

where C_t is consumption $P^e_{t+1/t}$ is the expected price in time t for the period t+1 and r_t is the rate of interest. Assuming that prices adjust to the market clearing value, equation 5.5 can be inverted to give,

$$\partial \ln P_t = b_0 + b_1 C_t + b_2(\ln P^e_{t+1/t} - \ln Pt) - b_3 r_t - b_4 S_t. \tag{5.6}$$

The difficulty with empirically estimating equation 5.6 is to formulate an expectations mechanism for the ($\ln P^e_{t+1/t} - \ln P_t$) variable.

Gilbert and Palaskas (1989) argue that instead of reacting to expected future prices, stockholders respond to expected future excess supplies, which are conditioned on rationally-formed price expectations. In their pricing equation, expected future supplies are used as one of the regressors. This variable is obtained by estimating the entire model (excluding the price equation) with price set at its mean value. That is, a variable,

$$ES_{t+1/t} = (Q_{t+1/t}(P) - C_{t+1/t}(P))/\ Q$$

(where P and Q are mean values of price and quantity) is added to the price equation together with lagged price and interest rates.

5.3 Review of Literature

Most of the econometric studies of the cotton sector discussed in previous sections have used single equation models where prices have been exogenous. Only in the studies by Mues and Simmons (1988) and Agbadi (1988) were the models closed with price endogenous. In the study by Mues and Simmons, a market clearing identity was used to solve for price and no price equation was estimated. Agbadi estimated the mill cotton price for the United States as an inverted mill demand function using domestic mill consumption of cotton and man-made fibers as regressors. The CPI for textile products was estimated as an inverted consumer demand function, with price explained by consumer consumption and income.

The ICAC (1988) estimated a single-equation regression model of the price of cotton in order to forecast near-term price movements. Price was regressed on net exports by China (expressed as a percentage of non-Chinese world consumption) and a ratio of stocks held outside China to use outside China (i.e., world ending stocks net of China's stocks and trade, divided by world consumption net of China's consumption). The rationale behind this specification is that, "... cotton prices are clearly related to the actual or perceived tightness of supply. Perhaps the best single indicator of this tightness is a ratio of available stocks to use. In recent years the size of China's stocks and the fact that a large proportion of those stocks were isolated from world markets have made it necessary to look at world stocks and consumption net of China." The equation fitted the data very well for the period 1974 to 1986 and provided accurate forecasts of the 1987 and 1988 prices.

5.4 A Model of Cotton Price Determination and Estimation Results

The pricing equation used in this model was based on the ICAC model. The price equation and identities are presented in equation 5.7.

$$\text{LN CTPWOR} = 7.24 - \underset{(-6.32)}{0.78}\ \text{LN CTESWORXCHI} + \underset{(5.12)}{0.92}\ \text{LN MUV} \quad (5.7)$$

$$+ \underset{(1.75)}{0.31}\ \text{LN CTCONWORXCHI} - \underset{(-3.33)}{0.86}\ \text{LN TIME}$$

R-SQUARED (CORR.): 0.94 SEE: 0.026 DW: 2.09 PERIOD OF FIT: 1964-88

Where: CTPWOR = World cotton price (Outlook Index "A"),
CTESWORXCHI = World cotton stocks excluding stock held in China (also see equation 5.8),
MUV = Manufacturing unit value 1/,
CTCONWORXCHI = World cotton consumption excluding consumption of China (also see equation 5.9),
TIME = Time variable,
LN = Indicates variable transformed into logarithms.

World price was specified as a function of ending world stocks net of China's stocks, a general deflator (MUV), world cotton consumption net of China's cotton consumption, and a time trend variable. All variables were converted into logarithms which fit the data better than in the linear form. The coefficient on the stocks variable was highly significant and correctly signed. The flexibility of price with respect to stocks, given by the coefficient on the stocks variable, was estimated to be -0.78. No other study has reported a corresponding elasticity for comparison. In order to capture the transactions demand for cotton stocks, world consumption, net of China's consumption, and time were added to the specification. Consumption was used based on the assumption that a certain fixed proportion of the quantity consumed is held each period to cover unanticipated changes in demand. Time was added to account for these stocks having declined over the estimation period. This is because improved milling technology and marketing and transportation channels have meant that less stocks are required for unforseen demand fluctuations. Since prices were estimated in levels, the MUV deflator was added to the specification to capture the effect of inflation.

The stocks and consumption variables used in the pricing equation 5.7 were obtained from the identities in equations 5.8-5.13.

$$\text{CTESWORXCHI} = \text{CTESWOR} - \text{CTESCHI} \quad (5.8)$$

$$\text{CTCONWORXCHI} = \text{CTCONWOR} - \text{CTCONCHI} \quad (5.9)$$

$$\text{CTESWOR} = \text{CTPDWOR} + \text{CTESWOR}(-1) - \text{CTCONWOR} \quad (5.10)$$

$$\text{CTESCHI} = \text{CTPDCHI} + \text{CTESCHI}(-1) - \text{CTCONCHI} - \text{CTNECHI} \quad (5.11)$$

1/ Unit Value in US dollar terms of manufactures exported from the G-5 countries (France, Germany, Japan, United Kingdom and the United States) weighted proportionally to the countries' exports to the developing countries.

$$CTPDWOR = \Sigma_i (CTHA_i * CTYD_i) + CTPDROW \quad (5.12)$$

$$CTCONWOR = \Sigma_i (CTSH_i * TFU_i) + CTCONROW \quad (5.13)$$

Where: CTESWORXCHI = World cotton stocks excluding stock held in China,

CTESWOR = World cotton stocks,

CTESCHI = China's cotton stocks,

CTCONWORXCHI = World cotton consumption excluding consumption in China,

CTCONWOR = World cotton consumption,

CTCONCHI = China's cotton consumption,

CTPDWOR = World cotton production,

CTPDCHI = China's cotton production,

CTNECHI = China's net exports of cotton,

$CTHA_i$ = Cotton area in country i,

$CTYD_i$ = Cotton yield in country i,

CTPDROW = Rest-of-World cotton production (production by countries not explicitly modeled, i.e., exogenous),

$CTSH_i$ = Cotton share of total fiber use in country i,

TFU_i = Total fiber use in country i,

CTCONROW = Rest-of-World cotton consumption (consumption by countries not explicitly modeled, i.e, exogenous).

World stocks were derived from a world market clearing identity (equation 5.10) and the stocks of China were derived from China's market clearing identity (equation 5.11). For China's market clearing identity, net exports were estimated (equation 5.14) as a function of lagged net exports and a variable capturing excess supplies. Price variables were found not to be significant in determining net exports.

$$\begin{aligned} CTNECHI = &- 326 + \underset{(5.78)}{0.23} (CTPDCHI + CTESCHI (-1) - CTCONCHI) \quad (5.14) \\ &+ \underset{(2.70)}{0.34} CTNECHI (-1) - \underset{(-2.80)}{528.4} D84 \end{aligned}$$

R-SQUARED (CORR.): 0.92 SEE: 142.9 DW: 1.80 PERIOD OF FIT: 1974-88

Where: CTNECHI = China's net exports of cotton,
CTPDCHI = China's cotton production,
CTESCHI = China's cotton stocks,
CTCONCHI = China's cotton consumption,
D84 = Zero-one variable, equals 1 in 1984, 0 otherwise.

5.5 Price Linkage Equations

In the supply equations for the four regions of the United States, for the three regions of India and for China, local prices were used instead of world prices adjusted for exchange rates. These were the prices most relevant to farmer's decision making and this was borne out by the estimation results. These local prices were linked to the world price of cotton in order to make these regions responsive to world market conditions.

In the case of the United States, price linkage equations were estimated linking local and world cotton prices. These are presented in equations 5.15-5.18.

$$LN\ CTPUS1 = 0.25 + \underset{(15.39)}{0.92}\ LN\ CTPWOR - \underset{(-2.38)}{0.31}\ D74 \tag{5.15}$$

R-SQUARED (CORR.): 0.92 SEE: 0.34 DW: 1.81 PERIOD OF FIT: 1964-87

Where: CTPUS1 = Cotton price in the Delta region of the United States,
CTPWOR = World cotton price,
D74 = Zero-one variable, equals 1 in 1974, otherwise 0,
LN = Indicates variable transformed into logarithms.

$$LN\ CTPUS2 = 0.34 + \underset{(15.10)}{0.91}\ LN\ CTPWOR - \underset{(-2.32)}{0.30}\ D74 \tag{5.16}$$

R-SQUARED (CORR.): 0.92 SEE: 0.34 DW: 1.85 PERIOD OF FIT: 1964-87

Where: CTPUS2 = Cotton price in the Southeast region of the United States,
CTPWOR = World cotton price,
D74 = Zero-one variable, equals 1 in 1974, otherwise 0,
LN = Indicates variable transformed into logarithms.

$$LN\ CTPUS3 = 0.32 + \underset{(15.05)}{0.90}\ LN\ CTPWOR - \underset{(-2.38)}{0.31}\ D74 \tag{5.17}$$

R-SQUARED (CORR.): 0.92 SEE: 0.34 DW: 1.83 PERIOD OF FIT: 1964-87

Where: CTPUS3 = Cotton price in the Southwest region of the United States,
CTPWOR = World cotton price,
D74 = Zero-one variable, equals 1 in 1974, otherwise 0,
LN = Indicates variable transformed into logarithms.

$$LN\ CTPUS4 = 0.09 + \underset{(13.74)}{0.96}\ LN\ CTPWOR - \underset{(-2.11)}{0.32}\ D74 \tag{5.18}$$

R-SQUARED (CORR.): 0.90 SEE: 0.46 DW: 1.79 PERIOD OF FIT: 1964-87

Where: CTPUS4 = Cotton price in the West region of the United States,
CTPWOR = World cotton price,
D74 = Zero-one variable, equals 1 in 1974, otherwise 0,
LN = Indicates variable transformed into logarithms.

A double-log functional form was used in all cases and a dummy variable for 1974 was added to account for very low prices in that year. In 1974 a target price policy was introduced, with direct payments made to growers if market prices fell below the target price. The transmission elasticities ranged from 0.90 in the Southwest region to 0.96 in the West region.

Price transmission equations were also estimated linking local prices in India and China with world prices. These equations performed badly, with world price not significant. This finding was consistent with price policy in these countries which is formed in isolation of world markets. However, it is unlikely that over the long-run world prices can be ignored by policymakers in these countries. Rather than have administered prices exogenous in the forecast period these prices were linked to the world price assuming an elasticity of 0.25 for China and 0.50 for India. 1/ These elasticities entered the model using the identity shown in equation 5.19.

$$LN\ LPP_t = LN\ LPP_o + \lambda * LN(WPP_t/WPP_o) \qquad (5.19)$$

Where: LPP_t = local producer price in period t,
LPP_o = local producer price in period o,
WPP_t = world producer price in period t,
WPP_o = world producer price in period o, and

λ = 0.5 for India and 0.25 for China.

5.6 Summary

In this section, the equations for the determination cotton prices were discussed. The equation explaining the world cotton price was specified as an inverted world stocks equation. The world price was explained by world stocks (net of stocks held in China). Transactions demand for cotton stocks was captured in the equation by a time variable and world consumption (net of consumption in China). The regression results were satisfactory and gave a flexibility estimate of the cotton price with respect to stocks of -0.78. In the model simulations this method of price determination gave results far superior to those obtained when price was derived through a world market clearing identity. This finding is consistent with Ghosh *et al.*

1/ The choice of elasticities was based on a study by Mundlak and Larson (1990) of the relationship between local and international prices.

VI. NON-CELLULOSIC FIBERS MODEL

6.1 Introduction

Estimates of the demand, supply and price equations for the non-cellulosic fibers (i.e., polyester, nylon and acrylic) are described in this section. The market for cellulosic fibers (i.e., acetate, rayon and triacetate), the other major group of manufactured fibers, has not been modeled. The reason for this was that cellulosic fibers contributed less than 10% of total world fiber availability in 1985 and less than 23% of manufactured fiber use. Further, these percentages have decreased significantly over time and are expected to continue to fall (despite a recent resurgence of rayon consumption). A cellulosic fiber model can be added at a later stage, if necessary.

In previous sections the theoretical issues and relevant literature were presented and reviewed. The theoretical assumptions for non-cellulosic demand are the same as for cotton demand (section 3.3). The theoretical basis for the pricing equation is similar to that of cotton, except that prices were determined from an inverted consumer demand equation rather than from a stocks demand equation. There are no stocks data for non-cellulosic fibers. The supply equation for non-cellulosic fibers was developed from the assumption of profit maximization by manufacturers. As far as the authors are aware there are no published econometric studies of the non-cellulosic fibers sector upon which to draw.

6.2 Demand for Non-cellulosic Fibers

The demand equation for non-cellulosic fibers was specified using a structure identical to that for cotton use. The proportion of non-cellulosics fibers of total fiber use was estimated as a function of the prices of cotton and polyester. The non-cellulosic share was then multiplied by total fiber use to obtain the consumer use of non-cellulosic fibers. That is,

$$\begin{aligned} NCU &= NCSH * PCTFU * POP, \\ NCSH &= f(\ PCT,\ PSP\ ), \\ PCTFU &= f(\ GDP\ ). \end{aligned}$$

where,

NCA = Non-cellulosic fibers for home use;
NCSH = Non-cellulosic share of total fibers for home use.

The non-cellulosic share was not specified as one minus the cotton share because there are other fiber types that make up total fiber demand. The per capita total fiber use equations were discussed in section 3.5.2. The non-cellulosic share equations are presented in equations 6.1-6.14 below. The equation specifications are very similar to the cotton share equations reported in section 3.5, which in most cases fitted the data well. The non-cellulosic share is a function of polyester and cotton prices 1/ which appears as a ratio in most of the equations. In many of these equations, price parameters are significant and have the correct sign. Price variables that were not significant but correctly signed were kept in the model (i.e., for Argentina and Central Africa). In initial equations for Egypt, India and Pakistan the price variables were not significant and were incorrectly signed and were dropped from the specification. To capture the effect of prices in these equations the cotton share of total fiber use was added to the specifications which, as shown in section 3.5, were functions of relative prices.

As reported in section 3.5.1, the non-cellulosic fibers share in these regions followed a very strong time trend throughout the estimation period. A time variable was significant in many of the equations, capturing the non-price determined substitution of cotton with non-cellulosic fibers. This point was discussed in section 3.4. In some cases a logarithmic functional form gave a better fit to the data. Dummy variables were used to capture outliers in the data. For example, dummy variables for 1972 and 1973 in the equation for the Republic of Korea captured the impact of political unrest on that economy during the early 1970s.

Non-cellulosic fibers share of total fiber use in Argentina.

$$\underset{}{NCSHARG} = 0.016 - \underset{(-1.82)}{0.03}\ DFPSPARG/DFCTPARG + \underset{(10.84)}{0.81}\ NCSHARG(-1) \tag{6.1}$$

R-SQUARED (CORR.): 0.92   SEE: 0.011   H-STAT: 0.47   PERIOD OF FIT: 1964-86

Where: NCSHARG = Non-cellulosic fibers share of total fiber use in Argentina,
DFPSPARG = Deflated polyester price in Argentina,
DFCTPARG = Deflated cotton price in Argentina.

Non-cellulosic fibers share of total fiber use in Australia.

$$NCSHAUS = 0.02 - \underset{(-3.01)}{0.05}\ DFPSPAUS/DFCTPAUS + \underset{(15.79)}{0.85}\ NCSHAUS(-1) \tag{6.2}$$

R-SQUARED (CORR.): 0.96   SEE: 0.009   H-STAT: - 0.86   PERIOD OF FIT: 1964-87

Where: NCSHAUS = Non-cellulosic fibers share of total fiber use in Australia,
DFPSPAUS = Deflated polyester price in Australia,
DFCTPAUS = Deflated cotton price in Australia.

1/ The polyester price used was the polyester staple price f.o.b. US plants taken from Cotton and Wool Situation and Outlook, USDA, Washington, D.C. The cotton price was the cotton outlook "A" Index c.i.f. North Europe, taken from Cotton Outlook.

Non-cellulosic fibers share of total fiber use in Brazil.

$$LN\ NCSHBRA = 1.55 - \underset{(-11.85)}{1.24}\ LN\ DFPSPBRA/LN\ DFCTPBRA \tag{6.3}$$

R-SQUARED (CORR.): 0.87   SEE: 0.888   DW: 1.19   PERIOD OF FIT: 1964-86

Where: NCSHBRA = Non-cellulosic fibers share of total fiber use in Brazil,
DFPSPBRA = Deflated polyester price in Brazil,
DFCTPBRA = Deflated cotton price in Brazil,
LN = Indicates variable transformed logarithms.

Non-cellulosic fibers share of total fiber use in Central Africa.

$$LN\ NCSHCAF = - 4.98 - \underset{(-1.11)}{0.10}\ LN\ DFPSPCAF/LN\ DFCTPCAF - \underset{(-11.66)}{1.03}\ LN\ TIME \tag{6.4}$$

R-SQUARED (CORR.): 0.95   SEE: 0.282   DW: 1.31   PERIOD OF FIT: 1964-86

Where: NCSHCAF = Non-cellulosic fibers share of total fiber use in Central Africa,
DFPSPCAF = Deflated polyester price in Central Africa,
DFCTPCAF = Deflated cotton price in Central Africa,
TIME = Time variable,
LN = Indicates variable transformed into logarithms.

Non-cellulosic fibers share of total fiber use in China.

$$LN\ NCSHCHI = 3.77 - \underset{(-9.41)}{1.02}\ LN\ DFPSPCHI/LN\ DFCTPCHI - \underset{(-16.42)}{6.40}\ LN\ CTSHCHI \tag{6.5}$$

R-SQUARED (CORR.): 0.97   SEE: 0.652   DW: 1.85   PERIOD OF FIT: 1964-86

Where: NCSHCHI = Non-cellulosic fibers share of total fiber use in China,
CTSHCHI = Cotton share of total fiber use in China,
DFPSPCHI = Deflated polyester price in China,
DFCTPCHI = Deflated cotton price in China.
LN = Indicates variable transformed into logarithms.

Non-cellulosic fibers share of total fiber use in the EEC-12.

$$LN\ NCSHEEC = - 1.00 - \underset{(-10.43)}{0.58}\ LN\ DFPSPEEC/LN\ DFCTPEEC + \underset{(3.05)}{0.38}\ D86 \tag{6.6}$$

R-SQUARED (CORR.): 0.85   SEE: 0.252   DW: 1.45   PERIOD OF FIT: 1964-87

Where: NCSHEEC = Non-cellulosic fibers share of total fiber use in the EEC-12,
DFPSPEEC = Deflated polyester price in the EEC-12,
DFCTPEEC = Deflated cotton price in the EEC-12,
D86 = Zero-one variable, equals 1 in 1986 0 otherwise.
LN = Indicates variable transformed into logarithms.

Non-cellulosic fibers share of total fiber use in Egypt.

$$NCSHEGY = \underset{}{0.50} + \underset{(7.65)}{0.29}\ LN\ TIME - \underset{(-7.51)}{0.38}\ CTSHEGY \qquad (6.7)$$

R-SQUARED (CORR.): 0.99 SEE: 0.006 DW: 2.65 PERIOD OF FIT: 1964-86

Where: NCSHEGY = Non-cellulosic fibers share of total fiber use in Egypt,
CTSHEGY = Cotton share of total fiber use in Egypt,
TIME = Time variable,
LN = Indicates variable transformed into logarithms.

Non-cellulosic fibers share of total fiber use in India.

$$LN\ NCSHIND = -\ 3.01 + \underset{(2.93)}{0.73}\ LN\ TIME + \underset{(5.33)}{0.67}\ LN\ NCSHIND\ (-1) \qquad (6.8)$$

R-SQUARED (CORR.): 0.98 SEE: 0.320 H-STAT: 1.12 PERIOD OF FIT: 1964-86

Where: NCSHIND = Non-cellulosic fibers share of total fiber use in India,
TIME = Time variable,
LN = Indicates variable transformed into logarithms.

Non-cellulosic fibers share of total fiber use in Japan.

$$LN\ NCSHJPN = -\ 0.34 - \underset{(-4.19)}{0.19}\ LN\ DFPSPJPN/LN\ DFCTPJPN \qquad (6.9)$$

$$+ \underset{(7.69)}{0.65}\ LN\ NCSHJPN\ (-1) - \underset{(-2.68)}{0.28}\ D72 - \underset{(-3.99)}{0.32}\ D74$$

R-SQUARED (CORR.): 0.92 SEE: 0.096 H-STAT: - 0.28 PERIOD OF FIT: 1964-87

Where: NCSHJPN = Non-cellulosic fibers share of total fiber use in Japan,
DFPSPJPN = Deflated polyester price in Japan,
DFCTPJPN = Deflated cotton price in Japan,
D72 = Zero-one variable, equals 1 in 1972, 0 otherwise,
D74 = Zero-one variable, equals 1 in 1974, 0 otherwise,
LN = Indicates variable transformed into logarithms.

Non-cellulosic fibers share of total fiber use in Korea.

$$NCSHKOR = -\ 0.70 - \underset{(-2.99)}{0.82}\ DFPSPKOR/DFCTPKOR - \underset{(-1.17)}{0.47}\ D72 - \underset{(-3.76)}{0.61}\ D73 \qquad (6.10)$$

R-SQUARED (CORR.): 0.83 SSE: 0.587 DW: 1.02 PERIOD OF FIT: 1964-86

Where: NCSHKOR = Non-cellulosic fibers share of total fiber use in Korea,
DFPSPKOR = Deflated polyester price in Korea,
DFCTPKOR = Deflated cotton price in Korea,
D72 = Zero-one variable, equals 1 in 1972, 0 otherwise,
D73 = Zero-one variable, equals 1 in 1973, 0 otherwise.

<u>Non-cellulosic fibers share of total fiber use in Mexico.</u>

$$NCSHMEX = \underset{(-3.60)}{0.058}\ DFPSPMEX/DFCTPMEX + \underset{(27.24)}{0.92}\ NCSHMEX(-1) \quad (6.11)$$

R-SQUARED (CORR.): 0.99 SSE: 0.009 H-STAT: 1.04 PERIOD OF FIT: 1964-86

Where: NCSHMEX = Non-cellulosic fibers shares of total fiber use in Mexico,
DFPSPMEX = Deflated polyester price in Mexico,
DFCTPMEX = Deflated cotton price in Mexico.

<u>Non-cellulosic fibers share of total fiber use in Pakistan.</u>

$$NCSHPAK = 0.64 - \underset{(-21.81)}{0.70}\ CTSHPAK \quad (6.12)$$

R-SQUARED (CORR.): 0.97 SSE: 0.199 DW: 1.64 PERIOD OF FIT: 1964-86

Where: NCSHPAK = Non-cellulosic fibers share of total fiber use in Pakistan,
CTSHPAK = Cotton share of total fiber use in Pakistan.

<u>Non-cellulosic fibers share of total fiber use in Turkey.</u>

$$LN\ NCSHTUR = -\ 4.75 - \underset{(-2.78)}{0.27}\ LN\ DFPSPTUR/LN\ DFCTPTUR + \underset{(11.92)}{1.12}\ LN\ TIME \quad (6.13)$$

R-SQUARED (CORR.): 0.96 SSE: 0.199 DW: 1.64 PERIOD OF FIT: 1964-86

Where: NCSHTUR = Non-cellulosic fibers share of total fiber use in Turkey,
DFPSPTUR = Deflated polyester price in Turkey,
DFCTPTUR = Deflated cotton price in Turkey,
TIME = Time variable,
LN = Indicates variable transformed into logarithms.

<u>Non-cellulosic fibers share of total fiber use in the United States.</u>

$$NCSHUSA = 0.17 + \underset{(6.13)}{0.001}\ DFCTPUSA - \underset{(-3.72)}{0.0005}\ DFPSPUSA + \underset{(6.27)}{0.012}\ TIME \quad (6.14)$$

R-SQUARED (CORR.): 0.94 SSE: 0.021 DW: 1.78 PERIOD OF FIT: 1964-87

Where: NCSHUSA = Non-cellulosic fibers share of total fiber use in the United States,
DFPSPUSA = Deflated polyester price in the United States,
DFCTPUSA = Deflated cotton price in the United States,
TIME = Time variable.

The own- and cross-price elasticities are reported in Table 6.1. They range from 0.1 in the Central Africa region to 1.24 in Brazil. In most cases the elasticities are inelastic but overall are higher than the own-price elasticities estimated for cotton. This may reflect the high degree of substitutability of non-cellulosic fibers with cellulosic fibers. In contrast to the cotton own-price elasticities, the responsiveness to prices does not tend to be greater or less in the industrial countries than in the developing countries.

Table 6.1: Price Elasticities of Non-Cellulosic Use a/

Region b/	Polyester Staple Price	Cotton Price c/
Argentina	-0.15	+0.15
Australia	-0.13	+0.13
Brazil	-1.24	+1.24
Central Africa	-0.10	+0.10
China	-1.02	+1.02
EEC	-0.58	+0.58
Egypt d/	-0.42	+0.42
Japan	-0.19	+0.19
Korea, Repub. of	-0.83	+0.83
Mexico	-0.12	+0.12
Pakistan d/	-0.32	+0.32
Turkey	-0.27	+0.27
United States	-0.22	+0.42

a/ Based on a regression period 1964-86 for developing countries; 1964-87 for industrial countries.

The elasticities of non-cellulosic use with respect to price ($E_{NCU/P}$) were derived from the non-cellulosic share equations.

$E_{NCU/P}$ = $(\partial NCU/\partial P).(P/NCU)$. Recall NCU = NCSH * TFU and that NCSH = (a + b.P). $(\partial NCU/\partial P)$ = b.TFU and $E_{NCU/P}$ = b.TFU.P/NCU.

Values for NCU, P and TFU were taken as historical means.

b/ No elasticities can be reported from model regions for which prices do not appear in the demand equations (i.e., India).

c/ Where polyester price elasticities equal the cotton elasticities, a ratio of these prices was used in the share equation.

d/ Elasticities calculated using cotton share elasticity estimates.

Cross-price elasticities can be compared using Tables 3.1 and 6.1. The comparisons show that non-cellulosic demand is more responsive to cotton price changes than is cotton demand to changes in the price of polyester. This may reflect the fact that historically the costs of raw cotton in textile manufacturing have exceeded those for non-cellulosic fibers. Therefore, the income effect of a change in the cotton price is larger than for a change in the polyester price.

This finding is consistent with the Slutsky condition from consumer demand theory. This states that:

$$e_{ij} = (w_i/w_j).e_{ji} + w_j.(e_{jy} - e_{iy})$$

where:

e_{ij} = the demand elasticity of good i with respect to the price of good j,

e_{ji} = the demand elasticity of good j with respect to the price of good i,

w_i = the income expenditure share allocated to good i,

w_j = the income expenditure share allocated to good j,

e_{iy} = the income elasticity of good i,

e_{jy} = the income elasticity of good j.

Let good i be cotton and j man-made fibers. Since, historically, manufactures have spent more on cotton than on non-cellulosic fibers, (i.e., w_i has exceeded w_j), then the elasticity of cotton demand with respect to the price of polyester is expected to be less than the elasticity of non-cellulosic fibers with respect to the cotton price [assuming the $w_j.\ (e_{jy}-e_{iy})$ term is small].

6.3 Supply of Non-Cellulosic Fibers

The supply of non-cellulosic fibers has been described by Thigpen and Mitchell (1988) as follows.

> " Non-cellulosic fibers are produced by industrial processes from long-chain synthetics polymers and are usually of petroleum origin. The levels of production can be adjusted quickly to market conditions within the limits of plant capacity. These fibers are produced by industrial processes which give producers a considerable degree of control of output over a relatively short period of time and within the limits of total capacity. The synthetic fiber market is comprised of a relatively small number of firms with individual firms large enough to influence the level of production and price."

The supply of non-cellulosic fibers is expected to depend on the profitability of producing non-cellulosic fibers which is determined by the price of non-cellulosic fibers relative to input costs, such as oil costs and interest rates. Equations were estimated for the major producing regions. However, difficulties were encountered in estimating production at a regional level with the prices of oil and polyester not significant in many cases. This may be because output is produced by a few very large multinational companies who do not respond directly to local economic factors, but rather to broader global economic conditions. Also, poor results may have resulted from the lack of accurate regional level data. Production of non-cellulosic fibers was therefore estimated at the world level using a single equation which is reported in equation 6.15.

$$NCPROD = -27116 - \underset{(-2.77)}{4397.}\ DFOILPR - \underset{(-2.53)}{127.6}\ RIRUSA + \underset{(5.49)}{1077.}\ DFPSPWOR(-1) \quad (6.15)$$

$$+ \underset{(13.18)}{12211.}\ LN\ TIME$$

R-SQUARED (CORR.): 0.99   SEE: 488.7   DW: 1.65   PERIOD OF FIT: 1964-88

Where: NCPROD = Non-cellulosic fibers production, World,
DFOILPR = Deflated price of oil (OPEC petroleum average prices),
RIRUSA = Real rate of interest (long term US bond yield),
DFPSPWOR = Deflated polyester price,
TIME = Time variable,
LN = Indicates variable transformed into logarithms.

Non-cellulosic production is estimated as a function of the deflated price of oil, the deflated price of polyester and the real rate of interest. The coefficients have the right signs and are all significant. The elasticities of supply with respect to the price of oil and own-price are 0.08 and 0.36, respectively. The logarithm of time was added to the specification to capture the dramatic increase in production of non-cellulosic fibers associated with technological innovations in the non-cellulosic fibers sector.

6.4 Price Determination

The polyester price was determined by an inverted demand equation 6.16. Demand in the Rest-of-the-World region was included and in turn was determined endogenously as the difference between supply and the demand from regions modeled explicitly (equation 6.17). The lagged price of oil captured the effects of oil prices on non-cellulosic fibers, while the MUV deflator accounted for general inflation throughout the estimation period. The equation fitted the data well with all coefficients significant and correctly signed. The flexibility of the polyester price with respect to the demand in the Rest-of-the-World is 0.90 which is consistent with the elasticity estimates reported in Table 6.1. The polyester price elasticity with respect to the MUV is 1.04.

$$PSPWOR = 79.6 + \underset{(6.83)}{1.74}\ MUV - \underset{(-5.66)}{0.05}\ NCUROW + \underset{(6.16)}{1.81}\ OILPR(-1) \quad (6.16)$$

R-SQUARED (CORR.): 0.96   SEE: 5.56   DW: 2.61   PERIOD OF FIT: 1969-88

Where: PSPWOR = Polyester price, World,
MUV = Manufactures unit value (deflator),
NCUROW = Non-cellulosic fibers use, Rest-of-the-World,
OILPR = Price of oil.

$$NCUROW = NCPROD - \Sigma_i (NCSH_i * TFU_i) \tag{6.17}$$

Where: NCUROW = Non-cellulosic fibers use, Rest-of-the-World,

NCPROD = Non-cellulosic fibers production, World (from equation 6.15),

$NCSH_i$ = Non-cellulosic fibers share of total fiber use in country i (from equations 6.1-6.14),

TFU_i = Total fiber use in country i (from equations 3.15-3.28).

6.5 Summary

In this section, an econometric model for the non-cellulosic fiber sector was presented. Equations for the non-cellulosic fibers share of total fiber use were estimated for each of the model regions, which were then combined with total fiber demand to determine non-cellulosic fibers consumption. The supply of non-cellulosic fibers was estimated for the world. The polyester price was determined from an inverted demand equation for non-cellulosics in the Rest-of-the-World which was derived from a market clearing identity. The non-cellulosic fibers model was linked to the cotton model through the polyester price which entered the cotton demand equations. Overall, the econometric equations were satisfactory with good explanatory power and coefficients and elasticity estimates at reasonable levels.

VII. VALIDATION OF THE MODEL

The single equation estimates presented in earlier chapters were accepted or rejected on the basis of a set of standard diagnostics such as the corrected R-squared, the Durbin-Watson statistic and standard error of residuals. The decision to accept or reject an equation often ultimately depends on the purpose for which the equation is being estimated. For example, models estimated for forecasting should have small standard errors, while those used for evaluating alternative policy scenarios or calculating structural elasticities should be specified to be consistent with economic theory. Once such single equations have been put together to form a multi-equation model, a similar evaluation procedure is necessary to test the properties of the entire model. This section presents different statistics which cover various aspects of model evaluation.

A major problem in validating a multi-equation model is that no statistically objective criteria or benchmarks exist by which to accept or reject a validation statistic. The criteria used are arbitrarily chosen by the modeler. As in single equation estimation, the decision to accept a model as satisfactory depends on the intended use of the model. Models designed for forecasting are typically put through more rigorous tests than those developed for evaluating alternative policy scenarios.

In this section, four sets of validation statistics are presented. These cover various aspects of the model's ability to plot historical data and to respond to economic stimuli in a manner consistent with both economic theory and empirical observation. The validation statistics include:

(1) Root Mean Square Percentage Error (RMSPE);
(2) Mean Squared Error (MSE);
(3) Theil's U-statistic;
(4) Graphical validation.

The validation statistics presented below are based on a simulation period from 1966 to 1988 for production and price variables and from 1966 to 1986 for consumption variables.

7.1 Validation using the Root Mean Squared Percentage Error

The root mean square percentage error (RMSPE) statistic shows how well simulated values of the endogenous variables match with their actual historical values. The RMSPE is defined as,

$$\text{RMSPE} = \left(1/n\Sigma_t \; ((A_t-P_t)/A_t)^2 \;\right)^{\frac{1}{2}}$$

where,

A_t = the actual value of an endogenous variable,

P_t = the simulated value of an endogenous variable, and

n = the number of periods in the simulation.

This statistic is very useful in that it provides a single value measuring the variation of the predicted values around actual values of the endogenous variables. The statistic does have two drawbacks. First, the RMSPE is an average which as a measure of central tendency can mask the true nature of the series which it represents. For example, a few very large errors can raise the RMSPE of a series that otherwise tracks very well. Second, in cases where the actual values are small (e.g., net exports), small errors in absolute terms give rise to substantial errors in percentage terms.

The RMSPEs for the endogenous cotton variables of the model are reported in Table 7.1a. 1/ At the world level the RMSPEs for cotton use and cotton production are 1.56% and 2.2%, respectively. The RMSPE for the world price of cotton is 8.42%. Thus, the model's tracking of the quantity variables tends to be better than for prices. This can be explained by the inelasticity of the supply and demand curves in which inaccuracies have a greater effect on prices than quantities.

For the individual regions the results for cotton use tend to perform better than those for production. Of the 14 consumption regions in the model all recorded a RMSPE of less than 15% and only for two regions (Pakistan and the Republic of Korea) have values of less than 10% been reported. On the cotton production side of the model the results are less good. However, only in three producing regions were RMSPEs of more than 20% obtained (Australia, Southeast region of the United States and Sind region of Pakistan), while for seven regions the simulation gave RMSPEs of less than 10%.

As mentioned above, the RMSPEs are sensitive to the levels of the variables. This explains the very high values recorded for stock and net trade in China (CTESPRC = 73.88 and CTNEPRC = 191.34). Both these variables are very close to zero during some periods of the simulation, resulting in very large percentage errors between actual and simulated values. This is also the reason for the very high value reported for per capita total fiber use in Central Africa (PCTFUCAF = 83.3). In these circumstances other validation statistics must be used to evaluate the performance of the variable in the model.

The RMSPEs for the non-cellulosic fiber variables are reported in Table 7.1b. The RMSPEs for world supply, demand and price are 11.58, 8.62 and 14.4, respectively. These are higher than their cotton counterparts but still indicate good model predictions of the historical series. Again, the price variable performs less well than the quantity variables, reflecting the inelasticity of demand for the non-cellulosic fibers. The non-cellulosic share equations do not perform as well as the cotton share equations. This may reflect the fact that the non-cellulosic share has been historically below the cotton share so that percentage differences are computed from a lower base level--accounting for the large RMSPEs reported for China, the Republic of Korea and Pakistan. The RMSPEs for the non-cellulosic fibers use reflect errors in the share and total fiber use equations which have been discussed already. The value for NCUROW is relatively low at 14.97. Accuracy in tracking this variable is important as it is the demand variable in the polyester price equation.

1/ It should be noted that dummy variables have artifically reduced many of the RMSPEs.

Table 7.1a: Root Mean Square Percentage Errors - Cotton Variables 1/

Variable	RMSPE	Variable	RMSPE	Variable	RMSPE
CTYDARG	10.50	CTYDAUS	11.63	CTYDBRA	7.50
CTYDCAF	6.78	CTYDEGY	13.90	CTYDINDN	5.92
CTYDINDS	11.43	CTYDINDW	4.15	CTYDMEX	5.08
CTYDPAKP	12.33	CTYDPAKS	9.21	CTYDPRC	3.35
CTYDTUR	6.35	CTYDUS1	9.19	CTYDUS2	15.18
CTYDUS3	7.90	CTYDUS4	6.63		
CTHAARG	11.82	CTHAAUS	29.78	CTHABRA	5.36
CTHACAF	2.51	CTHAEGY	5.38	CTHAINDN	10.49
CTHAINDS	4.02	CTHAINDW	1.24	CTHAMEX	17.41
CTHAPAKP	5.48	CTHAPAKS	11.76	CTHAPRC	5.94
CTHATUR	7.47	CTHAUS1	11.88	CTHAUS2	23.51
CTHAUS3	11.68	CTHAUS4	14.44		
CTPDARG	13.72	CTPDAUS	38.51	CTPDBRA	9.68
CTPDCAF	6.79	CTPDEGY	14.48	CTPDINDN	8.28
CTPDINDS	11.93	CTPDINDW	3.87	CTPDIND	4.30
CTPDMEX	17.44	CTPDPAKP	11.71	CTPDPAKS	21.72
CTPDPAK	10.19	CTPDPRC	4.75	CTPDTUR	7.96
CTPDUS1	12.18	CTPDUS2	27.57	CTPDUS3	15.88
CTPDUS4	16.14	CTPDUSA	8.31		
CTPDWOR	2.20				
CTSHARG	2.71	CTSHAUS	3.17	CTSHBRA	2.60
CTSHCAF	1.33	CTSHEEC	3.33	CTSHEGY	5.78
CTSHIND	3.38	CTSHJPN	3.38	CTSHKOR	7.50
CTSHMEX	3.07	CTSHPAK	2.86	CTSHPRC	2.48
CTSHTUR	5.51	CTSHUSA	5.28		
PCTFUURG	4.70	PCTFUAUS	4.54	PCTFUBRA	6.11
PCTFUCAF	83.30	PCTFUEEC	2.82	PCTFUEGY	5.07
PCTFUIND	1.70	PCTFUJPN	6.95	PCTFUKOR	11.05
PCTFUMEX	4.69	PCTFUPAK	12.81	PCTFUPRC	6.11
PCTFUTUR	3.59	PCTFUUSA	2.63		
CTUARG	4.36	CTUAUS	5.45	CTUBRA	6.11
CTUCAF	6.52	CTUEEC	3.79	CTUEGY	7.95
CTUIND	3.02	CTUJPN	7.54	CTUKOR	13.80
CTUMEX	7.52	CTUPAK	14.19	CTUPRC	6.56
CTUTUR	7.13	CTUUSA	5.97		
CTUWOR	1.56	CTESWOR	9.69	CTESPRC	73.88
CTNEPRC	191.34				
CTPWOR	8.42				

1/ See Appendix I for variable definitions.

Table 7.1b: Root Mean Square Percentage Errors - Non-Cellulosic Fiber Variables 1/

Variable	RMSPE	Variable	RMSPE	Variable	RMSPE
NCPDWOR	11.58	NCUWOR	8.62	PSPWOR	14.40
NCSHARG	11.24	NCSHAUS	9.62	NCSHBRA	25.43
NCSHCAF	22.32	NCSHEEC	12.53	NCSHEGY	12.05
NCSHIND	17.88	NCSHJPN	6.28	NCSHKOR	24.21
NCSHMEX	14.94	NCSHPAK	112.92	NCSHPRC	26.62
NCSHTUR	10.49	NCSHUSA	11.00		
NCUARG	12.52	NCUAUS	12.51	NCUBRA	25.17
NCUCAF	24.27	NCUEEC	13.03	NCUEGY	13.78
NCUIND	18.25	NCUJPN	12.59	NCUKOR	22.15
NCUMEX	20.80	NCUPAK	104.87	NCUPRC	29.36
NCUTUR	10.78	NCUUSA	11.70	NCUROW	14.97

1/ See Appendix I for variable definitions.

7.2 Validation Using Mean Squared Error (MSE)

The mean squared error (MSE) is similar to the RMSPE in that it measures the mean of the squared difference between actual and simulated variables. It can be defined in terms of the differences in the levels of the variables, that is,

$$MSEL = 1/n \quad \Sigma_t \; (P_t-A_t)^2$$

or in terms of percentage changes, that is,

$$MSEP = 1/n \quad \Sigma_t \; (p_t-a_t)^2 \quad \text{where,}$$

$$p_t = (P_t-A_{-1t})/A_{t-1} \text{ and}$$

$$a_t = (A_t-A_{t-1})/A_{t-1}.$$

Since the MSEL will depend on the units in which the variable is measured the MSEP is more useful in providing comparisons of forecasting accuracy for variables measured in different units.

The major usefulness of this statistic is that it can be broken down into separate components to reveal the sources of discrepancy between actual and simulated values. Two methods of decomposition can be derived. Theil (1966) suggested that the MSE should be broken down into its bias, variance and covariance components and these are derived as follows,

$$MSE = (P - A)^2 + S^2_{p-a},$$
$$= (P - A)^2 + S^2_p + S^2_a - 2rS_pS_a,$$
$$= (P - A)^2 + (S_p - S_a) - 2(1-r)S_pS_a,$$
$$1 = \frac{(P - A)^2}{MSE} + \frac{(S_p - S_a)}{MSE} - \frac{2(1-r)S_pS_a}{MSE},$$

where,

P = the mean of the simulated values,

A = the mean of the actual data,

S_p = the variance of the simulated data,

S_a = the variance of the actual data, and

r = the correlation coefficient between the simulated and actual data.

Theil defines,

$\frac{(P - A)^2}{MSE}$ as the bias component (U^b),

$\frac{(S_p - S_a)^2}{MSE}$ as the variance component (U^v),

$\frac{2(1-r)S_pS_a}{MSE}$ as the covariance component (U^c).

Note that $U^b + U^v + U^c = 1$.

The bias component shows whether the simulated values tend to be higher or lower than the actual values, while the variance component indicates to what extent the MSE is influenced by the variance of the actual and simulated values. The covariance component measures the unsystematic error (i.e., that which remains after errors in average values and average variabilities have been accounted for).

Maddala (1977) argues that there is no reason to insist that the variances of actual and simulated data should be equal and suggests that a decomposition into bias, regression and disturbance terms is more illuminating. These are derived as follows,

$$\begin{aligned} MSE &= (P - A)^2 + S^2_{p-a}, \\ &= (P - A)^2 + S^2_p + S^2_a - 2rS_pS_a, \\ &= (P - A)^2 + (S_p - rS_a)^2 + (1-r^2)S^2_a, \\ 1 &= \frac{(P - A)^2}{MSE} + \frac{(S_p - rS_a)^2}{MSE} + \frac{(1-r^2)S^2_a}{MSE}, \end{aligned}$$

Maddala defines

$\frac{(P - A)^2}{MSE}$ as the bias component (U^b),

$\frac{(S_p - rS_a)^2}{MSE}$ as the regression component (U^r),

$\frac{(1-r^2)S^2_a}{MSE}$ as the disturbance component (U^d).

Note again that $U^b + U^r + U^d = 1$.

Maddala describes the benefits of this approach using the regression of actual on simulated values as follows,

$$A_t = a + b * P_t$$

A perfect forecast yields $a = 0$ ($U^b = 0$) and $b = 1$ ($U^r = 0$). Figure 7.1 below shows a regression line between actual and simulated values in which the 45° line represents a perfect forecast ($P_t = A_t$). The error in the intercept ($a = 0$) is accounted for by U^b while the error in the slope is accounted for by U^r. The U^d represents unsystematic errors, derived from random disturbances that are contained within the actual data series. Since they are random and cannot be explained by the model, the forecast cannot be expected to capture these disturbances. Given that a perfect forecast yields $U^b = 0$ and $U^r = 0$ the validation statistics improve as, $U^b \to 0$, $U^v \to 0$, $U^c \to 1$, $U^r \to 0$, and $U^d \to 1$.

The MSE and its decompositions are presented in Tables 7.2a and 7.2b. Overall the model performs well in terms of this criterion. Most of the U^b and U^r values are close to zero, indicating that the simulated values do not tend to be higher or lower than their actual values. The U^d for most of the variables are close to one. This indicates that most of the errors in the simulated values are associated with randomness in the actual data series. Using the Theil decomposition of MSE into bias, variance and covariance, the model results further suggest that the errors in predicted values can be associated with unsystematic errors. The RMSPEs showed poor performance for some model variables--especially cotton stocks and net exports of China, per capita total fiber use in Central Africa, and the non-cellulosic share in Pakistan. Using the MSE criterion it appears that net trade of China and fiber use in Central Africa validate better. However, the Chinese stocks variable does not perform well, with a U^b as high as 27.7%.

Figure 7.1: The Regression of Actual Against Simulated Values

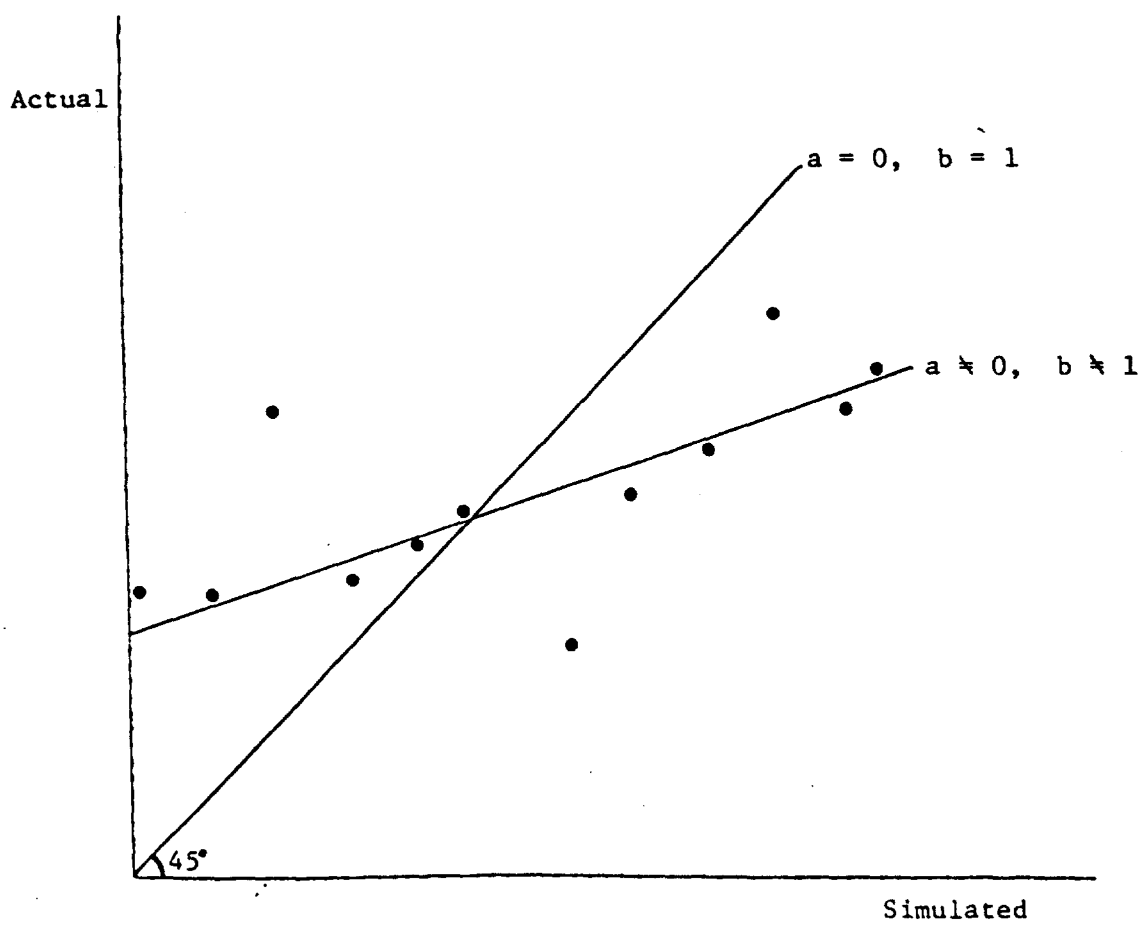


Table 7.2a: Mean-Square Error and its Decompositions - Cotton Variables

	MSE	U^b	U^r	U^d	U^v	U^c
CTYDARG	0.001	0.013	0.055	0.932	0.011	0.976
CTYDAUS	0.011	0.016	0.033	0.952	0.028	0.956
CTYDBRA	0.000	0.001	0.002	0.996	0.036	0.993
CTYDCAF	0.003	0.155	0.002	0.843	0.025	0.820
CTYDEGY	0.016	0.008	0.022	0.971	0.110	0.883
CTYDINDN	0.001	0.037	0.035	0.929	0.138	0.625
CTYDINDS	0.001	0.007	0.021	0.972	0.069	0.923
CTYDINDW	0.000	0.001	0.034	0.965	0.000	0.999
CTYDMEX	0.002	0.043	0.041	0.916	0.177	0.780
CTYDPAKP	0.001	0.005	0.116	0.879	0.004	0.990
CTYDPAKS	0.000	0.104	0.008	0.888	0.000	0.396
CTYDPRC	0.251	0.065	0.080	0.855	0.159	0.775
CTYDTUR	0.002	0.368	0.089	0.542	0.017	0.615
CTYDUS1	0.003	0.003	0.008	0.989	0.140	0.858
CTYDUS2	0.006	0.010	0.009	0.980	0.062	0.928
CTYDUS3	0.005	0.008	0.022	0.971	0.110	0.883
CTYDUS4	0.004	0.100	0.000	0.899	0.055	0.845
CTHAARG	3286.07	0.003	0.000	0.997	0.102	0.895
CTHAAUS	273.69	0.003	0.245	0.752	0.417	0.580
CTHABRA	15898.26	0.009	0.069	0.922	0.252	0.739
CTHACAF	5345.75	0.001	0.071	0.928	0.126	0.874
CTHAEGY	1094.30	0.000	0.016	0.984	0.085	0.915
CTHAINDN	5081.37	0.095	0.169	0.736	0.265	0.340
CTHAINDS	4306.78	0.000	0.000	1.000	0.030	0.969
CTHAINDW	4186.21	0.000	0.002	0.998	0.013	0.986
CTHAMEX	2344.42	0.012	0.012	0.976	0.070	0.918
CTHAPAKP	6013.91	0.040	0.199	0.761	0.111	0.450
CTHAPAKS	3474.91	0.071	0.013	0.516	0.000	0.428
CTHAPRC	45086.92	0.073	0.037	0.889	0.072	0.354
CTHATUR	2365.32	0.012	0.024	0.954	0.270	0.718
CTHAUS1	18037.55	0.044	0.006	0.949	0.103	0.852
CTHAUS2	5002.56	0.077	0.051	0.872	0.000	0.923
CTHAUS3	68040.40	0.036	0.118	0.846	0.341	0.623
CTHAUS4	8397.25	0.041	0.635	0.324	0.766	0.192
CTPDARG	452.45	0.000	0.001	0.999	0.065	0.935
CTPDAUS	435.45	0.009	0.272	0.720	0.430	0.561
CTPDBRA	3153.54	0.000	0.037	0.963	0.002	0.998
CTPDCAF	2144.80	0.156	0.000	0.844	0.048	0.795
CTPDEGY	5445.03	0.573	0.087	0.339	0.005	0.421
CTPDINDN	622.61	0.154	0.006	0.839	0.014	0.832
CTPDINDS	713.43	0.017	0.074	0.909	0.017	0.966
CTPDINDW	697.56	0.002	0.025	0.973	0.001	0.997
CTPDIND	2672.32	0.055	0.006	0.939	0.003	0.942

Table 7.2a continued

	MSE	U^b	U^r	U^d	U^v	U^c
CTPDMEX	1808.70	0.058	0.002	0.939	0.029	0.913
CTPDPAKP	2529.99	0.037	0.251	0.712	0.112	0.851
CTPDPAKS	1375.58	0.026	0.025	0.948	0.000	0.973
CTPDPAK	3026.27	0.128	0.153	0.719	0.064	0.808
CTPDPRC	31460.44	0.054	0.244	0.702	0.307	0.637
CTPDTUR	1454.47	0.011	0.077	0.911	0.002	0.987
CTPDUS1	2788.31	0.139	0.002	0.859	0.033	0.828
CTPDUS2	1813.70	0.158	0.197	0.645	0.056	0.787
CTPDUS3	11783.11	0.039	0.070	0.891	0.218	0.743
CTPDUS4	11661.31	0.010	0.442	0.548	0.624	0.366
CTPDUSA	47389.96	0.000	0.104	0.896	0.283	0.716
CTPDWOR	79929.04	0.036	0.294	0.671	0.354	0.610
CTSHARG	0.000	0.210	0.073	0.716	0.146	0.644
CTSHAUS	0.000	0.004	0.002	0.994	0.031	0.965
CTSHBRA	0.000	0.003	0.013	0.984	0.082	0.915
CTSHCAF	0.000	0.030	0.129	0.841	0.311	0.659
CTSHEEC	0.000	0.003	0.002	0.995	0.084	0.913
CTSHEGY	0.002	0.556	0.054	0.389	0.154	0.289
CTSHIND	0.000	0.002	0.050	0.948	0.165	0.833
CTSHJPN	0.000	0.032	0.004	0.964	0.151	0.818
CTSHKOR	0.001	0.005	0.003	0.993	0.011	0.984
CTSHMEX	0.000	0.097	0.026	0.877	0.043	0.860
CTSHPAK	0.001	0.007	0.019	0.974	0.080	0.913
CTSHPRC	0.000	0.001	0.000	0.999	0.017	0.982
CTSHTUR	0.001	0.061	0.022	0.917	0.140	0.799
CTSHUSA	0.000	0.000	0.018	0.981	0.074	0.926
PCTFUARG	0.105	0.001	0.015	0.984	0.119	0.880
PCTFUAUS	0.686	0.008	0.030	0.962	0.132	0.860
PCTFUBRA	0.104	0.536	0.227	0.238	0.284	0.181
PCTFUCAF	0.002	0.005	0.021	0.974	0.044	0.951
PCTFUEEC	0.146	0.022	0.011	0.967	0.001	0.976
PCTFUEGY	0.079	0.004	0.002	0.994	0.011	0.985
PCTFUIND	0.002	0.005	0.021	0.974	0.044	0.951
PCTFUJPN	0.005	0.005	0.015	0.980	0.014	0.982
PCTFUKOR	0.349	0.005	0.010	0.986	0.039	0.956
PCTFUMEX	0.173	0.022	0.409	0.569	0.631	0.348
PCTFUPAK	0.169	0.000	0.051	0.949	0.283	0.717
PCTFUPRC	0.039	0.004	0.004	0.991	0.004	0.992
PCTFUTUR	0.069	0.031	0.000	0.969	0.033	0.936
PCTFUUSA	0.309	0.002	0.010	0.987	0.080	0.918

Table 7.2a continued

	MSE	U^b	U^r	U^d	U^v	U^c
CTUARG	21.18	0.090	0.013	0.897	0.105	0.805
CTUAUS	32.71	0.006	0.080	0.914	0.000	0.994
CTUBRA	535.81	0.551	0.104	0.344	0.147	0.301
CTUCAF	344.20	0.118	0.060	0.822	0.001	0.882
CTUEEC	3152.24	0.003	0.019	0.978	0.003	0.994
CTUEGY	198.96	0.329	0.018	0.653	0.057	0.614
CTUIND	1101.70	0.008	0.008	0.984	0.022	0.970
CTUJPN	3055.42	0.023	0.000	0.977	0.053	0.924
CTUKOR	128.97	0.006	0.014	0.979	0.073	0.920
CTUMEX	110.81	0.018	0.206	0.776	0.006	0.975
CTUPAK	691.70	0.001	0.033	0.966	0.119	0.880
CTUPRC	18677.97	0.004	0.008	0.988	0.001	0.995
CTUTUR	188.37	0.016	0.131	0.853	0.008	0.976
CTUUSA	10276.55	0.001	0.000	0.999	0.052	0.948
CTAWOR	149.89	0.001	0.000	0.999	0.011	0.988
CTESWOR	271926.12	0.231	0.000	0.768	0.047	0.722
CTESPRC	160018.25	0.277	0.012	0.711	0.074	0.649
CTNEPRC	23664.84	0.004	0.059	0.937	0.295	0.701
CTPWOR	149.89	0.001	0.000	0.999	0.011	0.988

Table 7.2b: Mean Squared Error and its Decompositions - Non-Cellulosics Fiber Variables

	MSE	U^b	U^r	U^d	U^v	U^c
NCPDWOR	188388.0	0.083	0.123	0.794	0.082	0.835
NCUWOR	130798.0	0.004	0.086	0.910	0.124	0.872
PSPRWOR	396.9	0.119	0.014	0.867	0.029	0.853
NCSHARG	0.0006	0.027	0.000	0.973	0.026	0.947
NCSHAUS	0.0007	0.255	0.082	0.662	0.141	0.603
NCSHBRA	0.0010	0.007	0.002	0.992	0.059	0.935
NCSHCAF	0.0004	0.001	0.148	0.850	0.325	0.673
NCSHEEC	0.0010	0.007	0.013	0.979	0.132	0.861
NCSHEGY	0.0012	0.008	0.002	0.980	0.105	0.893
NCSHIND	0.0000	0.040	0.113	0.848	0.174	0.786
NCSHJPN	0.0003	0.013	0.000	0.987	0.021	0.967
NCSHKOR	0.0042	0.004	0.042	0.954	0.004	0.991
NCSHMEX	0.0008	0.044	0.122	0.833	0.174	0.781
NCSHPAK	0.0003	0.012	0.044	0.944	0.134	0.854
NCSHPRC	0.0004	0.000	0.048	0.952	0.005	0.995
NCSHTUR	0.0005	0.000	0.018	0.982	0.000	1.000
NCSHUSA	0.0010	0.028	0.256	0.716	0.361	0.611
NCUARG	27.76	0.018	0.007	0.975	0.008	0.974
NCUAUS	91.86	0.078	0.095	0.828	0.169	0.753
NCUBRA	387.79	0.171	0.079	0.750	0.160	0.668
NCUCAF	79.01	0.004	0.042	0.954	0.186	0.810
NCUEEC	19270.37	0.001	0.097	0.902	0.208	0.791
NCUEGY	90.91	0.005	0.041	0.954	0.183	0.813
NCUIND	98.85	0.056	0.162	0.781	0.224	0.720
NCUJPN	3400.47	0.000	0.089	0.911	0.179	0.821
NCUKOR	288.55	0.008	0.015	0.976	0.047	0.945
NCUMEX	214.23	0.003	0.234	0.763	0.301	0.696
NCUPAK	22.06	0.115	0.009	0.876	0.004	0.881
NCUPRC	6629.44	0.010	0.049	0.941	0.008	0.982
NCUTUR	51.86	0.003	0.022	0.975	0.003	0.994
NCUUSA	27161.71	0.011	0.210	0.779	0.303	0.686
NCUROW	64444.10	0.009	0.243	0.747	0.148	0.843

7.3 Validation Using Theil's U-Statistic

A useful statistic related to both the RMSPE and the MSE is Theil's inequality coefficient. Theil's inequality statistic has been defined as,

$$U_1 = \frac{\left(1/n\Sigma_t \ (P_t - A_t)^2\right)^{\frac{1}{2}}}{\left(1/n\Sigma_t \ (P_t)^2\right)^{\frac{1}{2}} \quad \left(1/n\Sigma_t \ (A_t)^2\right)^{\frac{1}{2}}}$$

This statistic is scaled so that U_1 will lie between 0 and 1 ($U_1 = 0$ represents a perfect fit while $U_1 = 1$ indicates a predictive performance as bad as it can possibly be). A major shortcoming is described by Leuthold (1975) since:

> "for both actual data and changes the error depends on the predictions themselves, that is, the purpose is to assess P_t but the assessment is made relative to P_t itself since P_t is in the denominator."

For this reason, a second Theil statistic is used given by,

$$U_2 = \left(MSE \ / \ 1/n \ \ \Sigma_t \ (A_t - A_{t-1})^2 \right)^{\frac{1}{2}}$$

U_2 takes on a value of 0 for a perfect forecast (as in the case of U_1) but has no upper limit. It can be shown also that $U_2 = 1$ indicates a prediction performance the same as a naive, no-change extrapolation.

The U_2 statistics for the endogenous variables of the model are presented in Tables 7.3a and 7.3b. All variables have a U_2 very close to zero, indicating that the model performs well. The variables that perform least well are stocks and trade in China and the non-cellulosic fibers share in Pakistan. This result is consistent with the findings suggested by the other validation statistics discussed earlier.

Table 7.3a: Theil U-Statistics (U_2) - Cotton Variables

Variable	U2	Variable	U2	Variable	U2
CTYDARG	0.0525	CTYDAUS	0.0517	CTYDBRA	0.0369
CTYDCAF	0.0380	CTYDEGY	0.0829	CTYDINDN	0.0316
CTYDINDS	0.0424	CTYDINDW	0.0201	CTYDMEX	0.0248
CTYDPAKP	0.0579	CTYDPAKS	0.0402	CTYDPRC	0.0502
CTYDTUR	0.0332	CTYDUS1	0.0446	CTYDUS2	0.0756
CTYDUS3	0.0300	CTYDUS4	0.0307		
CTHAARG	0.0637	CTHAAUS	0.1196	CTHABRA	0.0285
CTHACAF	0.0124	CTHAEGY	0.0281	CTHAINDN	0.0428
CTHAINDS	0.0202	CTHAINDW	0.0061	CTHAMEX	0.0531
CTHAPAKP	0.0277	CTHAPAKS	0.0525	CTHAPRC	0.0210
CTHATUR	0.0360	CTHAUS1	0.0524	CTHAUS2	0.0796
CTHAUS3	0.0585	CTHAUS4	0.0699		
CTPDARG	0.0755	CTPDAUS	0.1283	CTPDBRA	0.0462
CTPDCAF	0.0369	CTPDEGY	0.0849	CTPDINDN	0.0397
CTPDINDS	0.0503	CTPDINDW	0.0183	CTPDIND	0.0200
CTPDMEX	0.0593	CTPDPAKP	0.0575	CTPDPAKS	0.0884
CTPDPAK	0.0428	CTPDPRC	0.0309	CTPDTUR	0.0382
CTPDUS1	0.0347	CTPDUS2	0.0960	CTPDUS3	0.0632
CTPDUS4	0.0756	CTPDUSA	0.0435		
CTPDWOR	0.0104				
CTSHARG	0.0138	CTSHAUS	0.0159	CTSHBRA	0.0129
CTSHCAF	0.0068	CTSHEEC	0.0167	CTSHEGY	0.0306
CTSHIND	0.0167	CTSHJPN	0.0306	CTSHKOR	0.0334
CTSHMEX	0.0107	CTSHPAK	0.0145	CTSHPRC	0.0121
CTSHTUR	0.0248	CTSHUSA	0.0256		
PCTFUARG	0.0238	PCTFAAUS	0.0226	PCTFABRA	0.0341
PCTFUCAF	0.0330	PCTFAEEC	0.0142	PCTFAEGY	0.0266
PCTFUIND	0.0096	PCTFAJPN	0.0333	PCTFAKOR	0.0396
PCTFUMEX	0.0390	PCTFAPAK	0.0585	PCTFAPRC	0.0313
PCTFUTUR	0.0181	PCTFAUSA	0.0126		
CTUARG	0.0222	CTAAUS	0.0273	CTABRA	0.0335
CTUCAF	0.0321	CTAEEC	0.0182	CTAEGY	0.0418
CTUIND	0.0150	CTAJPN	0.0372	CTAKOR	0.0550
CTUMEX	0.0375	CTAPAK	0.0649	CTAPRC	0.0285
CTUTUR	0.0374	CTAUSA	0.0285		
CTUWOR	0.0078	CTESWOR	0.0452	CTESPRC	0.1528
CTNEPRC	0.5029				
CTPWOR	0.0448				

Table 7.3b: Theil U-Statistics (U_2) - Non-Cellulosic Fiber Variables

	U2	Variable	U2	Variable	U2
NCPDWOR	0.0281	NCUWOR	0.0226	PSPRWOR	0.0784
NCSHARG	0.0520	NCSHAUS	0.0343	NCSHBRA	0.0673
NCSHCAF	0.0742	NCSHEEC	0.0430	NCSHEGY	0.0481
NCSHIND	0.0585	NCSHJPN	0.0267	NCSHKOR	0.0674
NCSHMEX	0.0322	NCSHPAK	0.1046	NCSHPRC	0.0851
NCSHTUR	0.0477	NCSHUSA	0.0316		
NCUARG	0.0603	NCAAUS	0.0464	NCABRA	0.0740
NCUCAF	0.0889	NCAEEC	0.0431	NCAEGY	0.0402
NCUIND	0.0584	NCAJPN	0.0481	NCAKOR	0.0501
NCUMEX	0.0433	NCAPAK	0.1113	NCAPRC	0.0916
NCUTUR	0.0479	NCAUSA	0.0334	NCAROW	0.0588

7.4. Graphical Validation

A common method of validation involves examining plots of actual and simulated values against time. Graphs for world production, consumption and price for cotton and non-cellulosic fibers are presented in Figures 7.2-7.7, providing visual evidence of how well the model tracks. While providing an instantaneous perceptual measure, graphical validation may be misleading because the size of the differences between actual and predicted values depends on the scale of the graph. The smaller the scale, the better the validations appear.

Simulated and actual values for world cotton production are presented in Figure 7.2. The model tracks well, although tending to underestimate supplies in the late 1970s. However, all of the major turning points in the actual data are captured by the model, including the wide fluctuations in production which occurred in the early 1980s. The graph for cotton use is presented in Figure 7.3. Again the model tracks the actual data fairly well, especially before 1975 and after 1982. From 1976 to 1981 the model predicts consumption to be much more variable than actually occurred. During this period consumption did not seem to respond to the widely fluctuating prices and tended to trend slowly upwards. In the model, consumption is much more responsive to price fluctuations. Simulated and actual price data are plotted in Figure 7.4. Overall, the model appears to track cotton prices reasonably well, especially in the late 1960s and early 1970s. Most of the major turning points of the data are captured such as in 1976, 1980, 1983 and 1986. The underprediction of price during the late 1970s explains the underestimation of production during the same period. This underestimation should not persist if the demand side of the model is responsive to price levels.

Figure 7.2 World Cotton Production
Actual Vs Simulated Values

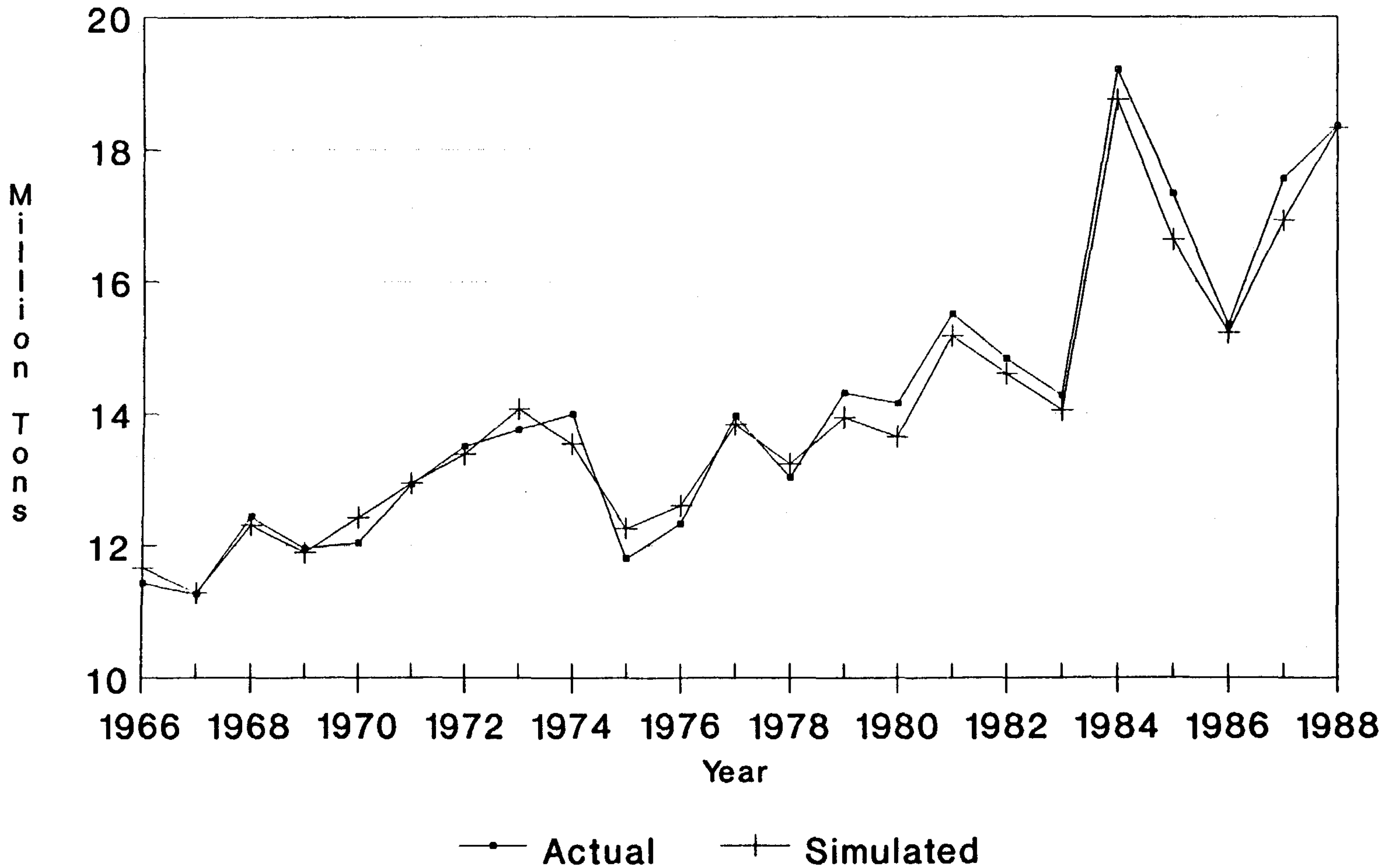


Figure 7.3 World Cotton Consumption
Actual Vs Simulated Values

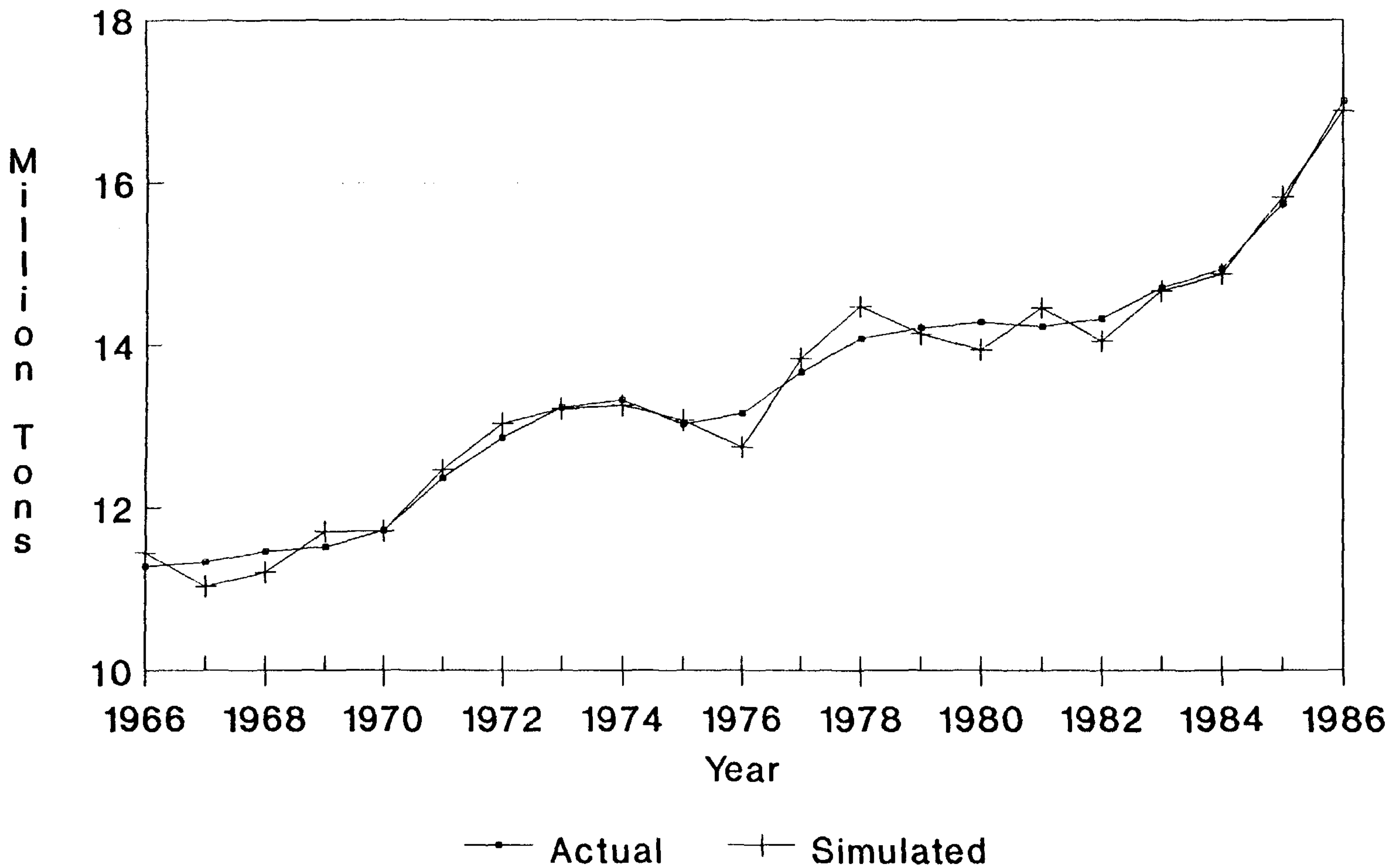
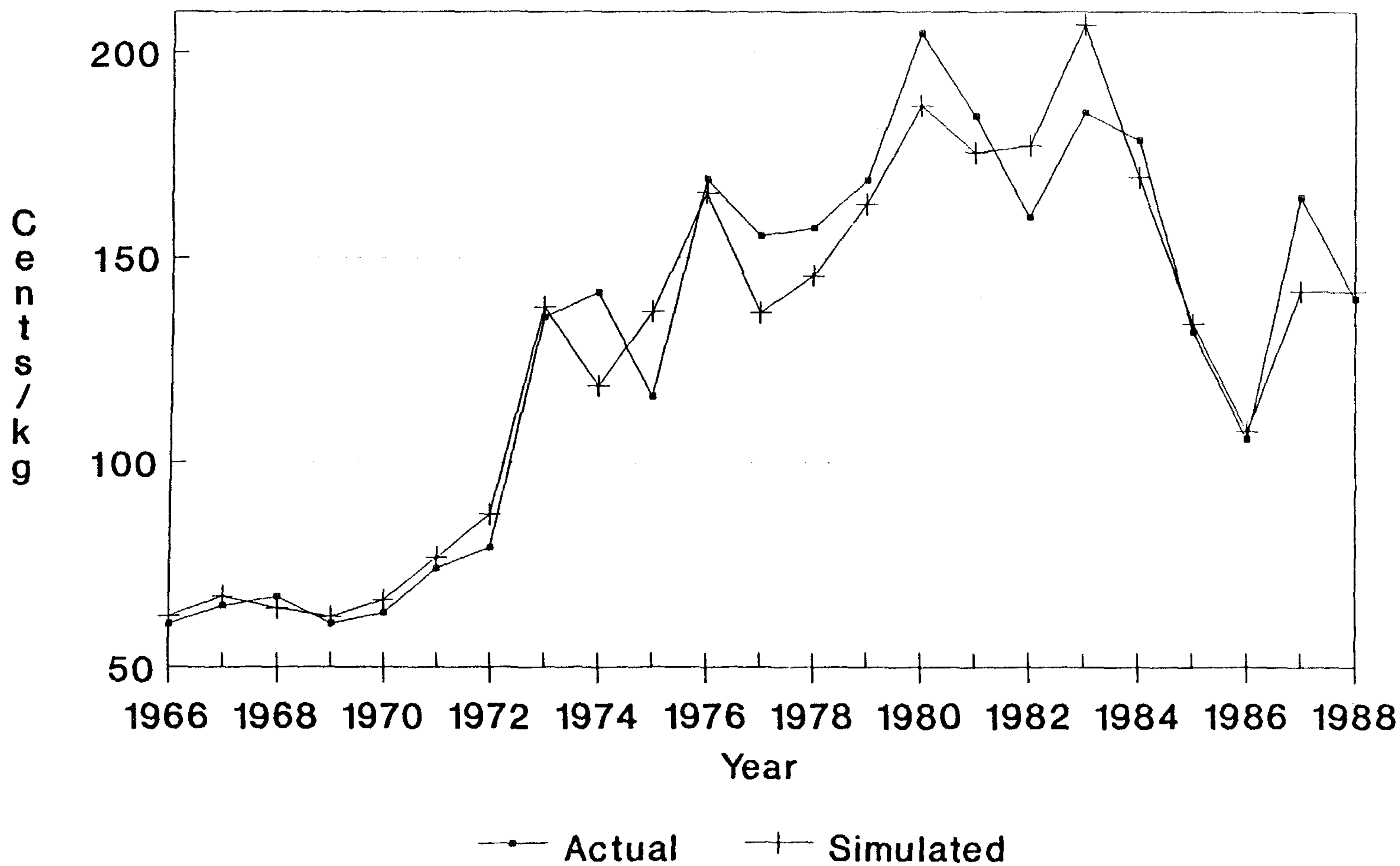


Figure 7.4 World Cotton Price 1/

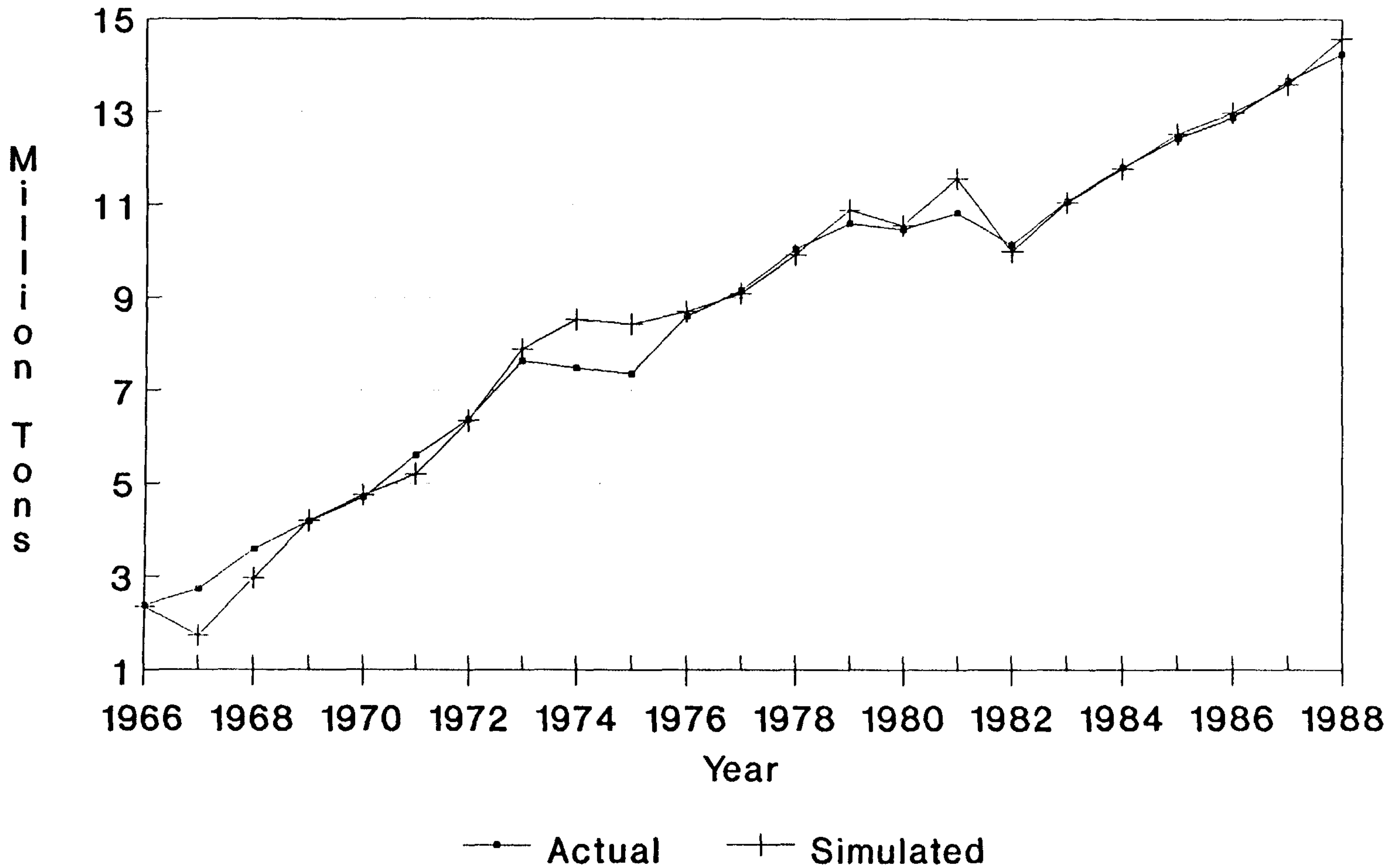
Actual Vs Simulated Values



1/ Outlook "A" Index

Figure 7.5 Non-Cellulosic Production 1/

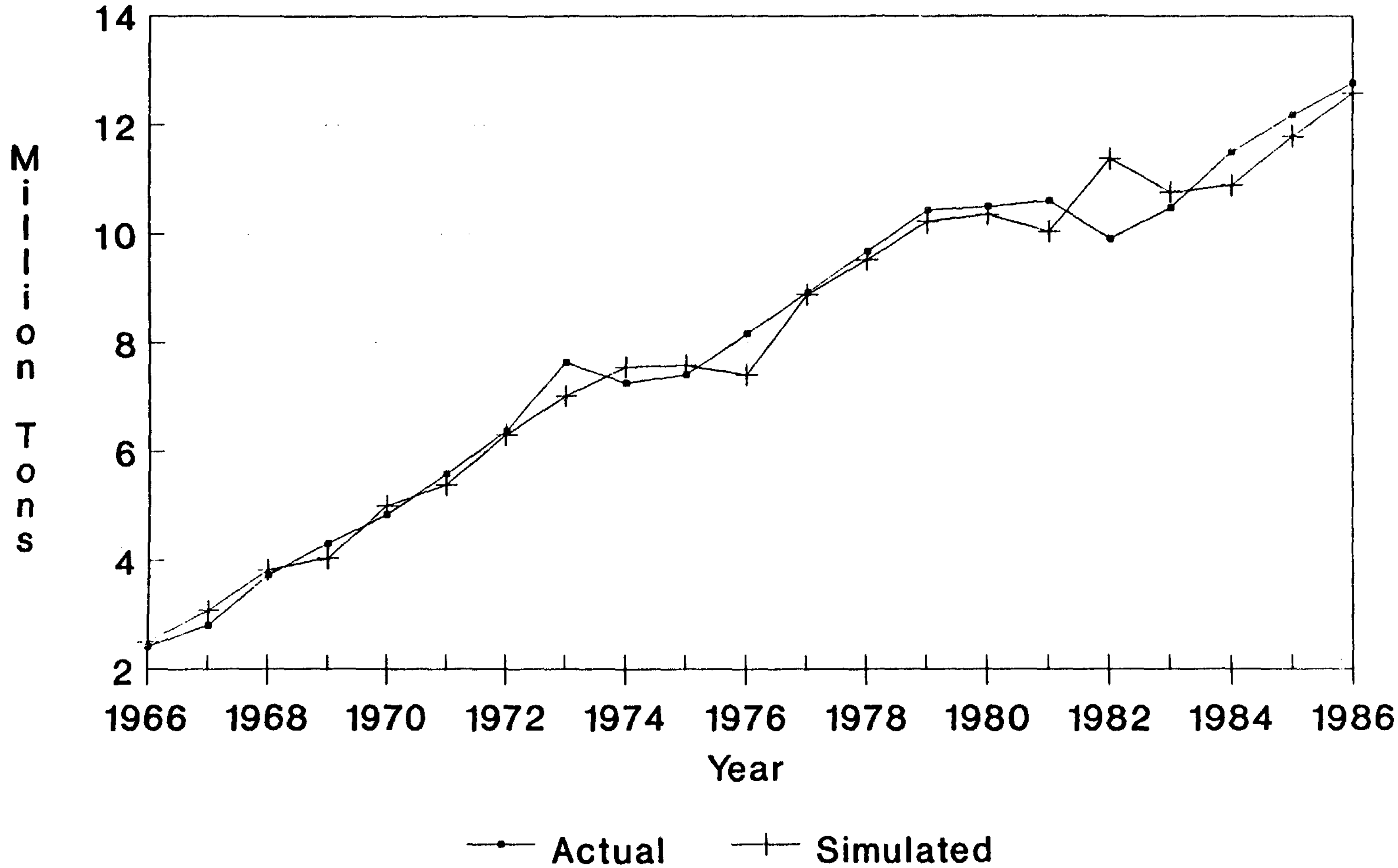
Actual Vs Simulated Values



1/ World Total

Figure 7.6 Non-Cellulosic Consumption 1/

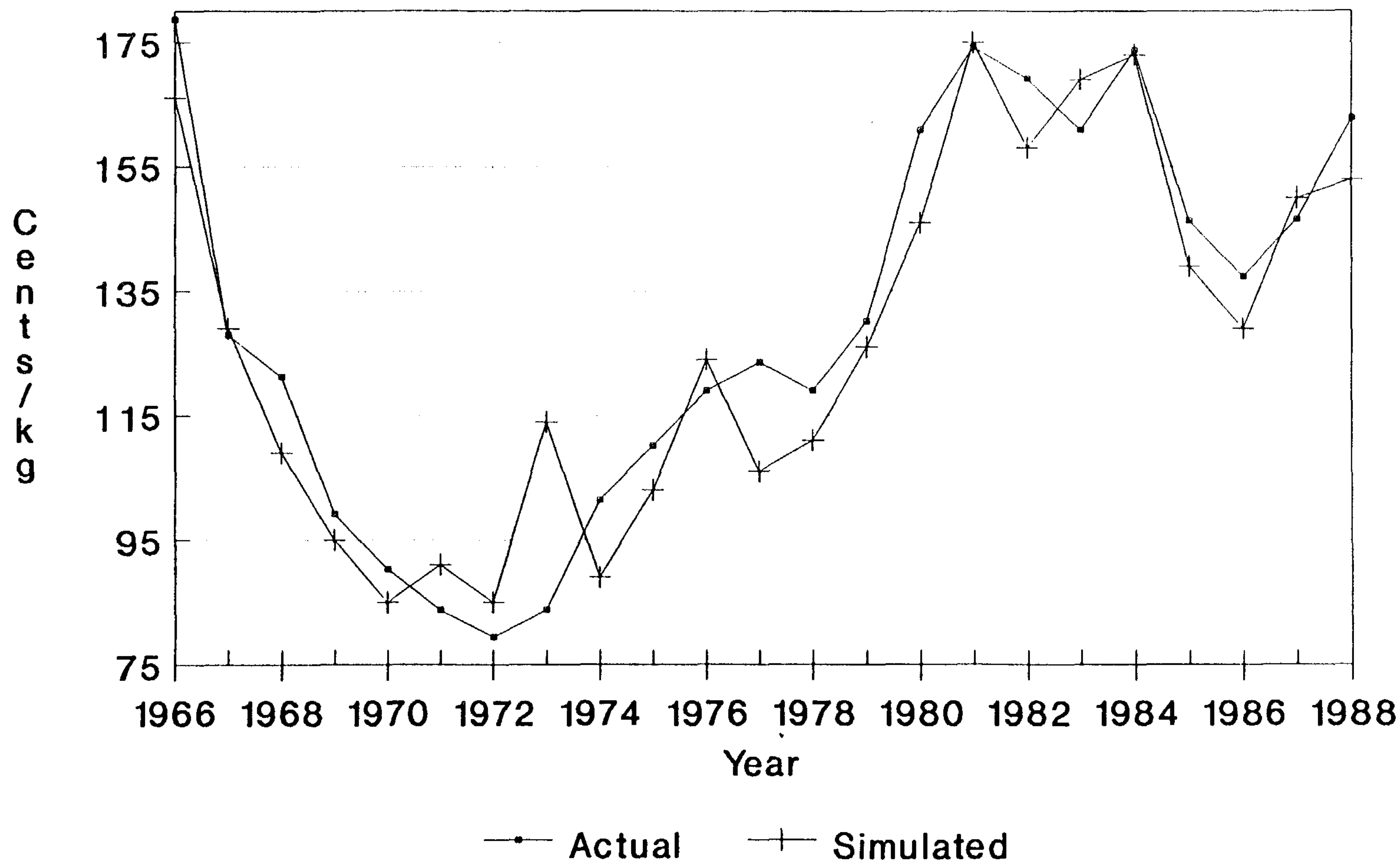
Actual Vs Simulated Values



1/ World Total

Figure 7.7 World Polyester Price

Actual Vs Simulated Values



The production and consumption of non-cellulosic fibers at the world level trend up throughout the simulation period as shown in Figures 7.5 and 7.6. This is captured well by the model except for the 1974/75 and 1981/82 periods. The polyester price shown in Figure 7.7 is tracked well by the model, with the simulated series catching the decline in the late 1960s, the increase in the 1970s, and the slight decline in the early 1980s.

7.5 Summary

The simulation results for cotton stocks and net exports in China and non-cellulosic fibers use in Pakistan are poor for all validation tests undertaken, which suggests that future modeling efforts should focus on these variables. However, in general, the model performs well and predicts actual market values reasonably accurately.

VIII. MODEL SIMULATIONS

A number of model simulations were undertaken in order to meet some of the research objectives outlined in the introductory section. In all, six simulations were performed. These were:

(i) a forecast of price, production and consumption variables for the period 1989-2005, given a basic set of macroeconomic assumptions;

(ii) a 10% decrease in cotton production in the USSR;

(iii) a 10% increase in cotton production in China;

(iv) a 10% decrease in domestic cotton prices in the United States;

(v) a 10% increase in the price of oil; and

(vi) an evaluation of the effects of the Multi-Fiber Agreement on the cotton and non-cellulosic fibers sectors.

8.1 Simulation One - Forecast for the Fiber Market to Year 2005

The model was simulated through to 2005 in order to provide forecasts of price, production and consumption in the cotton and non-cellulosic fibers sectors. This required that values for all the exogenous variables be evaluated for each year to the end of the simulation period. Annual percent growth rates in income and population for each region were used to project the levels of these variables for each year between 1990 and 2005. Exchange rates and CPIs were given their 1989 values, thus assuming that purchasing power parity was maintained over the long-run. Weather variables which appeared in the yield equations were set at their mean values and production and consumption in the Rest-of-the World region were forecasted based on a regression against time.

8.1.1 Cotton Price Forecasts

The nominal and deflated price forecasts are presented in Table 8.1 The nominal cotton price is forecast to be 189.8 c/kg in 1990 and to increase at an average of 1.8% annually over the next five years to reach 207.2 c/kg by 1995. Between 1995 and 2005 price is projected to increase at an average rate of 2.9% p.a., reaching 239.4 c/kg by the end of the century and 276.4 c/kg by the year 2005. Nominal prices were deflated by the MUV and US GDP (1985 = 100) and are also reported in Table 8.1. Based on the MUV deflator, the real price is predicted to decline throughout the forecast period, falling at an average annual rate of 1.76%, 2.25% and 2.84% for the periods 1990-95, 1995-2000 and 2000-2005, respectively.

Table 8.1: Nominal and Deflated Cotton Price Projections, 1990-2005

Year	Nominal (c/kg)	Nominal (c/lb)	MUV Deflated a/ (1985 = 100)	US GDP Deflated b/ (1985 = 100)
1990	189.8	93.7	133.0	159.5
1991	192.5	95.1	131.6	154.9
1992	195.4	96.5	128.3	151.2
1993	202.6	100.1	126.3	151.9
1994	204.4	101.0	121.7	148.1
1995	207.2	102.3	119.1	145.3
1996	211.4	104.4	117.6	143.7
1997	216.5	106.9	116.9	142.8
1998	223.5	110.4	117.3	142.5
1999	232.0	114.6	118.0	143.0
2000	239.4	118.2	117.7	142.9
2001	246.1	121.6	117.2	141.9
2002	252.8	124.9	116.6	141.0
2003	259.9	128.4	116.0	140.4
2004	267.2	132.0	116.2	139.9
2005	276.4	136.5	116.1	140.4

a/ Unit value index in US dollar terms of manufactures exported from the G-5 countries (i.e., France, Germany, Japan, United Kingdom and United States) weighted proportionally to the countries' exports to the developing countries. Source: World Bank, IECAP.

b/ Source: World Bank, IECAP.

8.1.2 Cotton Production Forecasts

The model production forecasts are presented in Table 8.2. In 1990 production is projected to reach 18.3 million tons and to increase at an annual growth rate of 1.1% p.a., reaching 21.8 million by 2005. The largest contributor to world output is China where production is projected to grow on average at 1.5% p.a.--increasing from 4.4 million tons in 1990 to 5.5 million tons in 2005. The increase is mainly associated with yield increases, since the potential for area expansion is limited, given that China's cultivated area is being fully used and that the costs of bringing new land into production are very high. Since the introduction of market incentives in China in the late 1970s, production has been determined largely by government-administered prices of cotton. In the model, China's cotton area and yields were explained by the administered price, which was exogenous. However, over the forecast period the Chinese price was linked to the world price with an assumed transmission elasticity of 0.25 (equation 5.19). As the future direction of China's producer price movements are highly uncertain, the forecasts must be treated with caution. In order to provide a sensitivity analysis of the cotton price assumption on the model forecasts, a simulation was performed with Chinese production set 10% above its historical level. The results of this simulation are presented in section 8.3.

Production in the United States is projected to increase at an average of 2.1% p.a., from 3.0 million tons in 1990 to 4.1 million tons in 2005. This expansion results in large part from increases in cotton area in the West and Southwest regions. On average, production is expected to grow at 2.3% p.a. in India. This growth is associated mainly with improved yields as irrigated acreage continues to increase in the North and West regions of India. Pakistan's output is forecast to increase from 1.4 million tons in 1990 to 1.8 million tons in 2005. This expansion is primarily the result of improved yields in both the Punjab and Sind regions.

The base forecast of future cotton production indicates a relatively stable geographical distribution of output with four of the five largest producers, which are endogenous in the model--China, the United States, India and Pakistan--accounting for 65% of world production in 2005 compared to their 58% contribution to global output in 1990. Due to the importance of the two large countries where cotton growing is strongly affected by administrative decisions--the USSR and China--simulations were run to determine the responses of other countries to 10% deviations of production in those countries from the base forecast.

8.1.3 Cotton Consumption Forecasts

A comparison of the model's consumption forecasts are reported in Table 8.3. World consumption is forecast by the model to rise from 18.0 million tons in 1990 to 21.6 million tons in 2005. This is an average annual growth rate of 1.2%.

Table 8.2: COTTON PRODUCTION FORECASTS FOR THE YEARS 1990, 1995, 2000 AND 2005

Region	1990	1995	2000	2005	Growth Rate a/
	----------('000 tons)----------				-----%-----
Argentina	168	245	304	391	5.8
Australia	232	259	277	290	1.5
Brazil	711	761	793	838	1.1
Central Africa	754	799	822	833	0.7
China	4,449	4,799	5,176	5,529	1.5
Egypt	341	335	328	322	-0.4
India	1,901	2,167	2,347	2,674	2.3
Mexico	144	148	151	154	0.4
Pakistan	1,367	1,427	1,689	1,830	2.0
Turkey	578	607	645	661	1.1
United States	2,995	3,331	3,702	4,090	2.1
Rest-of-World b/	4,702	4,639	4,392	4,214	-0.7
WORLD	18,342	19,517	20,626	21,826	1.1

a/ Average percentage growth rates per annum 1990-2005.

b/ Exogenous in the model.

Table 8.3 COTTON CONSUMPTION FORECASTS FOR THE YEARS 1990, 1995, 2000 AND 2005

Region	1990	1995	2000	2005	Growth Rate a/
	('000 tons)				%
Argentina	114	129	148	173	2.8
Australia	101	106	110	114	0.8
Brazil	543	588	640	679	1.5
Central Africa	184	187	249	393	5.2
China	4,597	4,803	5,001	5,121	0.7
EEC-12	2,405	2,553	2,697	2,876	1.2
Egypt	196	218	242	269	2.1
India	1,383	1,523	1,673	1,781	1.7
Japan	983	1,074	1,168	1,263	1.7
Korea, Republic of	176	189	207	231	1.8
Mexico	129	140	167	207	3.2
Pakistan	240	292	338	377	3.0
Turkey	222	233	260	291	1.8
United States	2,314	2,420	2,569	2,686	1.0
Rest-of-World	4,456	4,696	4,936	5,173	1.0
WORLD	18,043	19,151	20,328	21,634	1.2

a/ Average percentage growth rates per annum 1990-2005.

b/ Exogenous in the model.

The largest growth rates are forecast for some developing countries. For example, consumption in Argentina, Central Africa, Egypt, Mexico and Pakistan is expected to increase at growth rates of 2.8%, 5.2%, 2.1%, 3.2% and 3.0% p.a., respectively. These high growth rates can be largely explained by the high population growth rates assumed in these regions. With low base consumption levels in these regions, large percentage growth rates are derived for a relatively small expansion in consumption in absolute terms (e.g., Argentina and Mexico).

8.1.4 Non-Cellulosic Fibers Sector Forecasts

The model forecasts for consumption, production and price for non-cellulosic fibers are presented in Table 8.4. The nominal polyester staple price is expected to increase from 167.8 c/kg in 1990 to 357.0 c/kg in 2005. This is an annual average growth rate of 5.2%. In real terms, prices are expected to increase on average by 1.6% p.a. Such a price outlook would encourage non-cellulosic producers regarding future investments in new capacity, but they must also consider the negative impact of higher real prices on the growth of demand for non-cellulosic fibers. Non-cellulosic fibers consumption is expected to increase at 2% p.a.--from 14.9 million tons in 1990 to 19.7 million tons in 2005. The United States is the largest contributor to this expansion with an annual average growth rate of 3.7% over the forecast period. Large rates of growth are also expected in India, Egypt and Turkey, but these are all increases from small base levels.

8.2 Simulation Two - A 10% Decrease in Cotton Production in the USSR

The USSR is the world's third largest cotton producer, contributing about 15% to world production in 1988. USSR cotton production is not determined by world market prices. Instead, output is controlled administratively by government planning agencies which set area limits and determine seed and fertilizer use. Since data are not available to model the decision making of these government agencies, USSR production is exogenous in the model. However, in order to assess how USSR production affects the world market, the model was simulated over an 11-year period with production set 10% below its historical level. The percentage changes from the base simulations for some of the endogenous variables are reported in Tables 8.5 and 8.6.

The initial effect of decreased production in the USSR is to decrease world production by 2.07%. Lower production leads to the cotton price increasing by 5.07% above the base level and to consumption decreasing by 0.19%. The net effect of lower production and consumption is for world stocks to decrease 5.76% below the base simulation. In most production regions output is unchanged initially. This is because lagged prices are used as regressors in most of the supply equations. Decreases in cotton consumption lead to rises in consumption of non-cellulosic fibers and cause the price of polyester to increase 2.09% above the base level. This increase partially offsets the impact of higher cotton prices on demand and accounts for the small changes in consumption in the initial period.

Table 8.4: NON-CELLULOSIC FIBERS FORECASTS OF PRICE, CONSUMPTION AND PRODUCTION

Variable	Region	1990	1995	2000	2005	Gr. Rate a/
Polyester Price		-------------(c/kg)------------				----(%)---
Nominal	World	167.8	196.3	258.3	357.0	5.2
Deflated b/	World	117.6	112.8	127.0	149.9	1.6
Consumption		----------('000 tons)-----------				
	Argentina	70	83	93	101	2.5
	Australia	154	180	188	187	1.1
	Brazil	204	274	293	280	2.1
	Central Africa	33	32	36	46	2.2
	China	645	695	749	807	1.5
	EEC-12	2,084	2,142	2,112	2,048	-0.1
	Egypt	56	92	135	187	8.4
	India	308	452	632	853	7.0
	Japan	923	1,028	1,044	1,026	0.7
	Korea	269	286	284	282	0.3
	Mexico	243	285	309	318	1.8
	Pakistan	46	57	69	82	3.9
	Turkey	188	232	290	357	4.4
	United States	4,651	5,646	6,743	7,946	3.7
	World	13,770	15,706	17,219	18,615	2.0
Production						
	World	14,870	16,806	18,319	19,715	2.0

a/ Average annual growth rates 1990-2005
b/ Deflated by MUV (1985=100).

Table 8.5: Percentage Change in Cotton Variables for a 10% Decrease in Production in the USSR

Variable	Region	Impact	Average	Final
		--------(Percentage change)---------		
Production	USSR	-10.00	-10.00	-10.00
Price	World	5.07	9.16	12.60
Production	Argentina	0.54	10.22	12.57
	Brazil	0.34	1.12	1.42
	Central Africa	0.43	1.00	1.53
	Mexico	0.00	5.36	11.13
	Pakistan	0.15	1.42	1.53
	Turkey	0.00	0.56	0.76
	United States	0.00	2.77	3.76
	World	-2.07	-0.94	-0.69
Consumption	Argentina	-0.06	-0.63	-1.10
	Australia	-0.13	-0.34	-0.51
	Brazil	-0.70	-1.80	-2.59
	Central Africa	-0.31	-0.32	-0.39
	China	-0.23	-0.57	-1.06
	EEC	-0.25	-0.74	-1.05
	Korea, Rep. of	-0.68	-2.04	-2.85
	Mexico	-0.31	-2.61	-4.41
	Turkey	-0.60	-3.75	-5.81
	United States	-0.74	-1.13	-1.67
	World	-0.19	-0.48	-0.80
Ending Stocks	World	-5.76	-10.13	-16.15

Table 8.6: Percentage Change in Non-Cellulosic Fibers Variables for a 10% Decrease in Cotton Production in the USSR

Variable	Region	Impact	Average	Final
		--------(Percentage change)---------		
Price	World	2.09	3.72	5.39
Production	World	0.00	0.34	0.40
Consumption	Argentina	0.15	1.31	2.10
	Australia	0.28	2.21	3.77
	Brazil	2.35	6.30	9.54
	Central Africa	2.07	5.34	7.23
	China	2.81	8.63	13.40
	EEC	0.97	2.54	3.55
	Japan	0.35	2.37	3.69
	Korea, Rep. of	1.28	3.51	4.91
	Mexico	0.24	2.10	3.71
	Pakistan	0.00	0.00	0.00
	Turkey	0.20	0.49	0.83
	United States	0.88	1.23	1.55
	Rest of World	-2.67	-4.75	-7.30
	World	0.00	0.35	0.43

On average, the 10% decrease in USSR production causes the world cotton price to rise by 9.16%. Production in the price-responsive regions increases (e.g., the United States up by 2.77%, Mexico up by 5.36%, Pakistan up by 1.42%) and this partially offsets the effect of lower USSR production. The net effect is for world production to fall an average of only 0.94% below the base simulation level. The rise in price causes consumption to decrease on average 0.48%, and for stocks to fall 10.13% below the base level. The average effect on the non-cellulosic fibers market is for consumption to rise by 0.35%. This increases price by 3.72% and causes non-cellulosic fibers production to rise by 0.34%.

The long-run (or final) impact of the USSR production shock is to increase price by 12.6%. By the end of the 11-year simulation period the rise in production in the rest of the world offsets almost all of the USSR production decline, with production only 0.69% below the base simulation. Consumption continues to fall, but at a slower rate, in response to the declining rate of price increases in the later periods. The net effect of production and consumption changes is to lower ending stock levels 16.15% below their base values. The final impact on the non-cellulosic fibers sector is to increase the price of polyester by 5.39% above the base level and for production and consumption to increase by 0.40% and 0.43%, respectively.

The message from this simulation is that production in the USSR is a very important factor in price determination in the world market. For example, given a permanent 10% decrease in production, the world price rises, on average, by about 9%. This indicates that forecasts of price, both near- and long-term, must embody some prediction of USSR cotton policy and producer incentive structures and some analysis of how these might impact on its production performance.

8.3 Simulation Three - A 10% Increase in Cotton Production in China

Since the introduction of higher producer prices and other incentives in the late 1970s, China's cotton production has increased considerably--at an average rate of 9.5% p.a. between 1980 and 1987. Historically, the Chinese cotton price has had little relationship to the world market price and therefore appears as an exogenous variable in the model. For the forecast to 2005, the Chinese price and world price were linked by assuming an elasticity of 0.25, in the belief that it is unlikely that the administrators in China can altogether ignore the world market, especially over the long-run.

Given the importance of China's production, the responsiveness of farmers to the administered prices, and the unpredictability of Chinese price policy, a simulation of the model was performed for the period 1980-88 in which Chinese production was set 10% above its historical level. This simulation provides useful information on how China has affected the world market in the recent past and how developments in China might impact on the cotton and non-cellulosic fibers sectors in the future.

The results of the simulation are reported in Tables 8.7 and 8.8. The initial effect of a 10% increase in Chinese production is to increase world production 1.82% above the base level. This increase in cotton

Table 8.7: Percentage Change in Cotton Variables for a 10% Increase in China's Cotton Production

Variable	Region	Impact	Average	Final
		--------(Percentage change)---------		
Production	China	10.00	10.00	10.00
Price	World	-1.02	-10.10	-22.17
Production	Argentina	-0.11	-9.27	-13.30
	Brazil	-0.07	-1.10	-2.79
	Central Africa	-0.08	-1.63	-3.65
	Mexico	0.00	-2.23	-5.50
	Pakistan	-0.03	-1.03	-1.95
	Turkey	0.00	-0.23	-1.20
	United States	0.00	-1.97	-3.80
	World	1.82	1.84	1.53
Consumption	Argentina	0.12	0.40	1.00
	Australia	0.03	0.32	0.72
	Brazil	0.14	1.65	3.53
	Central Africa	0.01	0.18	0.42
	China	0.04	0.49	1.01
	EEC	0.05	0.68	1.43
	Korea, Rep. of	0.13	1.87	3.82
	Mexico	0.06	1.73	4.09
	Turkey	0.12	2.90	6.19
	United States	0.14	1.04	2.23
	World	0.04	0.42	0.91
Ending Stocks	World	5.47	17.94	31.23
	China	36.19	39.91	58.34
Net Trade	China	-8.71	43.87	468.91

Table 8.8: Percentage Change in Non-Cellulosic Fibers Variables for a 10% Increase in China's Cotton Production

Variable	Region	Impact	Average	Final
		---------(Percentage change)---------		
Price	World	-0.41	-3.63	-8.25
Production	World	0.00	-0.29	-0.49
Consumption	Argentina	-0.03	-0.83	-2.04
	Australia	-0.05	-1.48	-3.61
	Brazil	-0.46	-7.21	-14.87
	Central Africa	-0.40	-5.22	-10.94
	China	-0.54	-8.38	-18.60
	EEC	-0.19	-2.47	-5.33
	Japan	-0.07	-1.83	-4.31
	Korea, Rep. of	-0.25	-3.43	-7.39
	Mexico	-0.05	-1.33	-3.29
	Turkey	-0.04	-0.53	-1.16
	United States	-0.17	-1.18	-2.35
	Rest of World	0.52	4.33	10.39
	World	0.00	-0.30	-0.54

production causes the price of cotton to fall by 1.02%, which increases demand for cotton by 0.04%. The rise in cotton demand causes the demand for non-cellulosic fibers to fall and for the polyester price to decrease 0.41% below the base levels. This polyester price decrease partly offsets the impact of lower cotton prices on cotton demand.

On average, the 10% production increase in China raises world production by 1.84%. This is the net effect of higher Chinese production and lower production in the rest of the world in response to lower cotton prices. World consumption increases by 0.42% above the base level. The changes in world production and consumption cause stocks to rise 17.94% above the base level and world price to decrease by 10.10%. In the non-cellulosic fibers sector, consumption decreases 0.30% below the base simulation, causing the price of polyester to fall by 3.63%. Lower polyester prices reduce production by 0.29% and slow the rate of cotton consumption increases.

By the end of the 11-year simulation period, world cotton production is 1.53% above the base level. This expansion is the net effect of the increase in China's production and the decrease in production in the price-responsive regions. Despite lower cotton prices, consumption is only 0.91% higher. The consumption increase is dampened by higher polyester prices in the non-cellulosic fibers sector. The fall in non-cellulosic fibers demand continues to the end of the simulation period, which lowers production and price by 0.49% and 8.25%, respectively.

8.4 Simulation Four - A 10% Reduction in the United States Cotton Price

In the past, US cotton programs have had a major impact on world prices. For example, following the introduction of the Payment-in-Kind (PIK) program in 1983, the dramatic reduction in US stocks led to strong prices in 1983 and 1984 despite the large expansion of production and stocks in China. The 1985 Food Security Act was aimed at marketing the US cotton competitatively at world prices and reducing the cotton stocks held in the United States. This policy change was a major contributory factor to the 41% drop in the world cotton price between 1984 and 1986.

The major thrust of recent US cotton programs has been to reduce target prices further. Some commentators have advocated a policy of decoupling where, instead of maintaining farmer incomes through higher product prices, income transfers would be made in the form of direct payments. While the specific form of future cotton policy is unknown and while the price support system may continue it is possible that target prices in the United States will be set at lower levels in the future.

In order to test how such policy developments may impact on the world market, the model was simulated with US domestic prices set 10% below their historical values. The results are reported in Tables 8.9 and 8.10. The initial values reported are for the second year of the simulation. In the first year no changes are experienced in any variables. This is because only lagged values of producer prices enter the supply equations.

Table 8.9: Percentage Change in Cotton Variables for a 10% Decline in US Cotton Prices

Variable	Region	Impact	Average	Final
		---------(Percentage change)---------		
Price	United States	10.00	10.00	10.00
	World	1.30	3.70	5.30
Production	Argentina	0.10	4.29	4.15
	Brazil	0.08	0.45	0.73
	Central Africa	0.10	0.39	1.00
	Mexico	0.00	2.73	4.90
	Pakistan	0.03	0.48	0.64
	Turkey	0.00	0.21	0.36
	United States	-3.16	-2.93	2.42
	World	-0.58	-0.31	-0.15
Consumption	Argentina	-0.02	-0.23	-0.54
	Australia	-0.03	-0.13	-0.19
	Brazil	-0.18	-0.67	-0.96
	Central Africa	-0.01	-0.09	-0.14
	China	-0.05	-0.23	-0.26
	EEC	-0.07	-0.28	-0.39
	Korea, Rep. of	-0.16	-0.76	-1.06
	Mexico	-0.07	-0.95	-1.40
	Turkey	-0.14	-1.44	-2.00
	United States	-0.14	-0.43	-0.55
	World	-0.58	-0.19	-0.27
Ending Stocks	World	-1.63	-3.34	-4.64

Table 8.10: Percentage Change in Non-Cellulosic Fibers Variables for a 10% Decline in US Cotton Prices

Variable	Region	Impact	Average	Final
		---------(Percentage change)---------		
Price	World	0.42	1.46	2.12
Production	World	0.00	0.13	0.15
Consumption	Argentina	0.03	0.48	0.71
	Australia	0.06	0.82	1.22
	Brazil	0.77	2.81	3.85
	Central Africa	0.70	2.06	2.87
	China	1.17	3.50	4.68
	EEC	0.25	0.99	1.40
	Japan	0.10	0.90	1.37
	Korea, Rep. of	0.34	1.36	1.93
	Mexico	0.05	0.76	1.13
	Turkey	0.05	0.22	0.31
	United States	0.18	0.46	0.59
	Rest of World	-0.68	-1.82	-2.67
	World	0.00	0.13	0.16

Initially the 10% fall in the US cotton price leads to a decline in US production by 3.16% below the base simulation. Lower supplies cause world ending stocks to fall by 1.63% and for the world price to increase by 1.30%. The higher cotton price leads to a reduction of world cotton demand by 0.58% and to a small expansion of production in other regions, partially offsetting the effect of lower US supplies. The reduction in the demand for cotton creates an expansion of non-cellulosic fibers demand, which causes the price of polyester to increase 0.42% above the base simulation. Higher polyester prices dampen the impact of higher cotton prices on cotton consumption.

The average impact is for US cotton production to fall by 2.93% and world production to fall 0.31% below the base simulation. The reduction in supplies causes the world stock level to fall and prices to increase 3.7% above the base level. Higher prices reduce the demand for cotton with world consumption falling 0.19%. As expected, lower cotton consumption increases the consumption of non-cellulosic fibers, which increases on average 0.13% above the base level. Stronger demand increases the polyester price by 1.46% and production by 0.13%.

Over the long-run, the world price increases by 5.3% above the base level, with much of the fall in US production offset by an expansion in other regions. Higher prices continue to constrain world consumption, which falls only 0.27% below the base level. In the long-run the polyester price increases by 2.12%, stimulated by higher non-cellulosic fibers consumption following the decline in cotton consumption.

8.5 Simulation Five - A 10% Increase in the Price of Oil

Oil is a major input into the production of non-cellulosic fibers and therefore the price of oil is important in determining the production and price of non-cellulosic fibers. Given the close substitutability between cotton and non-cellulosic fibers, changes in oil prices affect production, consumption and price levels in the cotton market. For example, in 1974 the oil price shock increased the price of polyester by over 20% and reduced production and consumption levels substantially. While the macroeconomic consequences of the oil price shock were important, the rise in polyester price was a major contributory factor to the increase in the cotton price from 79¢/kg in 1973 to 135¢/kg in 1974 and for consumption to decline more than 7.5% over the same period. While such dramatic changes are not expected in the future, fluctuations in the oil price will continue to influence the fiber market significantly. In order to quantify these relationships the model was simulated with the price of oil set 10% above its historical level. The results of this simulation are reported in Tables 8.11 and 8.12.

In the initial period the oil price increase causes the price of polyester to increase by 2.42% and world consumption and production to fall 1.53%. In response to the higher polyester price, world demand for cotton increases 0.14% above the base level, which increases the price of cotton 0.32%. Cotton production increases a small amount in those regions where the supply equations contain a current price variable.

Table 8.11: Percentage Change in Cotton Variables for a 10% Increase in the Price of Oil

Variable	Region	Impact	Average	Final
		---------(Percentage change)---------		
Oil Price	World	10.00	10.00	10.00
Price	World	0.32	0.89	1.13
Production	Argentina	0.03	0.72	0.94
	Brazil	0.02	0.11	0.15
	Central Africa	0.03	0.17	0.21
	Mexico	0.00	0.72	1.08
	Pakistan	0.01	0.14	0.18
	Turkey	0.00	0.05	0.09
	United States	0.00	0.26	0.31
	World	0.00	0.08	0.10
Consumption	Argentina	0.07	0.27	0.34
	Australia	0.15	0.14	0.06
	Brazil	-0.04	-0.17	-0.21
	Central Africa	0.04	0.11	0.11
	China	0.26	0.21	0.08
	EEC	0.29	0.29	0.12
	Korea, Rep. of	0.77	0.80	0.33
	Mexico	0.35	1.25	1.47
	Turkey	-0.04	-0.35	-0.49
	United States	0.43	0.35	0.13
	World	0.14	0.13	0.05
Ending Stocks	World	-0.43	-1.03	-1.28

Table 8.12: Percentage Change in Non-Cellulosic Fibers Variables for a 10% Increase in the Price of Oil

Variable	Region	Impact	Average	Final
		(Percentage change)		
Price	World	2.42	2.92	1.99
Production	World	-1.53	-0.90	-0.45
Consumption	Argentina	-0.17	-0.88	-0.49
	Australia	-0.31	-1.03	-1.23
	Brazil	-2.67	-3.00	-1.15
	Central Africa	-2.33	-2.32	-0.87
	China	-3.17	-3.60	-1.39
	EEC	-1.10	-1.05	-0.42
	Japan	-0.40	-1.04	-1.01
	Korea, Rep. of	-1.45	-1.44	-0.58
	Mexico	-0.27	-0.98	-1.24
	Turkey	-0.23	-0.23	-0.10
	United States	-0.23	-0.14	-0.01
	Rest of World	-3.10	-0.90	-0.80
	World	-1.53	-0.88	-0.49

The average effect over the 11-year simulation is for the polyester price to increase 2.92% over the base level and for production and consumption to decline 0.90% and 0.88%, respectively. World cotton consumption increases by only 0.13%. This is because both polyester and cotton prices rise so that the overall substitution effects are fairly small. The cotton price increases 0.89% on average, causing a small supply response in some regions. By the end of the simulation period the polyester price is only 1.99% above the base level. This is lower than the average effect, indicating that the impact of the oil price shock becomes less important over time because throughout the simulation period the price of cotton increases. This price increase dampens cotton consumption, slowing the decline in non-cellulosic fibers consumption and reducing some of the downward pressure on price. By the end of the simulation period non-cellulosic fibers consumption is 0.49% below the base level and cotton consumption only 0.05% above.

8.6 Simulation Six - Analysis of the Multi-Fiber Agreement

While analysis of the MFA cannot be easily handled in this model (see the section endnotes), some crude estimates of the impact of the MFA on the fiber markets were obtained from a model simulation. The approach taken was to measure the percentage demand reduction in the importing countries which resulted from the MFA (using elasticities derived in other studies) and then to use the model to measure how this decline affected fiber prices, production and consumption. This procedure involved a two-step approach. First, tariff equivalents of the MFA quotas were taken from Pelzman (1988), showing the percentage change in the price of textiles resulting from the trade restrictions imposed by the agreements. Second, an elasticity of textile demand with respect to the price of textiles was used, based on the study by Houthakker (1965). Combining these elasticities gave the percentage change in textile demand resulting from the MFAs. The model was then simulated with demand set below the historical level according to these percentage declines and the results compared with the base simulation.

The tariff equivalents of the MFA quotas were estimated for the United States for the period 1979 through to 1986. This period covered most of the MFA II (January 1978 - December 1981) and the entire MFA III (January 1982 - August 1986). Pelzman provides tariff equivalent estimates for over 80 separate textile and apparel items. These were aggregated using a weighted average, with weights assigned to individual items according to their proportion of the total value of imports in each year. The aggregated tariff equivalents are reported in Table 8.13. Since no estimates were provided by Pelzman for the EEC, the reduction in fiber demand for this region was based on the percentage declines in the United States. The elasticity of textile demand with respect to the price of textiles was set at -0.282. This estimate has been used in other studies (e.g., Tarr and Morkre, 1984; Erzan, Goto and Holmes, 1989).

The impact of the MFA is to raise textile prices, ranging from increases of 12.11% in 1986 to 19.10% in 1981. This increase reduces total fiber consumption in the United States and EEC. In both regions during the 1979-81 period (MFA II), consumption on average is 4.98% lower than it would

Table 8.13: Percent Change in Cotton Variables Associated with the Multi-Fiber Agreement, 1979-86

Variable	Region	1979	1980	1981	1982	1983	1984	1985	1986
MFA Tariff a/ Equivalent (%)	United States and EEC	16.93	16.90	19.10	16.25	13.39	13.29	12.98	12.11
		(Percentage change)							
Total Fiber b/ Use	United States and EEC	-4.77	-4.77	-5.39	-4.58	-3.78	-3.75	-3.66	-3.41
Price	World	-3.38	-5.62	-5.61	-6.90	-7.47	-4.74	-3.63	-4.83
Production	World	-0.03	-0.26	-0.56	-0.65	-0.89	-0.82	-0.71	-0.57
Consumption	Australia	-0.20	0.02	0.02	0.12	0.17	0.08	0.01	0.01
	Brazil	0.47	0.92	1.11	1.31	1.50	1.09	0.83	0.93
	China	-0.33	0.03	0.04	0.19	0.27	0.15	0.02	0.02
	EEC	-5.12	-4.74	-5.34	-4.36	-3.45	-3.57	-3.63	-3.38
	Korea, Rep. of	-0.95	0.09	0.11	0.62	1.06	0.52	0.08	0.09
	Mexico	-0.46	-0.37	-0.27	0.04	0.44	0.56	0.51	0.45
	Turkey	0.26	0.94	1.54	2.33	3.26	3.64	3.25	2.86
	United States	-5.07	-4.30	-5.12	-3.94	-2.95	-3.36	-3.58	-3.34
	World	-1.23	-1.01	-1.08	-0.77	-0.58	-0.73	-0.69	-0.65

a/ Tariff equivalent of MFA is the percentage increase in the price of textiles resulting from the MFA trade restriction.

b/ Note: The decline is equal to the tariff equivalent times the elasticity of fiber demand with respect to the textile price (= -0.282).

have been without the agreement, while consumption averages 3.84% lower for the MFA III period (1982-86).

The reduction in fiber consumption in the EEC and United States leads to a small decline in world cotton consumption, ranging from 0.58% in 1983 to 1.23% in 1979. The reduction causes cotton stocks to accumulate which leads to a decline in price. Over the MFA II period the price of cotton falls an average of 4.87% as a result of the agreement, while during the MFA III period price averages 5.51% below the base level. The decline in price causes a reduction in cotton production. However, the production response is less than 1% below the base level in each year of the simulation.

In the non-cellulosic fibers sector the results are similar to those in the cotton sector (Table 8.14). The reduction in fiber consumption in the United States and EEC causes world consumption for non-cellulosic fibers to decline by up to 0.70% below the base level. The decline in consumption causes the price of polyester to fall. The price decline for the MFA II period is 5.01%, and there is a decline of 4.44% during MFA III. The lower prices result in a small reduction in production, but the decline never exceeds 1% below the base level.

With cotton and polyester prices declining by different percentages, consumption of individual fibers in each region either increases or decreases. For example, in Mexico during the MFA II period, the effect of lower cotton prices outweighs the effect of lower polyester prices, so that cotton consumption increases. Conversely, during the MFA III period, the response to relative prices is reversed, with non-cellulosic fibers consumption increasing at the expense of cotton. Overall, the consumption effects of the MFA on the countries which have not imposed restrictions are quite small, with most changes less than 1% above or below the base simulation levels.

Given the crude method used to derive these estimates, it is important to downplay the results somewhat. However, some general conclusions can be made. For example, the MFA has reduced world prices of cotton and polyester by, on average, about 5% between 1979 and 1986 (within a range of between 3% and 7%). The analysis does not cover the most restrictive period since 1986 and therefore the current impact of the agreements on world fiber prices is likely to be at the upper end of this range. While the impact of the MFA was to reduce raw fiber prices by around 5%, the impact on production and consumption was small. As a result of the agreements, cotton and non-cellulosic fibers production and consumption at the world level were changed less than 1% in most years. However, the effect on consumption in the United States and the EEC was much greater.

8.7 Summary

The simulation results discussed in this section provide many important insights into how the world fiber market operates and where it may be headed. Especially interesting are the forecasts for the period 1990 through 2005, while the simulations involving policy shocks in individual

Table 8.14: Percent Change in Non-Cellulosic Variables Associated with the Multi-Fiber Agreement, 1979-86.

Variable	Region	1979	1980	1981	1982	1983	1984	1985	1986
MFA Tariff a/ Equivalent (%)	United States and EEC	16.93	16.90	19.10	16.25	13.39	13.29	12.98	12.11
		(Percentage change)							
Total Fiber b/ Use	United States and EEC	-4.77	-4.77	-5.39	-4.58	-3.78	-3.75	-3.66	-3.41
Price	World	-5.07	-4.93	-5.04	-4.92	-4.74	-4.20	-3.93	-4.40
Production	World	0.00	-0.60	-0.63	-0.74	-0.64	-0.63	-0.56	-0.37
Consumption	Argentina	0.30	0.22	0.16	-0.01	-0.20	-0.27	-0.25	-0.24
	Australia	0.44	0.32	0.22	-0.05	-0.36	-0.47	-0.42	-0.39
	Brazil	3.41	-0.30	-0.52	-2.16	-2.84	-2.45	-0.30	-0.35
	Central Africa	2.50	-0.26	-0.47	-1.63	-2.53	-1.34	-0.22	-0.26
	China	4.34	-0.35	-0.77	-2.83	-3.18	-2.18	-0.36	-0.39
	EEC	-3.38	-4.89	-5.54	-5.41	-4.94	-4.39	-3.76	-3.53
	Japan	0.50	0.30	0.13	-0.23	-0.60	-0.65	-0.48	-0.37
	Korea, Rep. of	1.91	-0.16	-0.23	-1.16	-1.61	-0.92	-0.15	-0.16
	Mexico	0.37	0.28	0.21	-0.01	-0.28	-0.38	-0.36	-0.35
	Turkey	0.34	-0.03	-0.04	-0.18	-0.24	-0.13	-0.02	-0.03
	United States	-4.84	-5.59	-6.05	-5.53	-4.83	-4.40	-3.93	-3.64
	World	0.00	-0.57	-0.61	-0.70	-0.63	-0.61	-0.58	-0.41

a/ Tariff equivalent of MFA is the percentage increase in the price of textiles resulting from the MFA trade restriction.

b/ Note: The decline is equal to the tariff equivalent times the elasticity of fiber demand with respect to the textile price (= -0.282).

countries (i.e., USSR, China and the United States) provide information on how the forecasts must be modified in light of new developments in these markets. The MFA simulation sheds light on an important aspect of the agreement that has not been the subject of earlier research.

Between 1990 and 2005, the real world price of cotton is predicted to fall approximately 25%. This is a result which largely depends on the extrapolation of improvements in yields, through, for example, the development of better seed varieties, the use of lower-cost fertilizers, more effective pest and disease controls, and improved management. It may not be possible to maintain the productivity improvements of recent years, which will make it more difficult for cotton to be competitive with substitutes.

While a 25% decline has been predicted for cotton prices in real terms, the model forecasts a 10% increase in the real price of polyester over the period to 2005. This forecast is significant for the main user of cotton, that is, the textile manufacturing sector, which accounts for approximately 50% of consumption. Declining relative prices in favor of cotton should encourage the sector to invest in cotton textile manufacturing.

The shares of the major cotton producers do not change significantly over the forecast period. For example, in 1990, the three largest producers endogenous in the model--China, the United States and India--account for 53% of world production. In 2005, these three countries are expected to supply 52%, with a small reduction in the US share and a small increase in China's share. Brazil, Central Africa and India are all expected to maintain their market share throughout the next 15 years, while Pakistan is forecast to experience a small decline. To some extent the stability of market shares over the period 1990 to 2005 results from the fact that the exogenous variables used for forecasting are based on constant growth rates through to 2005.

Overall, the pattern of consumption also does not change very much over the period, with the top three consumers (China, the EEC and Japan) increasing their share of consumption from 49% in 1990 to 50% in 2005. The share of Brazil is forecast to increase substantially from 3% in 1990 to 7% in 2005, while the US share of total consumption is forecast to decline 2%--from 11% in 1990 to 9% in 2005. Again, the fact that world consumption patterns do not change significantly is partially explained by the fact that the growth rates of the exogenous variables used in the projection period are held constant.

Over the next 15 years the United States is forecast to strengthen its position in non-cellulosic fibers consumption--increasing its share of world consumption from 34% in 1990 to 43% in 2005. India is also expected to increase its share, reaching 5% of world consumption by 2005. All other regions show small declines in market share (e.g., the EEC from 15% to 11%; China from 5% to 4%; and Japan from 7% to 6%).

With the current emphasis in the USSR on environmental protection, soil and water conservation, and increased food production by improved crop rotations, cotton production in the USSR is expected to decline in the 1990s. This is in spite of innovations (e.g., the introduction of the Self-Financing Program and changes in land leasing arrangements) which are hoped will improve agricultural performance. While real cotton prices are forecast to fall between 1990 and 2005, the effect of declining production in the USSR would be to slow substantially the rate of price decline. For example, given a permanent 10% decrease in USSR production, the world price rises, on average, by about 9%. This indicates that forecasts of price, both near-and long-term, must embody some predication of USSR cotton policy and producer incentive structures and some analysis of how these might impact on its production performance.

For every 1% increase in China's production the world price of cotton falls, on average, about 1% and the price of polyester falls 0.35%. Therefore, if Chinese production increases at the unofficial forecast growth rate of 3% p.a., the cotton price can be expected to fall substantially. China is now the largest player in the world fiber market and its importance in determining world fiber prices and affecting production and consumption levels in the price-responsive regions of the world is demonstrated by the model. The results show that developments in China during the early 1990s must be monitored closely and included in fiber sector forecasting and policy analysis.

A model simulation was conducted to assess the possible impact of a decline in the US cotton producer price, which has been strongly affected by US policy. The results indicate that the effects of a decline in the US target price will not have a substantial effect on the world market. For a 10% fall in the US cotton price, US production falls on average less than 3% below the base simulation, while world prices increase an average of 3.7%. Consumption is affected by less than 1% in all regions.

Given the crude method used to derive the impact of the MFA on the world raw fiber market, it is important to downplay the results somewhat. However, some general conclusions can be made. For example, the MFA has reduced world prices of cotton and polyester by, on average, about 5% between 1979 and 1986 (within a range between 3% and 7%)--a significant impact. The analysis does not cover the most restrictive period since 1986 and therefore the current impact of the agreements on world fiber prices is likely to be at the upper end of this range. While the impact of the MFA was to reduce raw fiber prices by around 5%, the impact on production and consumption was small. As a result of the agreements, cotton and non-cellulosic fibers production and consumption were changed less than 1% in most years. This reflects the small size of the price transmission elasticity between raw fiber and textile prices and of the elasticities of raw fiber supply and demand with respect to price.

(VIII. ENDNOTES) - MODELING THE MULTI-FIBER AGREEMENT

An interesting policy experiment using the model is to evaluate the impact of the Multi-Fiber Agreement (MFA) on the world fiber market. At the outset of the study this was a main purpose of the model in addition to price forecasting. Some interesting research has already been completed on the MFA and this is comprehensively reviewed by Goto (1988). The majority of studies have focused on estimating the welfare costs of the trade distortions and seeing how these are distributed among producers and consumers of textile products and clothing in exporting and importing countries. None of the studies have attempted to estimate the impact of the MFA on cotton and polyester prices or to see how these price changes may have affected production and consumption of raw fibers. It was hoped that in this area the model would provide useful information and make a valuable contribution to the debate. For a number of reasons, modeling the impact of the MFA on the fiber market was found to be extremely difficult and eventually a rather crude method of capturing the MFA in the model was employed. The difficulties encountered were as follows.

Restrictions on trade in textiles have evolved slowly since the early 1960s within the scope of the short- and long-term arrangements followed by the four multi-fiber arrangements. With each new agreement, restrictions have become more stringent, but it has only been with MFA III (January 1982 - July 1986) and MFA IV (August 1986 - July 1991) that restrictions have been significantly prohibitive. The FAO data set used to estimate the demand side of the fiber model ends in 1986 for developing countries and 1987 for industrial countries and therefore does not cover the most restrictive time period.

Another problem is that the fiber model is based on quantities measured in tons of raw fiber equivalents. The MFA restrictions are in terms of numbers of specific manufactured textile products and clothing items, such as the number of pairs of gloves or the number of tablecloths; it is almost impossible to measure these items in terms of fiber content and weight. Therefore, the MFA cannot be quantified in a way compatible with the econometric model.

The MFA is negotiated bilaterally whereby trade flows between individual countries are specifically restricted (e.g., there are restrictions on the number of shirts imported into the United States from Hong Kong). To model the impact of such restrictions requires that bilateral trade flows be estimated for each importing and exporting country party to the MFA. Time series data are insufficient to allow such trade flows to be modeled. Further, where restrictions have become binding, countries have managed to maintain trade levels by either exporting through a third country whose exports are not restricted, or by establishing new processing plants in such countries. These 'leakages' are widespread. A final problem is that most of the textile trade has grown rapidly since the 1960s. The strong trend in these data prevented estimation of useful response parameters.

Several approaches were attempted in an effort to capture the effects of the MFA in the fiber model. Given that the MFA cannot be quantified in terms of raw fiber, dummy variables were constructed for each for the three MFA regimes operating during the estimation period (i.e., MFA I, 1974-77; MFA II, 1978-81; MFA III, 1982-86). It was hypothesized that the MFA, by restricting imports, would result in higher textile prices which would, in turn, reduce fiber use. The textile and apparel component of the CPI for the United States and the EEC (the two major importers under the MFA) were obtained and regressed on the following variables: prices of cotton and polyester, a measure of efficiency in the textile manufacturing sector, wage rates, and MFA dummy variables. While the equation fitted the data well for both regions, the MFA dummy variables were not correctly signed in either case. This is because, despite what effect the MFA has had, deflated textile prices have declined consistently throughout the estimation period. Even the regression of textile price growth rates against the MFA dummy variables revealed no statistically significant relationships. Further, the price of textiles was not significant in the total fiber use equations in both regions.

Another approach was based on the assumption that the decline in textile prices in the United States and the EEC is due to the penetration of cheap imports into these markets and that this penetration might have been slowed over time with the imposition of tighter MFA restrictions. Again, this hypothesis was not borne out by the data, with market penetration increasing at an increasing rate, despite increasingly stringent MFA controls.

Thus, no statistical evidence could be found that supports the hypothesis that the MFA has led to increases in the prices of textile and clothing products, or that the agreements have slowed the penetration of imported products into the US and EEC markets. Given these problems, the MFA was incorporated into the model using elasticity measures derived by Houthakker and Pelzman as described in section 8.6.

IX. SUMMARY, CONCLUSIONS AND AREAS OF FUTURE RESEARCH

9.1 Summary

The main purpose of this study was to specify and estimate an econometric model of the world fiber market, with emphasis on the cotton sector, and then, after testing and validation of the model, to forecast prices, production and consumption for the major world fiber market participants. In addition to forecasting, the model was used to estimate the impacts of some important market and policy developments. Model simulations were undertaken to analyze: (i) the impact of the expected expansion of China's cotton production; (ii) the impact of continued stagnation in the USSR cotton sector; (iii) the likely effect of the cotton provisions contained in the 1990 Farm Bill on the world fiber market; and (iv) the impact of the MFA on the raw fiber market. Analysis of these developments provide information for many groups and individuals with interests in the fiber market. In section II, the nature of the fiber market was described along with recent trends and market developments. This description provided the basis for the model specifications presented in later sections (e.g., world price determination, choice of model production and consumption regions, and treatment of textile demand).

In section III, the cotton demand component of the model was discussed. For each demand region in the model, two equations were estimated. The first was for per capita total fiber use, which was specified to be related to per capita income. In the second, the cotton share of total fiber use was estimated as a function of the cotton price relative to the polyester price. This specification captures the price sensitivity of manufacturers to changes in the relative prices of fibers. The econometric results were satisfactory and provided price elasticity measures ranging from -0.02 for India to -0.33 for the Republic of Korea. These conform closely to price elasticity estimates reported in previous studies. The income elasticity estimates ranged from 0.12 for Turkey to 1.08 for the EEC. These also were similar to income estimates found in other studies.

The cotton production component of the model was described in section IV. Based on previous econometric studies of annual crop production, cotton production in the model was derived from the product of area planted and average yield. Each of these components was estimated separately. Area planted equations contain as regressors the price of cotton and the price of crops in competition with cotton for farm acreage, as well as lagged area, based on the assumption that producers form price expectation adaptively. In the yield equations, weather variables were used if the data were available and were significant in most cases. The short-run supply elasticity estimates ranged from 0.07 for the north region of India to 0.87 for Argentina.

The model was closed by formulating a cotton pricing equation as an inverted world stocks demand equation. This was discussed in section V. In an earlier formulation of the model, the world price was solved using a world market clearing identity. This did not perform well in simulation and an alternative approach was adopted involving the use of a price equation. The world price of cotton was specified as a function of world stocks, net of stocks held in China. This was because, historically, a large proportion of stocks in this country were isolated from the world market. In addition to world stocks, world cotton consumption (net of Chinese consumption) was included in the equation to capture the transactions demand and gave an estimated flexibility of cotton price with respect to stock levels of -0.78.

The non-cellulosic fibers component of the model was presented in section VI. This fiber group makes up almost 80% of the manufactured fibers market. 1/ Non-cellulosic fibers share of total fiber use equations were estimated for each consumption region of the model, which were then combined with total fiber use to determine non-cellulosic fibers consumption. The supply of non-cellulosic fibers was estimated for the world. The polyester price was determined in an inverted demand equation for non-cellulosic fibers in the Rest-of-the-World region and influences the cotton market through the cotton share of total fiber use equations.

A number of validation statistics were presented in section VII that cover various aspects of the model's ability to reproduce actual data. The validation statistics reported were: (i) the Root Mean Squared Percentage Error (RMSPE), (ii) the Mean Squared Error (MSE), (iii) Theil's U-statistic, and (iv) graphical validation. In general, the model stood up to these testing procedures and predicted actual market values accurately enough to be used for policy experiments and forecasting.

The forecast and policy simulation results were reported in section VIII. Six sets of simulation results were presented. These were for (i) a forecast of price, production and consumption for the period 1990-2005; (ii) a 10% decrease in cotton production in the USSR; (iii) a 10% increase in cotton production in China, (iv) a 10% decline in domestic cotton price in the United States, (v) a 10% increase in the price of oil, and (vi) an evaluation of the impact of MFA on the cotton and non-cellulosic fibers sectors.

9.2 Conclusions

The model forecasts that between 1990 and 2005 the world price of cotton in real terms will fall approximately 25%, while a 10% price increase is forecast for polyester. These results suggest that cotton should maintain, or even expand, its share of the total fiber market in the coming decade. The forecast simulation results also show that the individual countries' shares of both production and consumption of cotton and non-cellulosic fibers change very little up to 2005. However, to some extent, this results from the fact that the exogenous variables used for forecasting are based on constant growth rates through to 2005. More realistic time paths for these exogenous variables would likely give different results.

1/ Adding a cellulosic fibers component to the model is among the areas of future research discussed later in this section.

Three model simulations involved shocking key variables in major producing regions (i.e., the USSR, China and the United States). In each case, the effect on the world market was significant. For example, given a permanent 10% decrease in production in the USSR, the world price rises by about 9%. This indicates that forecasts of price, both near- and long-term, should include information on USSR cotton policy especially as they affect producer incentives. Over an 11-year simulation of the model, for every 1% increase in China's production the world price of cotton falls, on average, about 1% and the price of polyester falls 0.35%. The impact of a simulated 10% decline in the US cotton price during the early 1990s was to reduce US production, on average, less than 3%, and to increase world prices an average of 3.7%. A simulation of the impact of an oil price change on the fiber market shows that the prices of both polyester and cotton increase, but that overall the impact on the markets is small.

The conclusion emerging from the MFA analysis is that world prices of cotton and polyester were reduced by, on average, about 5% between 1979 and 1986 (within a range between 3% and 7%)--a significant impact. The period of analysis did not cover the most restrictive period of the Agreement since 1986, and therefore, the current impact of the agreements on world fiber prices is likely to be at the upper end of this range.

9.3 Areas of Future Research

A number of areas have been identified for improving the model and for further policy simulations using the model. Some of these areas are listed briefly below.

a. While a large proportion of world production and consumption is covered by the regions already included in the model, more countries will be added in the future. In particular, some of the major African countries will be included, such as the Sudan, Nigeria and other West African countries. This will allow the effects of exogenous world market shocks on the cotton sectors in these countries to be measured.

b. While cotton and non-cellulosic fibers make up about 90% of the world fiber market, cellulosic fibers and wool are also important, especially for the major producers of these commodities (e.g., Australia and New Zealand in the production of wool). Given the analytical specification of the demand side of the model, the inclusion of these fibers would be relatively simple, requiring the estimation of share equations which could then be combined with the total fiber use equations to derive consumption.

c. Another area of future work will be to obtain and incorporate into the model more country-specific data such as local prices, regional production and weather information. As reported in section IV, the use of local price data (e.g., in China) and the breakdown of country production into specific regions (e.g., India and the United States) greatly improved the estimation results. Also, the inclusion of more weather variables in the yield equations is likely to improve the quality of these equations, as in the case of the United States and India.

d. To meet the objectives outlined in section I, trade and stock demand equations were not needed in the model. However, within the framework of the model these could be added. In fact, by using country market-clearing identities, either a stock or a net export equation could be estimated and the remaining variable derived from the identity. In practice, the estimation of these equations may prove troublesome. In an initial specification of the model, country-level stock equations were tried but performed unsatisfactorily with the price not significant in most equations. Also, trade equations are problematic because it is not possible to determine *a priori* the sign on the price variable if it is included in the specification.

e. In the current version of the model the production of non-cellulosic fibers is estimated at the world level. At a later stage world production will be disaggregated and equations estimated for each of the major producing areas. This is important as many developing countries are increasing their non-cellulosic fibers production capacity (e.g., China, India and Pakistan) and it will be important to assess the impact of this development on the world fiber market.

f. Given the unpredictability of cotton yields, production often fluctuates widely from year to year. It is possible to include a stochastic element into the yield equations and then to simulate the model. When the simulation is repeated a number of times the variances of the endogenous model variables can be estimated. This provides interesting information such as the likelihood that a certain market outcome (e.g., a given production or price level) will occur.

REFERENCES

Adams, F.G. and J.R. Behrman (1976), Econometric Models of World Agricultural Commodity Markets, Cambridge, Mass.: Ballinger Publishing Co.

Agbadi, I. (1988), An Econometric Analysis of the U.S. Cotton Man-Made Fibers and Textile Sectors, unpublished Ph.D dissertation, Texas Tech University, May.

Chow, G. (1960), "Statistical Demand Functions for Automobiles and their Use for Forecasting," in A.C. Heberger (ed.), The Demand for Durable Goods, Chicago: University of Chicago Press.

Deaton, A., and J. Muellbauer (1980), Economics of Consumer Behavior, New York: Cambridge University Press.

Donald, K.R., F. Lowenstein and M.S. Simon (1963), "The Demand for Textile Fibers in the United States," Economic Research Service, USDA, Technical Bulletin No. 1301.

Dudley, G.E. (1974), "U.S. Textile Fiber Demand: Price Elasticities in Major End-Use Markets," Economic Research Service, USDA, Technical Bulletin No. 1500.

Ecevit, L.U. (1987), "Recent Developments in the World Cotton Market and the Future Outlook," International Monetary Fund Staff Papers pp. 380-405.

Evans, S. (1977), "Competitive Relationships Between Cotton and other Crops, by Region, 1976 and 1977," Economic Research Service, USDA, Cotton and Wool Situation, February.

Food and Agricultural Organization, World Apparel Fiber Consumption Survey, Various Issues.

Ghosh, S., C.I. Gilbert, and A.J. Hughes Hallett (1987), Stabilizing Speculative Commodity Markets, Clarendon Press, Oxford.

Gilbert, C.L., and T.B. Palaskas (1989), "Modelling Expectations Formation in Primary Commodity Markets," unpublished.

Goto, J. (1988), Effects of the Multifibre Arrangement on Developing Countries. A Survey, World Bank, PPR Working Paper WPS 102.

Hamid, N., T. Pinckney, S. Gnaegy, and A. Valdes (1987), "The Wheat Economy of Pakistan: Setting and Prospects," International Food Policy Research Institute, November.

Houthakker, H.S. and L.D. Taylor (1966), Consumer Demand in the United States, 1929-1970, Analyses and Projections, Cambridge, Mass.: Harvard University Press.

Houthakker, H.S. and L.D. Taylor (1970), Consumer Demand in the United States, 1929-1970, Analyses and Projections: Second and Enlarged Edition, Cambridge, Mass.: Harvard University Press.

International Cotton Advisory Committee (1988), Cotton: Review of the World Situation, Vol. 41, No. 3, pp. 3-9.

Intriligator, M.D. (1978), Econometric Models, Techniques and Applications, New Jersey: Prentice Hall.

Keesing, D. and M. Wolf (1980), Textile Quotas Against Developing Countries, Trade Policy Research Center, London.

Leuthold, R.M. (1975), "On the Use of Theil's Inequality Coefficients," American Journal of Agricultural Economics, 54(1) pp. 84-91.

Maddala, G.S. (1977), Econometrics, New York: McGraw-Hill Inc.

Magleby, R.S., and E. Missaien (1977), "World Demand Prospects for Cotton in 1980, with Emphasis on Trade by Less Developed Countries," Economic Research Service, USDA, Foreign Agricultural Economic Report No. 1000.

Monke, E.A (1981), "International Market Demand for Cotton: A Survey of the Literature," Working Paper No. 2, The Interaction of Demand, Supply and Government Policy: A Case Study of Egyptian Cotton.

Monke, E.A., and L.D. Taylor (1983), "A Trade-Constrained Model for Cotton," unpublished.

Mues, C., and P. Simmons (1988), "The Effects of US Farm Policy on Australian Cotton Revenues." Paper presented at 32nd Annual Conference of the Australian Agricultural Economics Society, La Trobe University, Melbourne, 8-12 February.

Mundlak, Y., and D.F. Larson (1990), On the Relevance of World Agriculture Prices, World Bank Working Paper WPS 383.

Pelzman, J., (1988), "The Tariff Equivalents of the Existing Quotas under the Multi-Fiber Arrangement," (memo).

Starbird, I., and J. Hazera (1983), "Analysis of Factors Affecting Cotton Yields," Economic Research Service, USDA, Cotton Outlook and Situation.

Tarr, D., and M. Morkre (1984), Aggregate Cost to the United States of Tariffs and Quotas on Imports, Federal Trade Commission, Washington, D.C.

Theil, H. (1966), Applied Economic Forecasting, Chicago: Rand-McNally.

Theil, H. (1978), Introduction to Econometrics, Englewood Cliffs, New Jersey: Prentice Hall.

Thigpen, M.E. (1978), "International Cotton Market Prospects," World Bank Staff Commodity Paper No. 2, June.

Thigpen, M.E., and D.O. Mitchell (1988), "Modelling the World Fiber Market." Presented at the XXVth International Conference on International Commodity Market Modelling, Applied Econometric Association, World Bank, Washington, D.C., October.

APPENDIX I - VARIABLE DEFINITIONS

Endogenous

CTCONCHI = Cotton Consumption ('000 tons), China.
CTCONWOR = Cotton Consumption ('000 tons), World.
CTCONWORXCHI = World Cotton Consumption less China Consumption ('000 tons).

CTESCHI = Cotton Ending Stocks ('000 tons), China.
CTESWOR = Cotton Ending Stocks ('000 tons), World.
CTCONWORXCHI = World Ending Stocks less China Ending Stocks ('000 tons).

CTHAARG = Cotton area (number of hectares), Argentina.
CTHAAUS = Cotton area (number of hectares), Australia.
CTHABRA = Cotton area (number of hectares), Brazil.
CTHACAF = Cotton area (number of hectares), Central Africa.
CTHACHI = Cotton area (number of hectares), China.
CTHAEGY = Cotton area (number of hectares), Egypt.
CTHAINDN = Cotton area (number of hectares), North India.
CTHAINDS = Cotton area (number of hectares), South India.
CTHAINDW = Cotton area (number of hectares), West India.
CTHAMEX = Cotton area (number of hectares), Mexico.
CTHAPAKP = Cotton area (number of hectares), Punjab Pakistan.
CTHAPAKS = Cotton area (number of hectares), Sind Pakistan.
CTHATUR = Cotton area (number of hectares), Turkey.
CTHAUS1 = Cotton area (number of hectares), Delta Region, United States.
CTHAUS2 = Cotton area (number of hectares), Southeast Region United States.
CTHAUS3 = Cotton area (number of hectares), Southwest Region United States.
CTHAUS4 = Cotton area (number of hectares), West Region United States.

CTNECHI = Cotton Net Export ('000 tons), China.

CTPDWOR = Cotton production ('000 tons), World.
CTPRUS1 = Cotton Price, Delta Region, United States.
CTPRUS2 = Cotton Price, Southeast Region, United States.
CTPRUS3 = Cotton Price, Southwest Region, United States.
CTPRUS4 = Cotton Price, West Region, United States.

CTPRWOR = World Cotton Price, Outlook Index 'A' (¢/kg).

CTSHARG = Cotton share of total fiber use, Argentina.
CTSHAUS = Cotton share of total fiber use, Australia.
CTSHBRA = Cotton share of total fiber use, Brazil.
CTSHCAF = Cotton share of total fiber use, Central Africa.
CTSHCHI = Cotton share of total fiber use, China.
CTSHEEC = Cotton share of total fiber use, EEC.
CTSHEGY = Cotton share of total fiber use, Egypt.
CTSHIND = Cotton share of total fiber use, India.
CTSHJPN = Cotton share of total fiber use, Japan.

CTSHKOR = Cotton share of total fiber use, Korea.
CTSHMEX = Cotton share of total fiber use, Mexico.
CTSHPAK = Cotton share of total fiber use, Pakistan.
CTSHTUR = Cotton share of total fiber use, Turkey.
CTSHUSA = Cotton share of total fiber use, United States.

CTYDARG = Cotton yield (tons per hectare), Argentina.
CTYDAUS = Cotton yield (tons per hectare), Australia.
CTYDBRA = Cotton yield (tons per hectare), Brazil.
CTYDCAF = Cotton yield (tons per hectare), Central Africa.
CTYDCHI = Cotton yield (tons per hectare), China.
CTYDEGY = Cotton yield (tons per hectare), Egypt.
CTYDINDN = Cotton yield (tons per hectare), North India.
CTYDINDS = Cotton yield (tons per hectare), South India.
CTYDINDW = Cotton yield (tons per hectare), West India.
CTYDMEX = Cotton yield (tons per hectare), Mexico.
CTYDPAKP = Cotton yield (tons per hectare), Punjab Pakistan.
CTYDPAK = Cotton yield (tons per hectare), Sind Pakistan.
CTYDTUR = Cotton yield (tons per hectare), Turkey.
CTYDUS1 = Cotton yield (tons per hectare), Delta Region United States
CTYDUS2 = Cotton yield (tons per hectare), Southeast Region United States.
CTYDUS3 = Cotton yield (tons per hectare), Southwest Region United States.
CTYDUS4 = Cotton yield (tons per hectare), West Region United States.

DFCTPARG = Deflated cotton price, Argentina.
DFCTPAUS = Deflated cotton price, Australia.
DFCTPBRA = Deflated cotton price, Brazil.
DFCTPCAF = Deflated cotton price, Central Africa.
DFCTPEEC = Deflated cotton price, EEC.
DFCTPEGY = Deflated cotton price, Egypt.
DFCTPIND = Deflated cotton price, India.
DFCTPJPN = Deflated cotton price, Japan.
DFCTPKOR = Deflated cotton price, Korea.
DFCTPMEX = Deflated cotton price, Mexico.
DFCTPPAK = Deflated cotton price, Pakistan.
DFCTPTUR = Deflated cotton price, Turkey.
DFCTPUS1 = Deflated cotton price, Memphis, United States
DFCTPUS2 = Deflated cotton price, Montgomery, United States
DFCTPUS3 = Deflated cotton price, Dallas, United States
DFCTPUS4 = Deflated cotton price, Fresno, United States
DFCTPUSA = Deflated cotton price, United States.

DFPSPARG = Deflated polyester staple price, Argentina.
DFPSPAUS = Deflated polyester staple price, Australia.
DFPSPBRA = Deflated polyester staple price, Brazil.
DFPSPCAF = Deflated polyester staple price, Central Africa.
DFPSPCHI = Deflated polyester staple price, China.
DFPSPEEC = Deflated polyester staple price, EEC.
DFPSPEGY = Deflated polyester staple price, Egypt.
DFPSPIND = Deflated polyester staple price, India.

DFPSPJPN = Deflated polyester staple price, Japan.
DFPSPKOR = Deflated polyester staple price, Korea.
DFPSPMEX = Deflated polyester staple price, Mexico.
DFPSPPAK = Deflated polyester staple price, Pakistan.
DFPSPTUR = Deflated polyester staple price, Turkey.
DFPSPUSA = Deflated polyester staple price, United States.
DFPSPWOR = Deflated polyester staple price, World.

NCPROD = Non-Cellulosic Production ('000 tons), World.

NCSHARG = Non-Cellulosic share of total fiber use, Argentina.
NCSHAUS = Non-Cellulosic share of total fiber use, Australia.
NCSHBRA = Non-Cellulosic share of total fiber use, Brazil.
NCSHCAF = Non-Cellulosic share of total fiber use, Central Africa.
NCSHCHI = Non-Cellulosic share of total fiber use, China.
NCSHEEC = Non-Cellulosic share of total fiber use, EEC.
NCSHEGY = Non-Cellulosic share of total fiber use, Egypt.
NCSHIND = Non-Cellulosic share of total fiber use, India.
NCSHJPN = Non-Cellulosic share of total fiber use, Japan.
NCSHKOR = Non-Cellulosic share of total fiber use, Korea.
NCSHMEX = Non-Cellulosic share of total fiber use, Mexico.
NCSHPAK = Non-Cellulosic share of total fiber use, Pakistan.
NCSHTUR = Non-Cellulosic share of total fiber use, Turkey.
NCSHUSA = Non-Cellulosic share of total fiber use, United States.

PCTFUARG = Per capita total fiber use (kg), Argentina.
PCTFUAUS = Per capita total fiber use (kg), Australia.
PCTFUBRA = Per capita total fiber use (kg), Brazil.
PCTFUCAF = Per capita total fiber use (kg), Central Africa.
PCTFUCHI = Per capita total fiber use (kg), China.
PCTFUEEC = Per capita total fiber use (kg), EEC.
PCTFUEGY = Per capita total fiber use (kg), Egypt.
PCTFUIND = Per capita total fiber use (kg), India.
PCTFUJPN = Per capita total fiber use (kg), Japan.
PCTFUKOR = Per capita total fiber use (kg), Korea.
PCTFUMEX = Per capita total fiber use (kg), Mexico.
PCTFUPAK = Per capita total fiber use (kg), Pakistan.
PCTFUTUR = Per capita total fiber use (kg), Turkey.
PCTFUUSA = Per capita total fiber use (kg), United States.

PSPWOR = Price of polyester (US$/ton), World.

RCTFNPCAF = Ratio Cotton to Fertilizer Price, Central Africa.

Exogenous Variables

CTCONROW = Cotton Consumption ('000 tons), Rest of the World.
CTPDROW = Cotton Production ('000 tons), Rest of the World.

D66 = Annual dummy variable, equals 1 in 1966, 0 otherwise.
D67 = Annual dummy variable, equals 1 in 1967, 0 otherwise.
D68 = Annual dummy variable, equals 1 in 1968, 0 otherwise.
D69 = Annual dummy variable, equals 1 in 1969, 0 otherwise.
D70 = Annual dummy variable, equals 1 in 1970, 0 otherwise.
D71 = Annual dummy variable, equals 1 in 1971, 0 otherwise.
D72 = Annual dummy variable, equals 1 in 1972, 0 otherwise.
D73 = Annual dummy variable, equals 1 in 1973, 0 otherwise.
D74 = Annual dummy variable, equals 1 in 1974, 0 otherwise.
D75 = Annual dummy variable, equals 1 in 1975, 0 otherwise.
D76 = Annual dummy variable, equals 1 in 1976, 0 otherwise.
D77 = Annual dummy variable, equals 1 in 1977, 0 otherwise.
D78 = Annual dummy variable, equals 1 in 1978, 0 otherwise.
D79 = Annual dummy variable, equals 1 in 1979, 0 otherwise.
D80 = Annual dummy variable, equals 1 in 1980, 0 otherwise.
D81 = Annual dummy variable, equals 1 in 1981, 0 otherwise.
D82 = Annual dummy variable, equals 1 in 1982, 0 otherwise.
D83 = Annual dummy variable, equals 1 in 1983, 0 otherwise.
D84 = Annual dummy variable, equals 1 in 1984, 0 otherwise.
D85 = Annual dummy variable, equals 1 in 1985, 0 otherwise.
D86 = Annual dummy variable, equals 1 in 1986, 0 otherwise.
D87 = Annual dummy variable, equals 1 in 1987, 0 otherwise.

DFCGPARG = Deflated coarse grain price, Argentina.
DFCGPAUS = Deflated coarse grain price, Australia.

DFCTPCHI = Deflated cotton price, China.
DFCTPINDN = Deflated cotton price, Punjab, India.
DFCTPINDS = Deflated cotton price, Karnataka, India.
DFCTPINDW = Deflated cotton price, Maharashtra, India.

DFFNPBRA = Deflated fertilizer price, Argentina.
DFFNPCHI = Deflated fertilizer price, China.
DFFNPUSA = Deflated fertilizer price, United States.

DFOILPR = Deflated oil price, World

DFSBPUSA = Deflated soybean price, United States.
DFSGPUSA = Deflated sorghum price, United States.
DFRIPUSA = Deflated rice price, United States.

DMFAI = MFA dummy variable, equals 1 in 1974-77, 0 otherwise.
DMFAII = MFA dummy variable, equals 1 in 1978-81, 0 otherwise.
DMFAIII = MFA dummy variable, equals 1 in 1982-1985, 0 otherwise.

IRRPAK = Irrigated area ('000 hectares), Pakistan.

MUV = Manufacturing Unit Value, World Bank.

OILPR = Price of oil ($/bbl), OPEC.

PDGDPARG = Per capita deflated GDP, Argentina.
PDGDPAUS = Per capita deflated GDP, Australia.
PDGDPBRA = Per capita deflated GDP, Brazil.
PDGDPCAF = Per capita deflated GDP, Central Africa.
PDGDPCHI = Per capita deflated GDP, China.
PDGDPEEC = Per capita deflated GDP, EEC.
PDGDPEGY = Per capita deflated GDP, Egypt.
PDGDPIND = Per capita deflated GDP, India.
PDGDPJPN = Per capita deflated GDP, Japan.
PDGDPKOR = Per capita deflated GDP, Korea.
PDGDPMEX = Per capita deflated GDP, Mexico.
PDGDPTUR = Per capita deflated GDP, Turkey.
PDGDPUSA = Per capita deflated GDP, United States.

RINDN = Annual Rainfall (mm) North India.
RINDS = Annual Rainfall (mm) South India.
RIRUSA = Real interest rate (US T.Bill), United States.
RSPUS1 = Spring Rainfall Delta Region United States (inches).
RSUINDW = Summer Rainfall (mm) West India.
SKRWUS1 = Dummy Variable for Skip Row Policy (equals 1 1966-67, otherwise 0).
SMUS3 = Soil Moisture Level, Southwest Region, United States.

TFLUS1 = Fall Temperature Delta Region United States (Degrees C).
TFLUS2 = Fall Temperature Southeast Region United States (Degrees C).
TFLUS3 = Fall Temperature Southwest Region United States (Degrees C).

TSMUS1 = Summer Temperature Delta Region United States (Degrees C).
TSMUS2 = Summer Temperature Southeast Region United States (Degrees C).
TSMUS3 = Summer Temperature Southwest Region United States (Degrees C).
TSMUS4 = Summer Temperature West Region United States (Degrees C).

TIME = Time trend.

UNEMPEEC = Unemployment Rate (%), EEC.
UNEMPUSA = Unemployment Rate (%), United States.

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