ABSTRACT

NATRAJAN, VIGNESH (Inter-Fiber Competition: Econometric Modeling of U.S. Cotton and Polyester Fiber Demand. (Under the direction of Dr. Jeffrey A. Joines)

The estimation of the U.S. cotton and polyester demand is essential to effectively track both the performance of the U.S. domestic textile industry as well as the U.S. economic performance as reflected in consumer demand for these two fibers. In order to track the above mentioned parameters the two most effective benchmarks would be the U.S. fiber mill demand and U.S. total or retail fiber demand. The level of fiber demanded by U.S. mills for conversion into yarn and subsequently fabric and apparel, is reflective of the competitiveness of the U.S. spinning industry. This is true because the same fiber demand could be shifted to a low cost manufacturing base like Asia, South America or Mexico given their economies of scale and/or preferential trading agreements with the U.S. At the retail level, the total fiber demand for cotton and polyester are reflective of the U.S. consumer demand for cotton and polyester products, which in turn reflects the general U.S. economic performance. The inter-fiber competition dimension captures the demand substitution effects between cotton and polyester specifically.

A review of previously published literature revealed some interesting observations about U.S. inter-fiber competition and their demand estimation. First, most of the models developed in the recent past focused on estimating U.S. inter-fiber demand between cotton and man-made fibers or between cotton and synthetic fibers. Earlier research work had clearly established that within man-made fibers, cotton shared a substitutive relationship only with synthetic fibers and not the cellulosic fibers even though data for individual fiber demand within synthetic fibers was not available. This effectively renders the clustering of all man-made fibers under one grouping ineffective in tracking the derived individual fiber demand. Further, with regards to competition to U.S. cotton, polyester is known to be its chief competitor. However, there was not a single model found in previous literature that

captured inter-fiber competition between U.S. cotton and polyester. This could also be the reason for the lack of estimation models to explain inter-fiber substitution effects between cotton and polyester. Second, the previous models ignored the effect of cotton promotion. Though there are references to cotton promotion efforts as a driver of cotton consumption, no previous estimation model included that as an explanatory variable. Third, even though the last fiber demand model estimated cotton fiber demand from 1965 to 1997, it did not account for cotton promotion, whose effect on cotton consumption was evident since 1980. The choice of time span for this study was from 1990 to 2001, in order to account for more recent economic changes in the U.S. fiber demand situation. Finally, not a single model found in the previous literature estimated U.S. polyester demand at the mill and end use level. Even the clustered man-made fiber models were built on the hypothesis of being influenced by man-made fiber promotion apart from the obvious parameters of U.S. income and fiber prices. However, man-made fiber promotion, which was a major consumption driver for polyester during its introductory phase in the 1960's, has largely disappeared due to very low margins. Instead cotton promotion as described above has become the key factor since 1980. Since then, polyester has largely relied on cheaper prices and its technological development to produce new value added properties due to which it remains the most popular among synthetic fibers as well as cotton's chief competitor. Ordinary least squares regression, which has been the most widely used estimation method for U.S. fiber demand as seen in past research, was used to develop the demand estimation models for U.S. cotton and polyester demand in this study. The explanatory variables for the regression model were based on past research as well as newer variables introduced to reflect the changes in the U.S. cotton and polyester demand scenario during the study period of 1990 to 2001 as described above. The demand models developed based on a new hypothesis accounted for nearly 95% of the variation in U.S. annual cotton demand at both mill use and end use levels. This was a significant improvement over past models. The U.S. cotton promotion was found to be the strongest influencing factor on U.S. total cotton demand. On the other hand, U.S. cotton textile deficit was the most significant factor influencing U.S. cotton mill demand. In the case of polyester, its technological development was found to be the major factor influencing end use demand whereas at the mill level, the U.S. total fiber demand was its major driver.

INTER-FIBER COMPETITION: ECONOMETRIC MODELING OF U.S. COTTON AND POLYESTER FIBER DEMAND

By

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Dedication

This thesis is dedicated to my parents, Mr. Rajagopalan Natarajan and Mrs. Shanta Natarajan.

BIOGRAPHY

Vignesh Natrajan was born on December 3, 1976 in Coimbatore, India. At age 13 Vignesh moved to Chennai, India where his family still resides. Vignesh graduated from D.A.V. Higher Secondary School in 1994. From fall 1994 Vignesh pursued his Bachelor of Man made Textile Technology from the Textile and Engineering Institute at Shivaji University, Kolhapur, India graduating in May 1998. From June 1998 Vignesh was employed at Ashima Syntex Limited as Operations Engineer at its Texcellence Textile Manufacturing Complex in Ahmedabad, India performing rotations in Process Engineering, Product Development and Project Planning and Implementation. In fall 2000 Vignesh entered the Master of Science program after being awarded a research assistantship by the Textile Engineering, Chemistry and Sciences department of North Carolina State University at Raleigh, North Carolina, USA.

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1.

Introduction

1.1 Motivation

The world fiber market has undergone a significant change from 1990 to 2002. In this period the share of cotton on a global demand basis declined from 48.56% to 40.42%. On the other hand, the market share of polyester as a percentage of total fiber demand rose from 29.36% in 1990 to 39.31% in 2001[1]. Within the world man-made fiber industry, polyester market share rose from 49.12% in 1990 to 68.96% in 2001.

The reflection of this vast economic transformation in the global textile fiber industry has translated into equally vast changes for the U.S. textile fiber industry. On the supply side, the U.S. still retains its position as the world's second largest cotton producer. Production in 2001 increased an impressive 30.93% over the 1990 level to touch a new record high of 9744 million pounds. While this has increased U.S. raw cotton supply at a compounded annual growth rate (CAGR) of 2.97%, the U.S. mill demand for raw cotton has seen only a growth of 1.07% and therefore has been unable to match this supply increase. The slowdown in raw cotton demand in the period 1990-2001 was due to a composite effect of declining U.S. mill consumption, which recorded an average growth of –0.31% as well as fluctuating U.S. raw cotton exports. On the other hand, U.S. retail level cotton fiber consumption, also known as U.S. end-use consumption, showed a strong total increase of 57.44% in 2001 over 1990 with an annual growth of 3.86%, making the U.S. the largest retail level consumer of cotton in the world. The gap in the U.S. retail and mill cotton demand was met by extremely competitive imports, as seen by the widening textile trade deficit which grew from 1772 million pounds in 1990 to 5421 million pounds in 2001 [2]. This has been on account of cost competitive imports bolstered by the strong appreciation of the U.S. dollar in this period [3].

In comparison, the U.S. polyester fiber market witnessed a stabilized trend between production and mill use. U.S. polyester production in 2001 stood at 3803.80 million pounds with a 19.05% growth over 1990 levels. The growth in mill consumption of polyester was 19.32% higher in 2001 over 1990 levels, and thus commensurate with production increases [4]. At the mill consumption level, polyester, recorded an average year-to-year growth of 1.03% over 1990 to 2001 while cotton consumption as stated earlier declined by 0.31%. However, it was different at the end-use or retail level. U.S. polyester consumption increased by 34.89% in 2001 over 1990 levels with a CAGR of 2.53%, making it second only to cotton at the retail level. The average year-to-year growth, which is more reflective of individual years' performance, was higher at 4.34% for cotton while polyester was only 2.92% was second at the end-use or retail level.

In this analysis, end-use consumption for cotton and polyester fiber is defined as the sum of annual mill consumption plus the net textile trade deficit i.e., imports minus exports in raw fiber equivalent in these fibers. The trade deficit in cotton increased from 1772.21 million pounds to 5421.47 million pounds, which is a 205% increase while polyester, in keeping with its comparatively lower end-use consumption registered only a 187.98% increase.

Past research studies have focused on individual fiber demand estimation for mill-use and end-use consumption, with most of the emphasis being exclusively on cotton [5,6,7,8]. The high relative importance attached to cotton, due to its origin as a farm product, attracts higher research and tracking mostly in relative consideration with competing crops like corn, soybean and wheat to determine farm policy direction and individual crop initiatives. There is very little published literature on the estimation of polyester mill-use and end-use consumption. At the mill-use level, most studies have clustered polyester under a single man-made fiber classification. This clustering approach masks the underlying dynamics of individual fibers, especially since polyester is the largest competitor to cotton in all four major end-use categories of apparel, home furnishings, industrial and floor coverings [9,10]. While cotton mill use and end-use data are directly reported by the United States Department of Agriculture (USDA), polyester end-use consumption estimation has received extremely scant attention mostly due to the lack of availability of end-use data by individual man-made fiber type since both the USDA and Fiber Economics Bureau (FEB) report a single clustered man-made fiber and manufactured fiber end-use consumption figure respectively. Thus, earlier research largely ignores inter-fiber competition specifically between cotton and polyester, which contribute to more than half of the total U.S. fiber demand. In this analysis, the polyester mill consumption was derived from the FEB data, as the sum of annual domestic shipments and imports of staple, filament, and process waste. In the case of end-use consumption, the lack of polyester specific imports and exports (in raw fiber equivalent) data would be an obstacle in quantifying polyester end-use consumption for regression modeling. This obstacle was overcome by internal data provided for this study specifically by the Fiber Economics Bureau, which divided domestic man-made fiber consumption by fiber type [11]. However, FEB data was limited to the period from 1990 to 2001, which coincides with the period of study for this research. This percentage distribution was applied to the total man-made figure to provide polyester imports and exports data to arrive at the final consumption figure.

1.2 Modeling U.S. Cotton and Polyester Inter-Fiber Competition

The opposing trends in inter-fiber demand at the mill consumption and end-use consumption levels for cotton and polyester are impacted by different factors. The drivers of U.S. fiber supply, fiber demand and final market shares are unique to both cotton and polyester fibers. The U.S. cotton supply side sector, being under the purview of governmental legislation under the farm bill has been affected, by a unique set of factors [12]. The farm bills starting from the Food Security Act (FSA) of 1985 to the latest farm bill of 2002 have progressively reduced government subsidization of U.S. cotton through income and price support though still retaining reduced levels of support. This move has been aimed at increasing market orientation to prepare for meeting the obligations under the World Trade Organization (WTO) in 2005 while reducing government intervention in farm sector volumes and pricing. The reduced subsidization also reduces the financial pressure on the federal budget. Thus support and intervention on the supply side has been progressively reducing. Instead, the government continues to support demand side promotion initiatives. This participation is indirect and limited to providing the necessary legislative framework. The government established the Cotton Board, as a quasi-governmental, non-profit administrator of the Cotton Research and Promotion Act passed in 1966. Cotton promotion and research both to the U.S. mill-level and retail-level consumers has in turn been contracted out to Cotton Incorporated, another separate entity [13]. The annual U.S. cotton promotion expenditure has risen from a mere $20 million in 1972, when Cotton Incorporated began, to $63 million in 2001. The effect of cotton promotion on cotton consumption will be considered in this study. At the mill level, cotton promotion through research and marketing has tried to combat the marketing efforts of synthetic fiber producers [14]. Past studies have considered cotton mill level demand as a function of cotton to polyester price ratio, textile trade deficit, total fiber demand and structural changes in trade agreements while largely ignoring the effects of cotton promotion [6,7,8]. At the end-use consumption level, Cotton Incorporated targets the retail consumer through marketing, advertising and importer support programs. Earlier research has considered total cotton demand as a function of income and fiber pricing. This study will consider the impact of cotton promotion on end-use cotton consumption as well.

Polyester, on the other hand, being a crude-oil derivative is affected by the demand-supply and pricing of upstream polyester fiber intermediates i.e., purified terephthalic acid (PTA), mono-ethylene glycol (MEG), and to a lesser extent di-methyl terephthalate (DMT). Polyester mill level and end-use consumption have been driven primarily by its price competitiveness and constant technological innovation to deliver newer performance engineered polyester fibers. The effect of these two factors will be considered in deriving polyester fiber demand at both levels.

This study intends to initially derive the determinants of cotton and polyester fiber demand from the mill-use and end-use consumption standpoints. The second step will attempt to econometrically quantify the inter-relationships between cotton and polyester fiber demand and their determinants. This would be achieved by developing four equations for estimating U.S. cotton mill demand, U.S. total cotton demand, U.S. polyester mill demand and finally U.S. total polyester demand.

Finally, the results of the econometric regression model will be used to quantify the effect of the determinants on mill-use and end-use demand for cotton and polyester fiber respectively.

Chapter 2 will present the review of past research and literature on approaches and estimation methods for U.S. cotton and polyester fiber demand. Chapter 3 presents the supply side analysis of the U.S. cotton and polyester fiber market. Chapter 4 presents the demand analysis for cotton and polyester fibers at the mill-use and end-use consumption levels and factors that determine them. Chapter 5 will present the econometric model for cotton and polyester demand that is derived from the supply and demand analysis. Finally, chapter 6 will present the conclusions, derived from the econometric models of chapter 5, followed by the recommendations for future work.

2.

Literature Review

2.1. Inter-fiber competition

Several researchers have investigated the econometric modeling of inter-fiber competition in the past. Lewis [15] developed mill demand equations for natural fibers (cotton, apparel wool and carpet wool) and man-made fibers (Rayon-acetate staple, rayon-acetate filament, synthetic staple and synthetic filament). The equations were estimated from data over the period 1920 to 1966 and then simulated for 1967 to 1970. This study hypothesized that cotton mill demand was then influenced by fiber price and the rate of change of per capita income. Synthetic fiber demand was estimated with two additional dummy variables for capturing the effect of the depression and war years respectively. The resulting satisfactory equations were of the linear form, even though, the log linear form performed better for synthetics, which the author speculates could be due to rapid-post war growth. The conclusions of this study were that mill demand for a given fiber is inelastic to its own price. Further, the author states that for natural fibers, cotton and wool, a small shift in supply or demand in the absence of federal support schemes would result in a large price change. This price-support dependence of cotton is cited as the reason for high federal crop price support. Conversely, supply control through farm policy ensures a high level of demand inelasticity that can be changed only by a surge in mill consumption [15].

2.2 Establishment of the presence of inter-fiber substitution effects

Shui et al. [9] confirmed Lewis's observations that mill demand of fiber was inelastic to its own pricing and significantly cross elastic to manmade fiber pricing indicating substitution effects. This meant that a large change in the minimum support price for the crop would need to occur to cause a significant shift in fiber pricing. This shift would be relatively hard to come by due to U.S. farm price protection schemes in the 1960's. Lewis's regression model showed significant cross fiber price coefficients indicating that federal farm policy would impact fiber pricing that in turn would decide the extent of inter-fiber demand shifts at the mill level. Lewis' paper clearly states that his model does not include promotion and technological change effects. Lastly, Shui's model firmly establishes that synthetic fiber growth is endogenous to the economic system.

Additionally, Shui et al. [9] in their study of price and non-price effects expanded from Lewis' work by including scale effects and technological development in addition to own price (fiber under consideration) and cross pricing (competing fibers) to account for inter-fiber demand. The study was performed by clustering cotton with wool under natural fibers and polyester with rayon for prices and quantities over 1950-1987. The authors hypothesized that technological change could be captured and quantified using a time trend variable as well as by measuring the rate of shuttle less weaving capital investment. Results clearly pointed to a favorable effect of technological change on man-made fiber mill demand. Shui et al expanded on Lewis' work by performing a decomposition analysis to evaluate the extent of contribution of own price, cross price and technical change. This analysis revealed that factors other than cross-price elasticity contributed to more than 70% of the decline in natural fiber share. According to Shui et al, a decomposition of textile fiber consumption by fiber type rather than a broad clustering of natural and man-made fibers would be able to explain structural change in derived fiber demand in an improved way. However, Shui's effort was concentrated on mill use level only.

2.3 Man-made fiber "clustering" and its effects

Based on this premise of analyzing inter-fiber substitution effects by decomposing fiber consumption by fiber type Zhang et al. [10] analyzed derived fiber demand specific to competition between cotton and synthetic man-made fibers, and cotton versus cellulosic man-made fibers. Earlier studies assumed a constant mill demand relationship between cotton and synthetic fibers over time even though, synthetic fiber share of demand clearly varied over time on the influence of development in textile technology and changing end-user or consumer preferences. Using a time-varying parameter model Zhang et al. [10] observed that the estimated coefficients for cellulosic man-made fiber were statistically insignificant at the five percent level thus eliminating cellulosic fiber as a substitute for cotton in textile manufacture. On the other hand, polyester displayed significant coefficients for the study period establishing the direct substitutability of non-cellulosic fiber over cotton at the mill consumption level. The conclusive evidence from this study revealed that differing relationships of cotton with cellulosic and non-cellulosic fibers render the clustering of cellulosic and non-cellulosic as a single man-made fiber cluster ineffective in estimating inert-fiber substitution effects. A combination of this conclusion with the necessity for demand decomposition by fiber type established by Shui et al, gives rise to the need for estimating cotton versus polyester, nylon and olefins individually. Among these three main synthetic fibers, polyester competes directly with cotton in all of its end-use segments, namely, apparel, yarn and fabric and home furnishings. Further, polyester accounts for almost 40% of man-made fiber end use consumption, which is the highest among synthetic fibers (see Appendix Table 8.10). Hence it becomes essential to consider inter-fiber competition specifically between cotton and polyester. Nylon and Olefins compete for minimal share in these segments, relying more on carpets and industrial fabrics for demand [3].

2.4 Previous Estimation models and modeling approaches

Most of the previous published works in fiber demand estimation have focused on developing a system of two equations for total fiber end-use consumption followed by a second equation for derived cotton mill-demand. The only model that estimates only the cotton and polyester end use demand was Barlowe's [5] model. Barlowe's [5] model estimated both cotton and man-made fiber demand, though the period of study was from 1948 to 1964. However, there was no model found that specifically estimated polyester end use demand. The significance of Barlowe's study period is due to vast changes in the fiber demand situation in the current study period of 1990 to 2001. This is highlighted by the choice of explanatory variables in Barlowe's model presented below.

Barlowe's Cotton end use demand estimation model:

$$C_{tc,t} = 28.2717 + 0.0138\, I_{\Delta} - 33.1473\, M_{p,t}$$

(+3.45) (-10.26)

R-squared = 0.89, DW statistic = 1.63

where,

$C_{tc,t}$ denotes pounds of cotton consumed in the production of aggregate end uses, divided by the population of the U.S. on July 1, including armed forces overseas,

I_{Δ} denotes change from preceding year in real per capita DPI, and,

$M_{p,t}$ denotes the real per capita man-made fiber industry promotion expenditure.

Barlowe's man-made end use demand estimation model:

$$C_{tm\text{-}m,t} = -13.1774 + 0.2038\, P_{c,t-1} + 0.0055\, I_t + 69.5326\, M_{p,t}$$

(+5.37) (+2.22) (+ 9.08)

R-squared = 0.99, DW d-statistic = 2.06

where,

$C_{tm\text{-}m,t}$ denotes cotton equivalent of man-made fibers consumed in the production of aggregate end-uses in pounds per capita,

$P_{c,t-1}$ denotes real price per pound for middling 15/16-inch cotton for group B mill points,

I_t denotes the U.S. real disposable personal income, and

$M_{p,t}$ denotes the, real per capita man-made fiber promotion expenditure in dollars.

From the above equations, it is clear that Barlowe hypothesized cotton end-use demand to be influenced by change in income, represented by the change in per capita disposable personal income (DPI) and man-made fiber promotion expenditure. On the other hand, man-made fiber end-use demand was hypothesized to be influenced by real cotton price, real per capita DPI and man-made fiber promotion expenditure. However, during the period of Barlowe's study (1948-1964), synthetic fibers were newly introduced and aggressively promoted [14]. During the period of this study from 1990 to 2001, cotton and polyester end-use demand was still influenced by income and fiber price though promotion of man-made fibers was almost non-existent in the same period [16,17]. In turn, since the passage of the Cotton Research and Promotion Act and the subsequent cotton promotion by Cotton incorporated, cotton promotion has now become a decisive factor in boosting U.S. cotton end use demand since 1980 (see chapter 5)[18,19]. This turnaround has not been captured in any of the past literature reviewed. However, since most of the cotton mill demand models at the mill level were built with a view to capture inter-fiber substitution effects with polyester, these models could be used as yardsticks to compare the proposed cotton and polyester models for end-use and mill-use consumption in Chapter 5.

The models developed by Evans [8], Sanford [7] and Meyer [6] would also be worth considering for end use demand although they focus on total fiber demand (all fibers) rather than individual fiber demand, since the underlying variables are similar except for the fiber specific variables (in this case cotton promotion). Included in the discussion of these three models is a discussion of their respective cotton mill demand models also. However, there was no single model in previous literature to estimate polyester mill demand and hence there is no model available for discussing the same. Evans [8] analyzed the factors affecting cotton and apparel wool demand from 1955 to 1976. This study developed an equation for the estimation of cotton mill consumption and total fiber consumption separately. This study hypothesizes total fiber consumption to be influenced by the ratio of wholesale price index to the personal consumption expenditure (PCE) and a time trend variable representing non-measurable factors such as technological and cultural change. Using an

Ordinary Least Squares (OLS) regression method the following equations was developed (values in parentheses are the t-values of the variable directly above it).

Evans' U.S. per capita total fiber demand estimation equation:

$$\begin{array}{l} \text{Ln (DFP)} = 1.18 - 0.92\ \text{Ln (PTX/PCEP)} - 0.104\ \text{Ln (T)} \\ \qquad\qquad\qquad (14.6) \quad (9.1) \qquad\qquad\qquad (3.4) \end{array}$$

where,

Ln denotes natural logarithm,

DFP, denotes total fiber consumption in pounds per capita,

PTX/PCEP, ratio of the wholesale price index of textile products and apparel (1967= 100), to total per capita personal consumption expenditure, and

T denotes the time trend variable where 1955 = 1.

This equation explained 92% of the variation in per capita total fiber consumption. Even though the model had a high R-square value of 0.92, the author hypothesis that the negative coefficient of the trend variable could be indicative of substitution effects between man-made fibers and natural fibers over time. However, since the negative coefficient is based on a total fiber consumption figure, it is unclear whether this is the effect of the contribution of technological change (which is exclusive only to the man-made fibers) or changes in consumer preference. This further, strengthens the need for end-use consumption equations by individual fiber type.

Evans' U.S. per capita cotton mill demand estimation equation:

$$LQCMP = 1.55 + 0.33\ L\ DFP - 0.35\ L\ \frac{(PCT_{t-1})}{(PPOL_{t-1})}$$

(2.8) (2.3) (8.1)

$$LQCMP = 0.70 + 0.46\ L\ DFP - 0.32\ L\ (PCT_{t-1}) + 0.40\ (PPOL_{t-1})$$

(0.7) (2.3) (5.9) (5.9)

$$QCMP = 10.2 + 0.17\ DFP - 0.13\ (PCT_{t-1}) + 0.09\ (PPOL_{t-1})$$

(2.0) (2.1) (5.4) (5.9)

where,

L denotes natural logarithm,

QCMP denotes mill consumption of cotton per capita for the calendar year,

DFP denotes domestic fiber consumption in pounds per capita,

PPCT denotes the price of middling 1(1/16) inch cotton price at Group B mill points in cents per pound, and

PPOL denotes the reported average price for 1.5-denier polyester staple for cotton blending in cents per pound.

From the above equations, it is evident that Evans hypothesized U.S. per capita cotton mill demand to be influenced by total domestic fiber consumption, cotton mill delivered price, and polyester mill delivered price. This equation was able to explain about 90% of the variation in per capita cotton mill demand. In another study, Sanford [7] developed a system of two equations for total fiber end-use consumption and cotton mill demand for the period 1960 to 1986.

Sanford's U.S. per capita total fiber demand estimation equation:

$$Ln\ (TFPC) = -9.32 - 0.18\ Ln\ (COTP) + 1.78\ Ln\ (RCS) - 0.19\ Ln\ (YR)$$

(-3.5) (-3.7) (5.0) (-2.4)

where,

Ln, denotes natural logarithm,

COTP, denotes real cotton price,

TFPC, denotes total fiber consumption per capita,

RCS, denotes real consumption expenditure, and

YR, is a trend variable, where 1960 = 1.

Sanford's U.S. per capita cotton mill demand estimation equation:

$$QCMP = 17.17 + 0.191\ (TFPC) - 12.68\ (RATIO) - 0.557\ (YR)$$

(12.03) (5.69) (- 4.87) (- 2.4)

R-squared = 0.98, DW d-statistic = 1.35

where,

QCMP, denotes per capita cotton mill consumption,

TFPC denotes total per capita fiber consumption,

RATIO, denotes cotton price divided by polyester price lagged one year, and

YR is a trend variable where 1961 = 1.

However, his hypothesis differed from Evans's approach. In his hypothesis for total U.S. fiber consumption Sanford, used real personal consumption expenditure (PCE) as the income variable instead of the ratio of wholesale price index for textile and apparel to per capita PCE. Further, cotton fiber price was added as an explanatory variable whose influence is significant as reflected in its significant t-value. However, the trend variable to reflect changes in consumer preferences was retained when compared to Evans' total fiber consumption model.

In the case of U.S. per capita cotton mill demand Sanford's model was similar to Evans' model in using total U.S. per capita fiber consumption. However, the price variable in Sanford's model used only the price ratio compared to Evans' model that used both individual prices as well as a price ratio. The trend variable though intended to capture changes in consumer preference, could be picking up any other unnoticed effects.

Sanford's model was able to explain 88% of the variation in total fiber consumption and 98% of variation in cotton mill consumption on a per capita basis. The end-use consumption model adopted deflated 'real' cotton prices as a proxy for all fibers on the assumption that cotton's 30% share of total fiber consumption would make its price reflective on average fiber price levels. Efforts at developing an aggregate fiber price index were however unsatisfactory. In addition, income was represented by real PCE rather than disposable personal income (DPI) as the author found the ratio of expenditure to income increasing due to decreasing saving levels. Meanwhile, the cotton mill consumption model remained similar to Evans's model except for the added trend variable. However, these equations were developed in 1988 and thus could not account for the large increases in cotton and polyester imports that have widened the textile trade deficit since 1990 [3]. In order to be able to account for the structural changes in textile trade, Meyer [6] further expanded on Sanford's model.

The fiber demand model developed by Meyer [6] consisted of a set of two equations similar to the previously discussed models but over the period of 1962 to 1997. Meyer's equations were evaluated using a two stage least squares (2SLS) approach instead of the ordinary least squares (OLS) regression method used by Evans [8] and Sanford [7]. This was due to the assumption that most econometric applications are interdependent and hence separate estimation would lead to biased coefficient estimation. In comparison, a two stage least squares approach assumes interaction via the error terms and hence produce coefficients of reduced bias [20].

Meyer's U.S. per capita total fiber demand estimation equation:

$$\text{Ln (TFD)} = 2.121 + \underset{(12.21)}{0.980} \text{ Ln (DPI)} - \underset{(-\,4.68)}{0.178} \text{ Ln (Fiber Price)} + \underset{(3.85)}{0.128} \text{ (NAFTA)}$$

Adjusted R-squared = 0.9096, DW d-statistic = 1.253

where,

TFD denotes total fiber demand (Sum of total demand for U.S. cotton, man-made and wool fibers) in pounds per capita,

DPI denotes per capita real U.S. disposable personal income,

Fiber Price, denotes nominal U.S. mill delivered cotton price (chosen as proxy for cotton, wool and man-made fiber prices), and

NAFTA is a dummy trend variable equal to one in 1994 (NAFTA inception) and zero in prior years.

Meyer's U.S. per capita cotton mill demand estimation equation:

$$\text{Ln (CMD)} = -\,2.448 + \underset{(7.05)}{1.315} \text{ Ln (TFD)} - \underset{(-14.31)}{0.494} \text{ Ln (Ratio)} - \underset{(-10.68)}{0.252} \text{ Ln (Deficit)}$$

$$+ \underset{(5.38)}{0.136} \text{ (1 + TradeLib)}$$

Adjusted r-squared = 0.9312, DW d-statistic = 1.672

where,

CMD denoted U.S. per capita cotton mill demand in pounds per capita,

TFD denotes U.S. total fiber demand in pounds per capita,

Ratio denotes the ratio of nominal U.S. cotton mill delivered price lagged by one year divided by the nominal U.S. polyester mill delivered price lagged by one year,

Deficit denotes U.S. per capita cotton textile deficit in pounds per capita (deficit equals U.S. cotton imports minus U.S, cotton exports in raw fiber equivalent), and

TradeLib is a trend variable where 1984 = 1 and previous years equal zero.

Meyer hypothesized that per capita U.S. total fiber demand was influenced by real disposable personal income, fiber pricing and a dummy variable to reflect changes in trading structure due to the North American Free Trade Agreement (NAFTA). On the other hand, cotton mill demand was hypothesized to be influenced by total fiber demand, price ratio of nominal cotton mill delivered price to nominal polyester mill delivered price lagged by one year, cotton textile trade deficit and a dummy variable to reflect trade liberalization.

The total fiber demand model was able to explain almost 90% of variation in total fiber demand, while the mill demand model was able to explain 93.12% of the variation. While Meyer's [6] model aims to explain demand based on recent changes in the U.S. textile trading structure it is inclusive of the previous models' objectives too [7,8]. The period of Meyer's study was from 1965 to 1997 though the effect of cotton promotion, which had been initiated within this period, was ignored. Further, man-made promotion all but disappeared during this period. These two changes were not accounted for by Meyer's model.

2.5 Discussion

In order to qualify the objectives of this study, it would be essential to summarize the observations from the review of past literature so as to define and justify the goals of this thesis study. As stated in chapter 1 the ultimate aim of this study is to develop four estimation models for U.S. total cotton demand (TCD), U.S. cotton mill demand (CMD), U.S. total polyester demand (TPD) and U.S. polyester mill demand (PMD).

In the case of U.S. fiber end use demand models Barlowe's [5] model, which was the only previous research on fiber specific end use estimation, provides estimation equations for cotton and man-made fiber end use demand or total demand. However, the period of this study was 1948 to 1964 when synthetic fibers were new and hence large promotion budgets were expended on synthetic fibers. This presents two problems. First, the period from 1990 to 2001 has witnessed the increase of U.S. per capita cotton consumption from almost 23 pounds to 35 pounds. Valderrama [18], attributes this increase in large measure to the U.S. cotton promotion program. There has been no model developed so far to account for this change. Secondly, Barlowe's model clusters man-made fibers into a single grouping for comparison against cotton thereby masking the underlying dynamics of individual fibers (see section 2.3). Polyester by virtue of being the largest synthetic fiber (40% share) presents the single largest substitution fiber for cotton [18,9,10]. However, there has been no model in previous literature reviewed that provides a polyester end use demand model. Thus this study will address these two problems by developing specific fiber end use demand models for cotton and polyester.

In the case of U.S. mill demand Meyer's [6] model, which is the most recent study and was also inclusive of Evans' [8] and Sanford's [7] models, explains almost 93% of the variation in annual per capita U.S. mill demand. However, all the three models do not account for the influence of U.S. cotton promotion on mill consumption. Jacobson and Smith [14], point to the Cotton Incorporated's promotion program as being aimed at both mills as well as the retail consumer as part of its 'push-pull' strategy. However, its influence on U.S. cotton mill demand has not been modeled so far. This need will be addresses by the U.S. cotton mill demand model in this study. In the case of U.S. polyester mill demand (PMD), there is no preceding model found in past literature, which makes the PMD model developed in this study, the first. The effect of cotton promotion on U.S. PMD will also be measured in this study.

3.

Supply analysis of U.S. Cotton and Polyester fiber

Following the discussion in the literature review in chapter 2, it would be essential to now understand the demand side situation for cotton and polyester fiber and derive their determinants in order to develop an econometric model for the same. In the case of cotton, a part of U.S demand is satisfied by U.S. grown cotton that proceeds to U.S. mills for conversion into textile products. However, U.S. farm policy provisions in turn influence cotton production. On the other hand, polyester fiber supply is influenced by U.S. polyester production capacity and its utilization since polyester is a manufactured fiber. Further, polyester capacity utilization would be reflective of demand for U.S. polyester as well as import competitiveness. In summary, this chapter will provide an understanding of the supply situation for cotton and polyester fiber that would help in understanding the underlying demand for these two fibers.

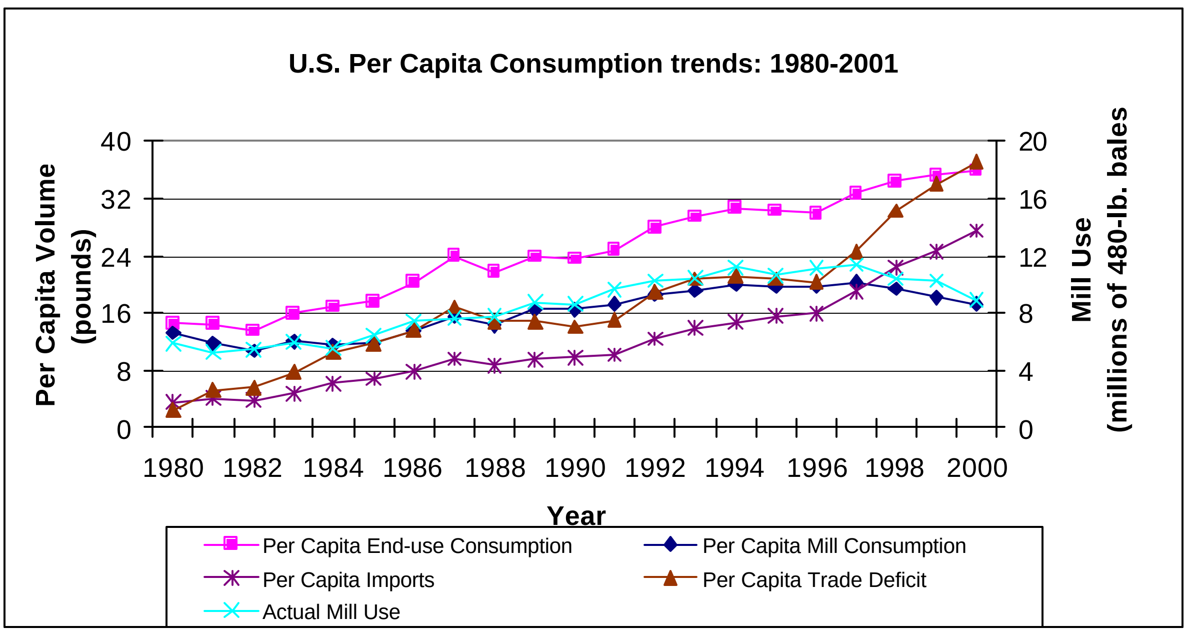
3.1 Background and significance of cotton in the U.S. Economy

In order to build an econometric model for U.S. cotton and polyester demand it would be essential to understand their economic importance as well as their production trends. In the case of cotton, the U.S. also happens to be among the largest producers of cotton. However, the U.S. cotton acreage and consequently the production are influenced by U.S. farm policy [12]. In line with this observation, the supply analysis of cotton is intertwined with related policy measures. However, U.S. polyester supply depends on raw material feedstock prices, installed capacity and capacity utilization due to its origin as a manufactured fiber and petrochemical derivative product.

3.1.1 Economic significance

The cotton industry from the farm to the mill plays a pivotal role in U.S. employment and gross domestic product (GDP). A total of about 400,000 jobs are generated across the entire cotton supply chain. The net worth of cotton goods and services produced is over $25 billion annually. The U.S. is the world's largest exporter of raw cotton accounting for 25% of the world cotton trade in the 1990's.

3.1.2 Key cotton consumption trends



Source: USDA Cotton and Wool Situation and Outlook Report: November 2002

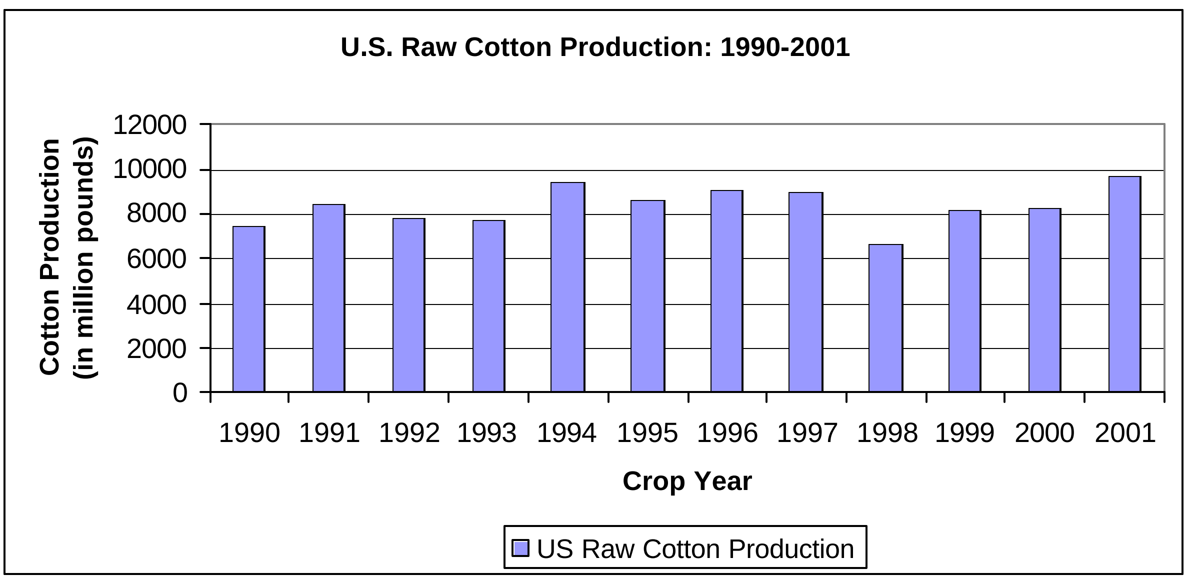
FIGURE 3.1: U.S. COTTON CONSUMPTION TRENDS: 1980-2001

From figure 3.1 it is evident that the U.S. cotton per capita consumption at the end-use or retail level has witnessed an increasing trend over the period 1980 to 2001. The per capita consumption of cotton, which stood at 14.6 pounds, has more than doubled to reach 35.8 pounds in 2000. After China and India, U.S. is the third largest consumer with an 11% share of global cotton consumption. However, while U.S. end-use consumption has registered a consistent increase as seen in the figure, mill use has experienced a slowdown. The U.S. mill use (in million pounds) trend shows that barring 1997 (when the U.S. economy was in the midst of its largest expansion in history) mill use has recorded a consistent decline since 1994.

This trend is directly linked to the massive surge in textile imports and as a result a spike in the textile trade deficit since 1994 [21]. The situation has been exacerbated by the strong appreciation in the value of the U.S. dollar making imports economically more lucrative. As a consequence, the U.S. mill sector has experienced massive layoffs and plant closures.

3.1.3 Key cotton production trends

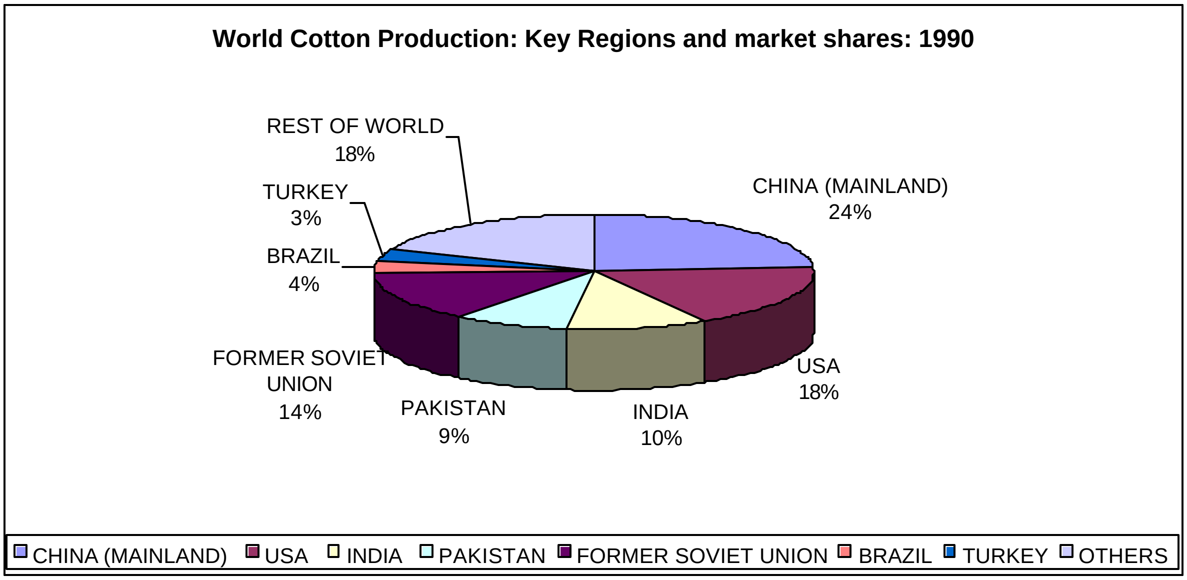
From the figure 3.2 it is evident that, in the period from 1990 to 2001, U.S. raw cotton production rose by almost 30% to reach the highest ever recorded production of 9684 million pounds for crop year 2001.



Source: USDA Cotton and Wool Situation and Outlook Report: November 2002

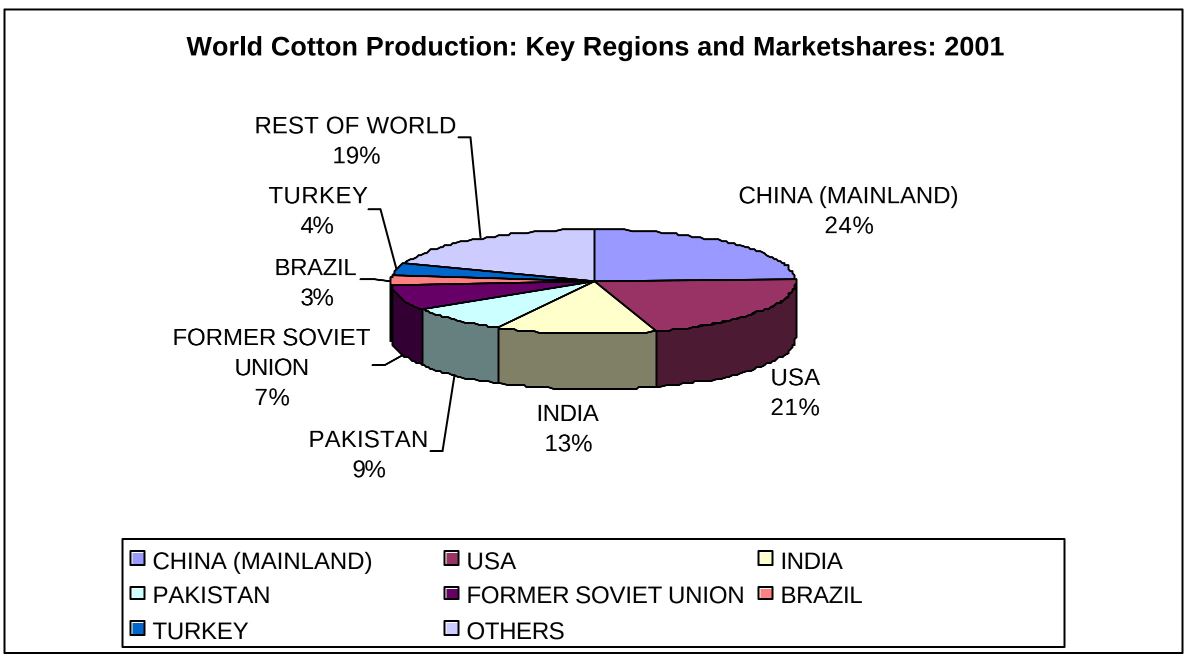
FIGURE 3.2: U.S. RAW COTTON PRODUCTION: 1990- 2001

In the same period, the global composition of key production areas for cotton had undergone a significant change as illustrated by Figure3.3 and Figure 3.4. The largest change was due to the collapse of the former Soviet Union that accounted for 14% of world cotton production in 1990 to just half this amount at 7% in 2001.



Source: USDA Cotton and Wool Situation and Outlook Report: November 2001

FIGURE 3.3: KEY COTTON GROWTH REGIONS AND PRODUCTION SHARES: 1990



Source: USDA Cotton and Wool Situation and Outlook Report: November 2001

FIGURE 3.4: KEY COTTON GROWTH REGIONS AND PRODUCTION SHARES: 2001

Consequently, the U.S. and India each gained 3% share as a result of the decline. In light of this change in the structure and composition of the global cotton production, the U.S. cotton supply has increased. However, U.S. mill consumption has fallen dramatically during the same period. This has shifted the export thrust that rose 20.62% over 1990 to reach 9.4 million bales in crop year 2001.

3.2 Approach for U.S. raw cotton supply-demand analysis

The analysis of the U.S. cotton fiber supply and demand can be performed at various tiers of the cotton supply chain as seen in Figure 3.5. The U.S. cotton supply chain can be broadly analyzed from the raw cotton, mill consumption and end-use consumption standpoints. The definition of these cotton supply chain tiers enables a clear understanding of the dynamics unique each of these tiers [18].

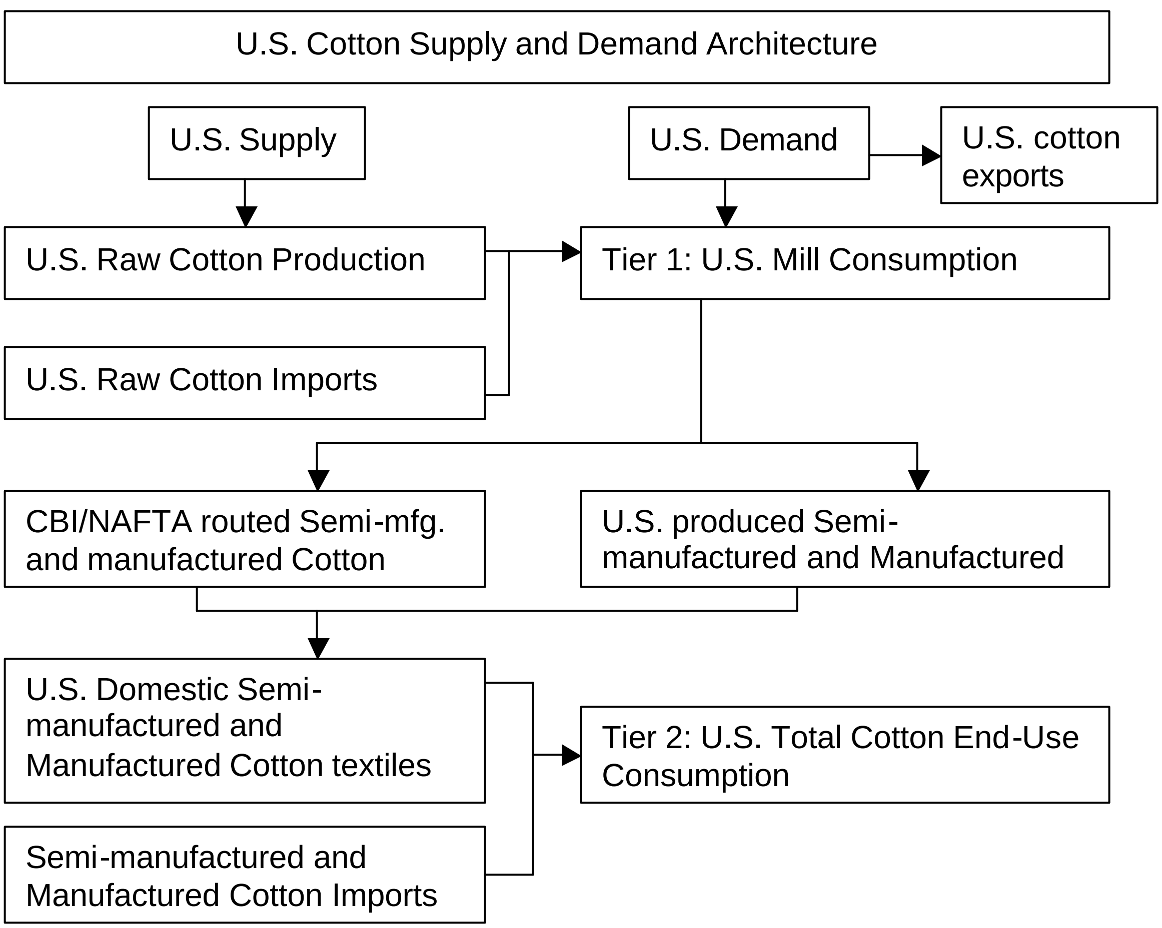


FIGURE 3.5: U.S. COTTON FIBER SUPPLY CHAIN

The first tier of the cotton supply chain is the U.S. raw cotton market. This tier is uniquely impacted by U.S. farm policy, agricultural price control/support mechanisms discussed in section 3.5. The second tier of the cotton supply chain is from the U.S. mill consumption standpoint discussed in chapter 4. The third tier of analyzing the U.S. cotton supply chain would from the end-use consumption standpoint. This tier provides a composite of the first and second by capturing the combined effect of U.S. mill consumption and textile trade deficit in raw fiber-equivalent terms and is discussed in chapter 4.

3.2.1 Framework for analysis of U.S. raw cotton supply and demand

In order to analyze the U.S. cotton supply situation it would be essential to provide a framework that is derived from the overall U.S. cotton supply chain illustrated in Figure 3.5. This framework is based upon the methodology used by USDA in calculating net available U.S. cotton supply and is illustrated in Figure 3.6 [2].

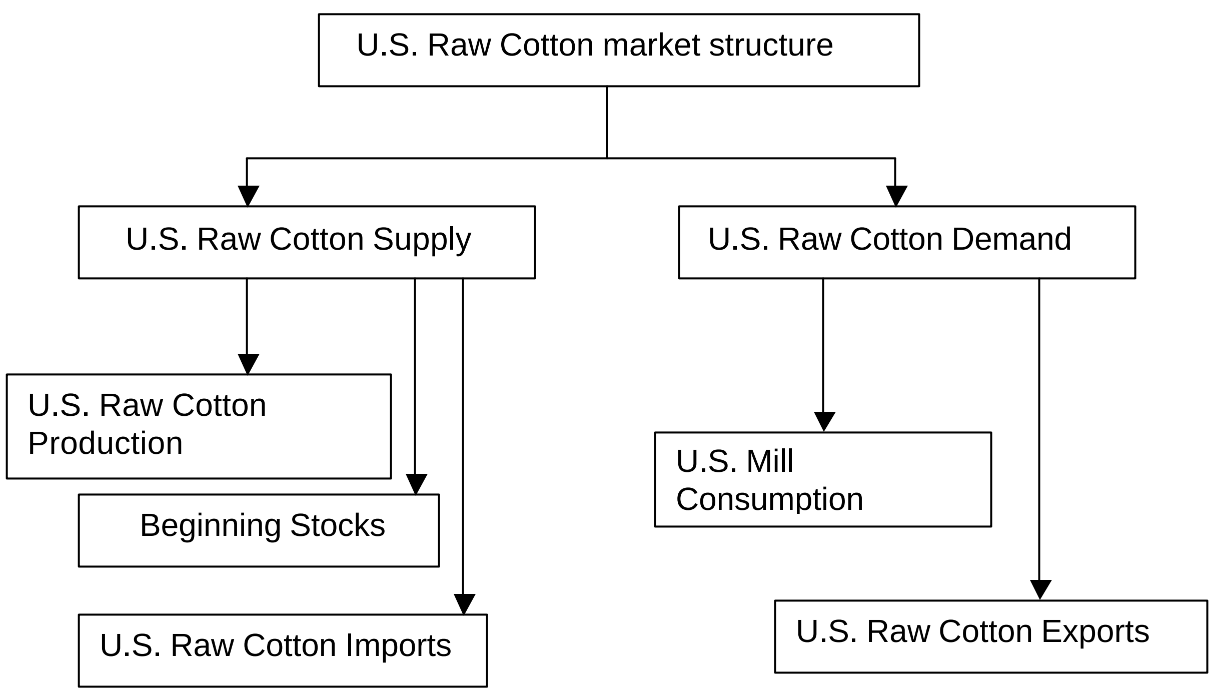
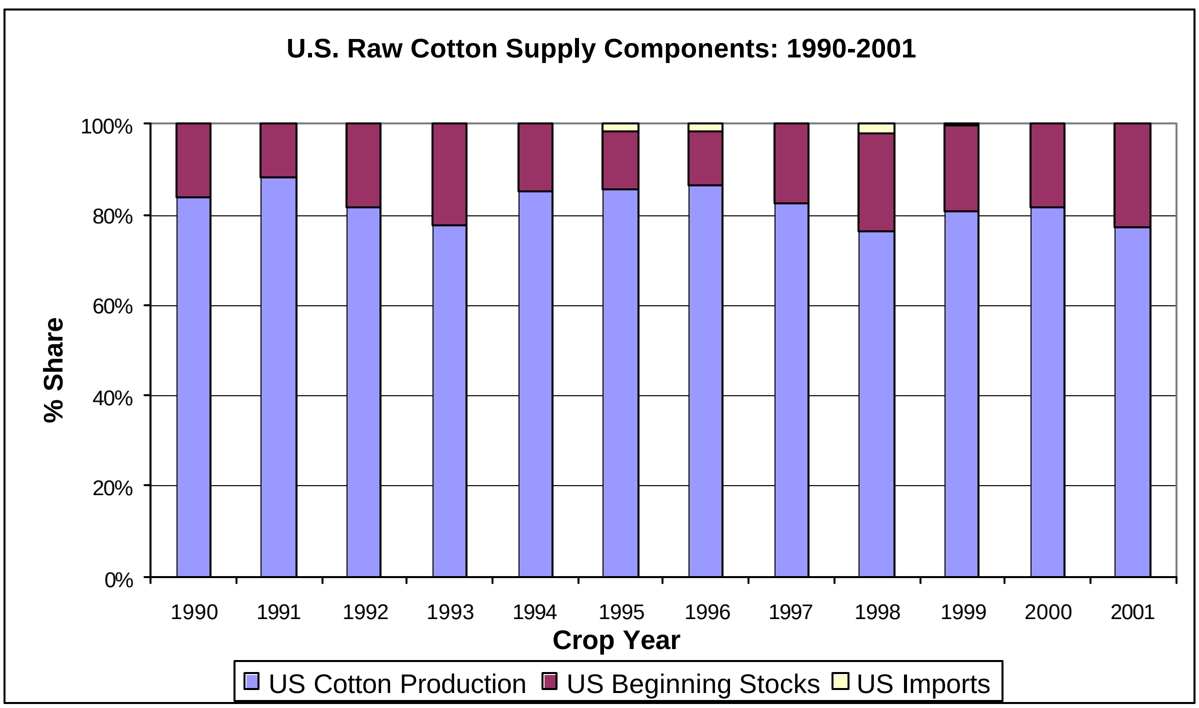


FIGURE 3.6: DEMAND-SUPPLY ARCHITECTURE OF U.S. RAW COTTON MARKET

3.3 U.S. Cotton Fiber Supply Analysis

The analysis of the supply situation of U.S. cotton and polyester fiber will provide an understanding of the factors that influence the fiber consumption in relation to fiber production and net textile trade in raw fiber. In this analysis, raw cotton supply is defined as the sum of the annual cotton production, season beginning stocks and imports as reported by the USDA. On the other hand, U.S. raw cotton demand is defined as the sum of the annual U.S. mill consumption and U.S. cotton exports. The five cotton supply-demand components of production, beginning stocks, imports, mill consumption and exports are highly inter-related. Hence, in order to gain an understanding of the U.S. mill level demand it is essential to understand the impact of the other four components as well. U.S. cotton production consistently accounted for almost 80% of the U.S. raw cotton supply followed by season beginning stocks averaging roughly 15-20% with cotton imports remaining almost negligible (see Figure 3.7).



Source: USDA Cotton and Wool Situation and Outlook Report: November 2001

FIGURE 3.7: U.S. RAW COTTON SUPPLY COMPONENTS: 1990-2001

Several past studies indicate that U.S. cotton production is influenced by planted acreage and yield that in turn are influenced significantly by U.S. farm policy provisions [22,23]. These policies have traditionally been a government instrument to control cotton supply management, income support and price stabilization since the 1930's [24]. However, successive farm bills from the 1985 Food Security Act (FACT) to the latest Farm bill of 2002 have resulted in a transformed cotton production scenario driven by greater market-orientation in keeping with the need to meet the WTO-specifications in 2005. The following section presents an analysis of U.S. cotton production and its underlying policy provisions.

3.3.1 Analysis of cotton production based on U.S. farm policy

The U.S. raw cotton supply and demand dynamics for 1990-2001 has primarily been a function of the changing U.S. farm policy adopted during this period. The ten-year period has seen a shift in farm policy from a highly government subsidized environment to a market-oriented economic structure. This period can be broadly divided into 3 phases based on the farm policy in effect during the relevant period. The three key phases of farm policy during 1990 to 2001 were:

(1) 1990-1995: Food, Agriculture, Conservation and Trade Act (FACT Act)

(2) 1996-2001: Federal agriculture Improvement and reform act (FAIR Act)

(3) 2002-2007: Farm Security and Rural Investment Act of 2002 (FSRI Act)

The supply side analysis of U.S. cotton fiber spanning 1990-2001 in the following sections is classified in line with the prevailing farm policy for the purpose of highlighting the relevant policy impacts as while simplifying the time span into two periods form 1990 to 1995 and 1996 to 2001 for better understanding. The supply side dynamics of cotton and polyester are distinctly unique to both cotton and polyester. Cotton supply is influenced by federal legislation and policies in supply management, income support and price stabilization. The supply of polyester fiber, which is a crude-oil derivative product, is determined by upstream raw material prices especially purified terephthalic acid (PTA) and mono-ethylene glycol (MEG) and their production capacities and utilization.

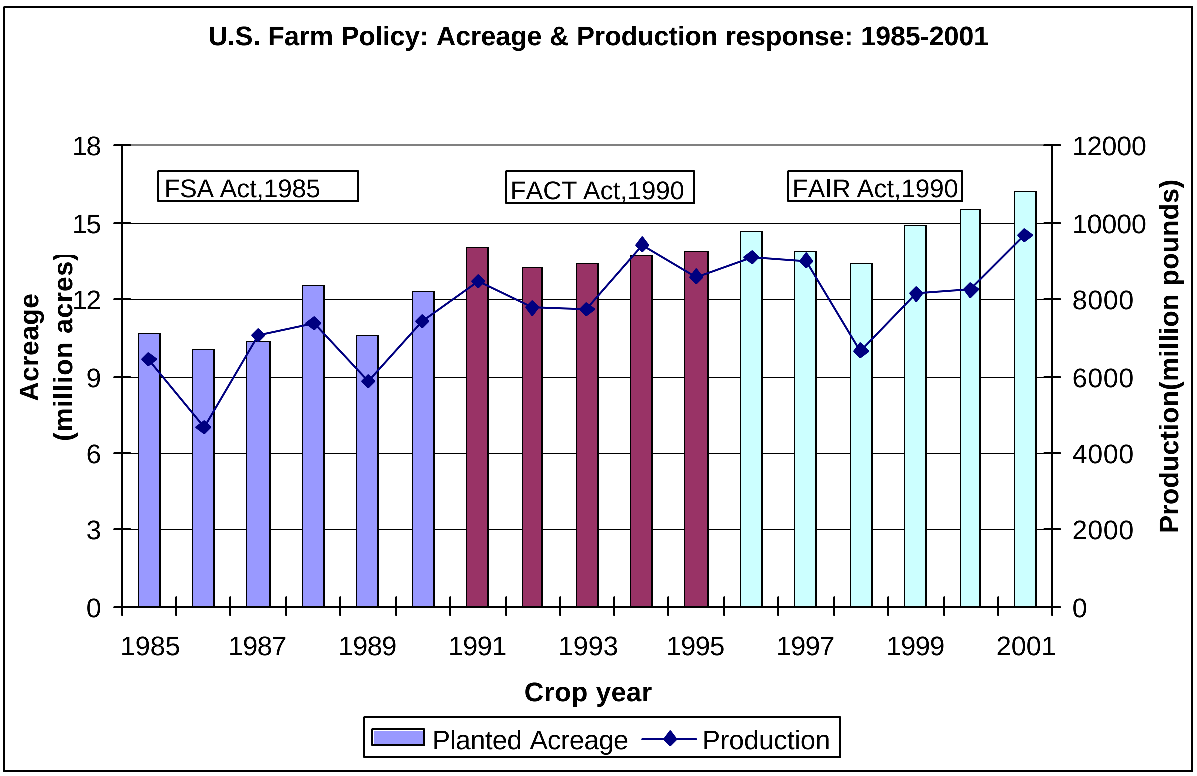
3.3.2 Background of U.S. farm programs and policy provisions

U.S. farm policy as an influencing factor in cotton acreage, production and final U.S. cotton supply has been analyzed by several researchers [12,23]. Cotton happens to be one of the eight program crops covered under the U.S. farm income support and supply management programs. On a national basis cotton primarily competes for planted acreage with corn, wheat soybeans and sorghum [24]. The effect of planted acreage on cotton is studied with reference to competing crop choices amongst the above-mentioned crops.

3.3.3 Influence of U.S. farm policy on U.S. raw cotton production and supply

The U.S. cotton industry from 1930-1960 has witnessed consistent excess capacity and overproduction. The infusion of technology developments and improved varieties has added to the situation, with supply outdistancing demand by a wide margin [24]. Therefore, the price and income support programs are central to U.S. farm policy design. Historically, the U.S. cotton production and consequently supply have been influenced by government programs from the 1960's right up until 2001 [24,3]. The U.S. farm policy linkage to production and eventual supply scenario proves very crucial to the world cotton demand-supply owing to the high stake of U.S. cotton in production and exports. The U.S. is the world's second largest producer (21% share) after China and the world's largest exporter of raw cotton (low domestic mill consumption) [2]. The available supply of U.S. cotton is a sum total of beginning stocks, production, and imports. Among the three components, production alone accounts for about 82% of total supply on a ten-year average basis (1990-2001) as seen in Figure 3.7. It would be fair to say that production single handedly decides the U.S. available supply in a given crop year. Since 1980, U.S. cotton production has historically tracked planted acreage as illustrated in Figure 3.8.

Hence U.S. cotton production is primarily a function of planted acreage (assuming normal yields and abandonment rates). Planted acreage is thus the underlying driver of U.S. cotton production and in turn U.S. raw cotton supply or availability. Lin and Skinner [23] have investigated and established the dependence of planted acreage on farm policy. Starting from 1990 until 2001 the farm policy has evolved from a tight income support and supply managed era to one of total planting flexibility and market-determined production decisions.



Source: USDA Cotton and Wool Situation and Outlook Report: November 2001

FIGURE 3.8: U.S. FARM POLICY: ACREAGE AND PRODUCTION RESPONSE: 1990-2001

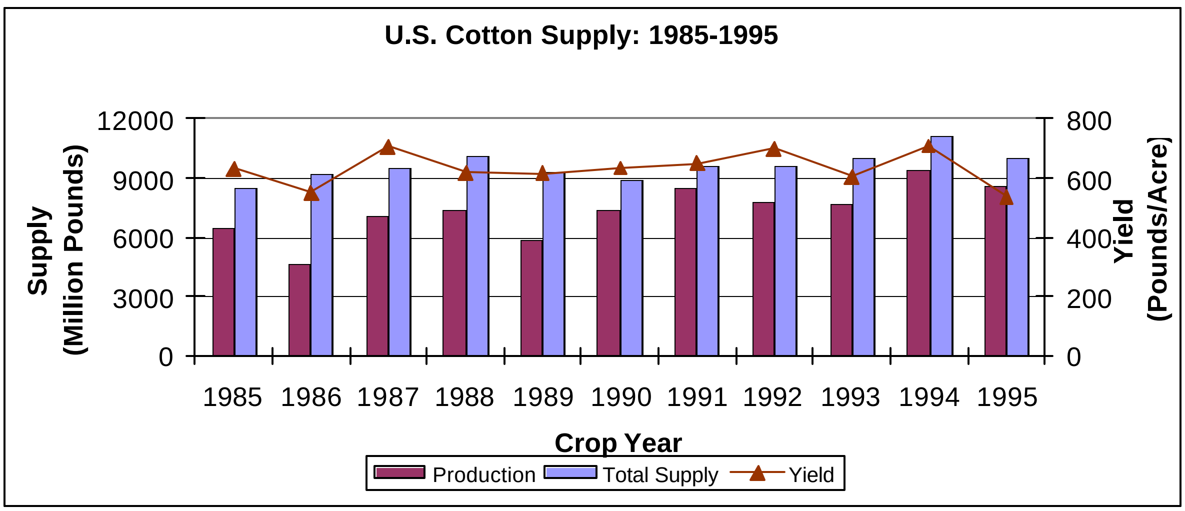
From the above discussion, it is clear that U.S. farm policy was a decisive factor in determining U.S. raw cotton supply and its influence on U.S. mill demand and end use demand would be helpful in order to build a model to estimate them.

3.4 Analysis of U.S. raw cotton supply situation from 1990-2001

Following the discussion in section 3.5 regarding the effect of U.S. farm policy as the major factor influencing available cotton supply it would be easier to interpret the trends in U.S. raw cotton supply presented in sections 3.6.1 and 3.6.2. This is due to the fact that that the supply situation in any given year is interpreted based on the prevailing U.S. farm policy. This also forms the basis of dividing the U.S. cotton supply situation into two periods of 1990 to 1995 and 1996 to 2002.

3.4.1 Analysis of U.S. raw cotton supply situation from 1990-1995

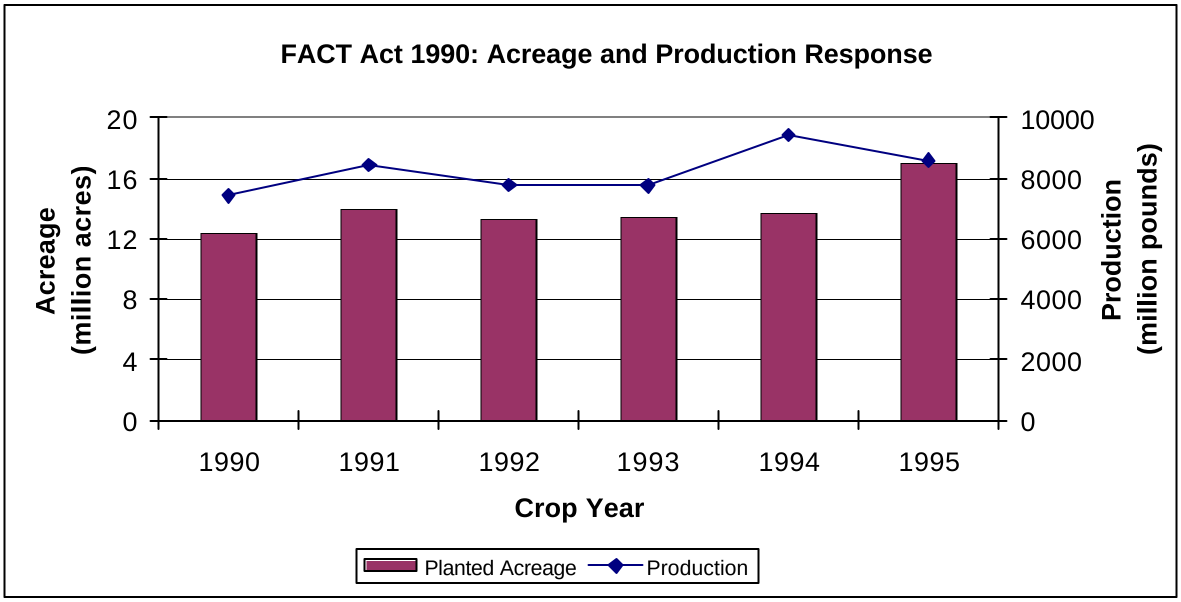
The U.S. raw cotton supply from 1990 to 1995 consistently witnessed low beginning stocks in the face of high export demand and increased mill use [25]. This trend was in contrast to the supply scenario from 1985 to1990 as seen in Figure 3.9.



Source: USDA Cotton and Wool Situation and Outlook Report: November 2001

FIGURE 3.9: U.S. COTTON SUPPLY SITUATION: 1985-1995

The U.S. cotton production in 1990 reached 1440 million pounds, the second highest cotton output since 1982 and a 27.13% increase over the 1989 crop year. The production increase was primarily due to the reduced acreage under the ARP combined with the second highest yield since 1980 at 634 pounds/acre as illustrated in figure 3.10 [3,26].

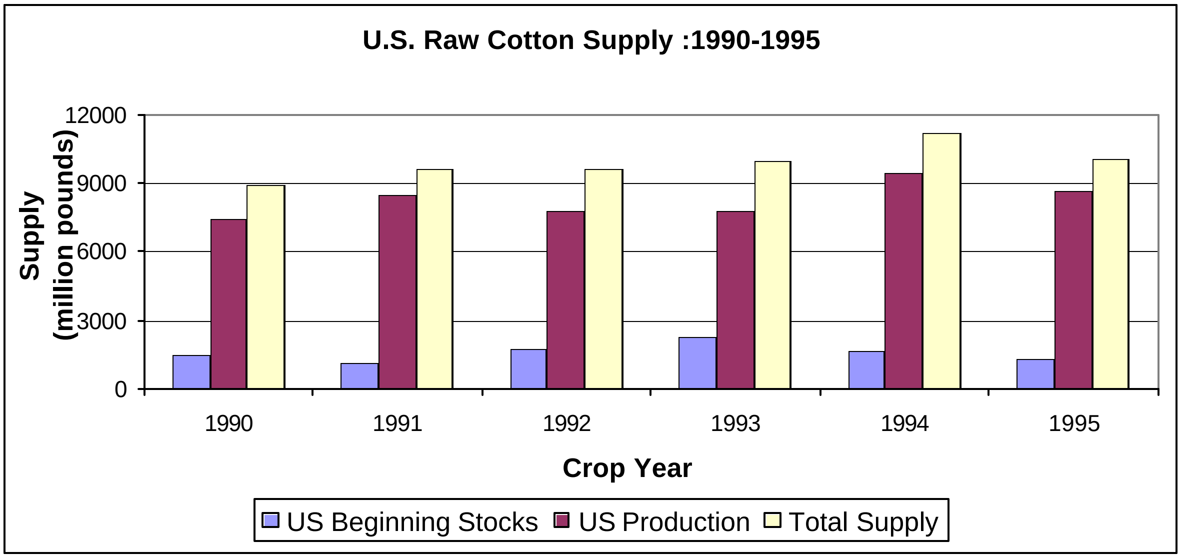


Source: USDA Cotton and Wool Situation and Outlook Report: November 2001

FIGURE 3.10: FACT ACT 1990: ACREAGE AND PRODUCTION RESPONSE

The first cotton crop planted under the FACT Act in 1990 was the second highest planted acreage since 1980 at 12.34 million acres. Planted acreage rose 27.13% over the 1989 crop year, with significant acreage additions coming from the farm policy changes and reduced ARP [27]. Beginning with the 1990 Act, the planted acreage increased from 12.34 million acres in 1990 to 13.93 acres in 1995 with a high of 14.05 million acres in 1992. Cotton has attracted this additional acreage primarily due to the normal flex acres provision adding 100,000 to 350,000 acres over the FACT Act period [25].

The 1991 season continued the trend of increasing production reaching 8454 million pounds. Figure 3.11 shows that the increase was primarily due to the beginning stocks touching a 20-year low of 1125 million pounds. In turn, producers planted an increased acreage of 14.05 million acres towards cotton amidst lower acreage reduction program (ARP) requirements.

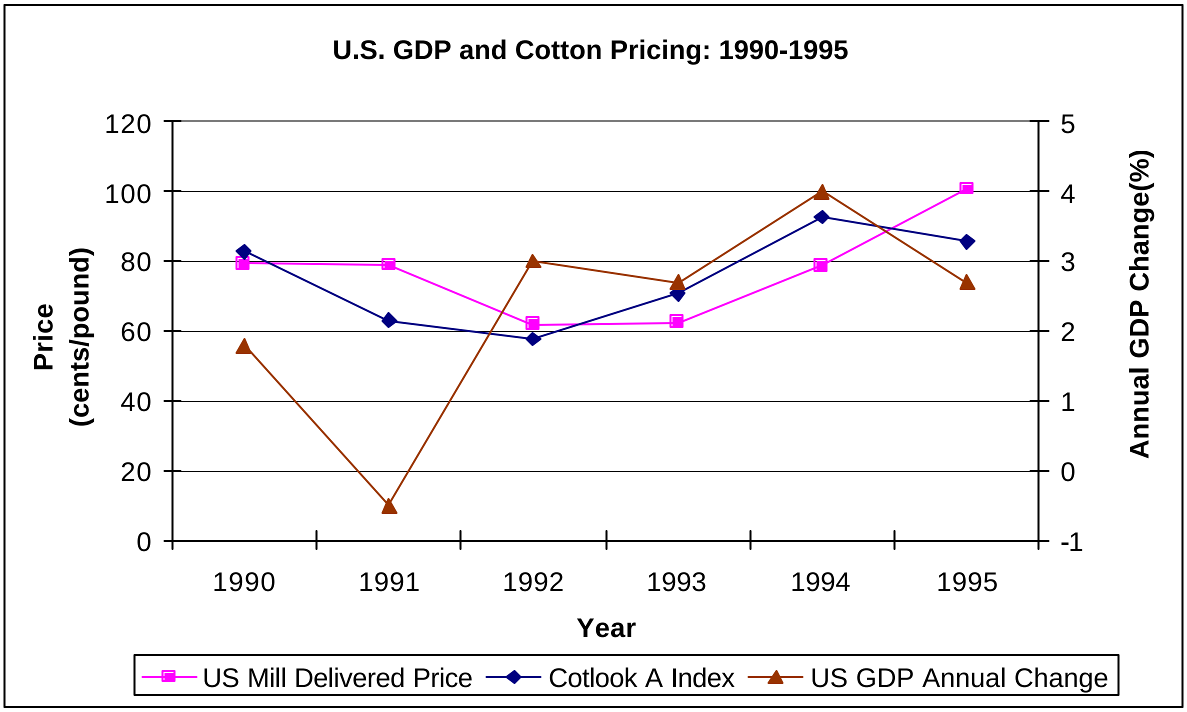


Source: USDA Cotton and Wool Situation and Outlook Report: November 2001

FIGURE 3.11: U.S. RAW COTTON SUPPLY: 1990-1995

The total supply still reached 9563 million pounds close to the 9586 million pounds of 1991 on account of higher beginning stocks and the highest yield as yet under the FACT Act of 700 pounds/acre. The U.S. cotton supply in 1993 recorded a 4.41% increase over 1992 because of the dramatic 25.86% increase in beginning stocks though production declined a slight 0.52% over 1992 at 7744 million pounds. This increase was due to a massive 22% decline in U.S. exports in 1992 over 1991 pushing exports to a 10-year low of 2496 million pounds [28]. The 1992 U.S. export faced intense foreign competition specifically from Central Asia. The newly formed Central Asian republics resorted to selling below cost price and developed special barter arrangements in light of severe economic hardships resulting from the collapse of the Soviet Union [29]. The U.S. cotton price quoted nearly 5.5 cents/pound above competing foreign cotton and world trade shrank by 10% causing the high export decline [25]. The 1994 season was perhaps the most outstanding season since 1980. U.S. production reached an all time high of 9437 million pounds, increasing almost 22% over 1993. This increase was primarily due to 4% U.S. GDP growth over 1993 and increased acreage as well as record yields reaching 708 pounds/acre, as seen in figure 3.12 [30,31]. The acreage increase came on account of the producers adding a net 356,000 cares through the flex-acre provision of the

FSA Act [32]. U.S. real GDP touched 7347.7 billion dollars (1996 base year), a 4% real GDP growth over 1993 and the highest since 1990. The other notable factor was the fundamental revision in the structure of cotton trade with the North American Free Trade Agreement (NAFTA) becoming effective in January 1994. [25].

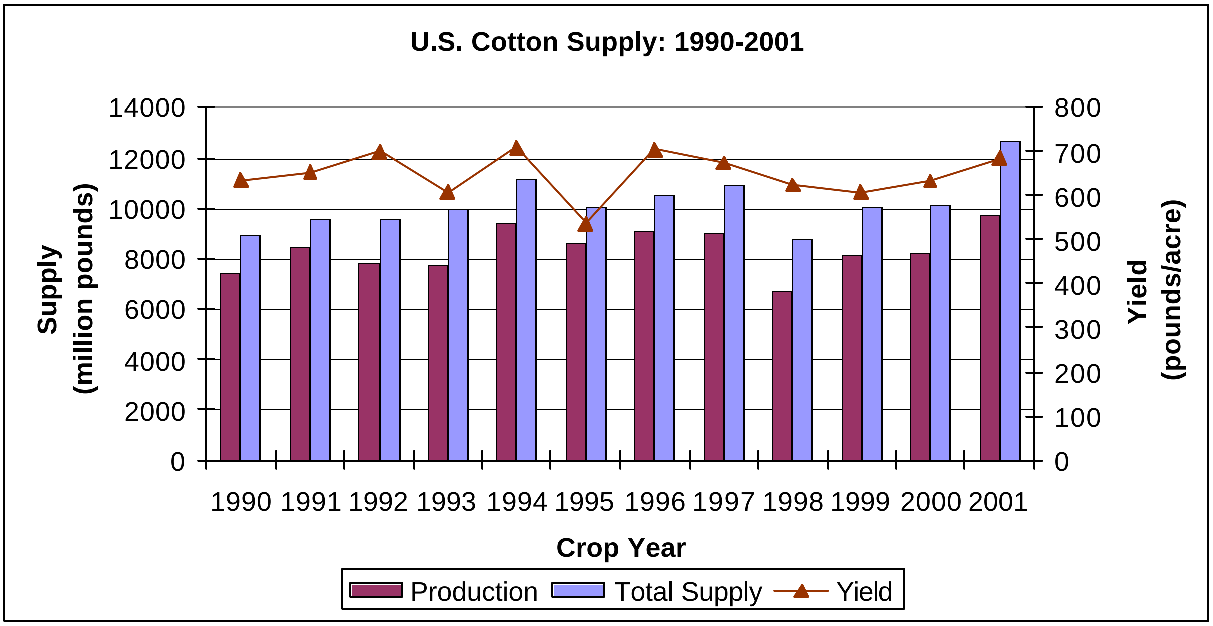


Source: National Cotton Council (NCC) of America and U.S. Census Bureau
FIGURE 3.12: U.S. GDP AND COTTON PRICING: 1990-1995

The ARP level of 11% increased planted acreage from 13.43 million acres to 13.72 million acres in 1994. The last crop planted under the FSA Act in 1994, was announced at the7.5% level [31]. The lowered ARP resulted in a 1.53% increase in 1995-planted acreage at 13.93 million acres. Producers increased acreage to almost 17 million acres in response to the highest prevailing U.S. cotton prices since 1990 at nearly 100 cents per pound [33]. This acreage was the highest recorded acreage since 1956. However, the acreage increase was offset by yield declining to 537 pounds/acre, the lowest since 1983 resulting in final U.S. production of 8592 million pounds. In summary, the FSA Act period, registered an average production of 8242 million pounds, yield of 639 pounds/acre and a supply level of 9870 million pounds.

3.4.2 Analysis of U.S. raw cotton supply from 1996-2002

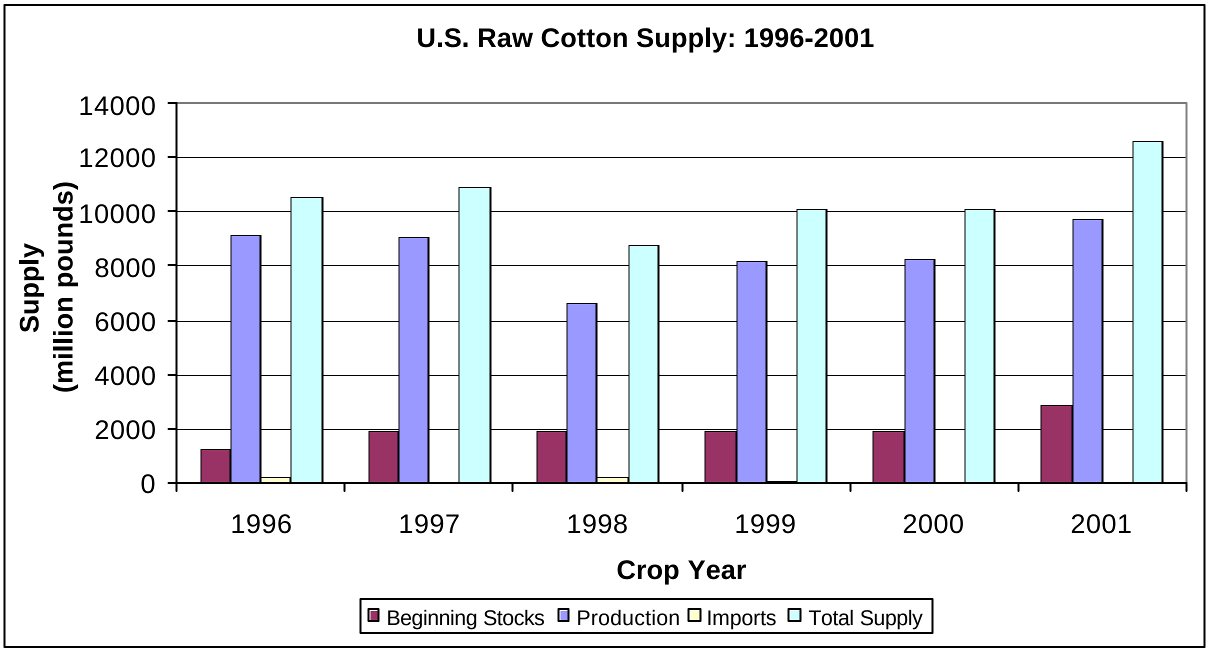
The U.S. cotton supply scenario from 1996 to 2002 recorded an increasing trend on key supply metrics in comparison with the FACT Act period of 1990-1995 as illustrated in Figure 3.13. Average production increased 2.99% to 8488 million pounds from 8242 million pounds during the FACT Act period. This production increase may be attributed to the 5.26% increase in average planted acreage to reach 14 million acres from 13.94 million acres as well as a 2.34% increase in average yield to reach 654 pounds/acre from 639 pounds/acre [3].



Source: USDA Cotton and Wool Situation and Outlook Report: November 2001

FIGURE 3.13: U.S. COTTON SUPPLY: 1990-2001

With total planting flexibility, producers lowered planted acreage on cotton down to 14.65 million acres in 1996, down from the record 16.93 million acres of 1995 owing to acreage shift to grain crops. This shift was a producer response to record level prices of competitive grain crops. Additionally, national abandonment rate was close to 12% owing to weather vagaries in Texas [34]. Crop year production at 9092.16 million pounds was 5.82% higher than 1995 due to a rebound in yield from to 705 pounds/acre. An important point to note is the significant rise in U.S. cotton imports, particularly in 1995 and 1996 at 195.84 and 193.44 million pounds respectively. This increase came on account of low beginning stocks and lower world prices relative to the U.S cotton market prices.

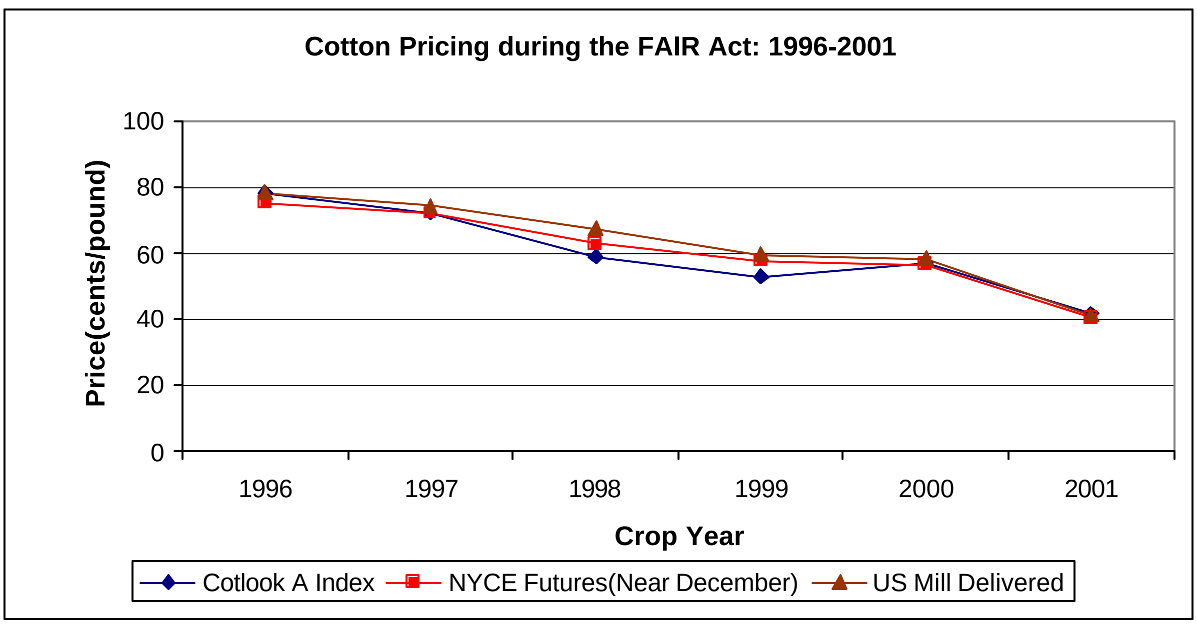


Source: USDA Cotton and Wool Situation and Outlook Report: November 2001

FIGURE 3.14: U.S. COTTON SUPPLY: 1996-2001

In spite of a 3% decrease in planted acreage to 13.89 million acres in 1997, the harvested acreage increased 4% over 1996 owing to a decrease in the national abandonment rate from 12% to a mere 3.5%. However, a lower yield of 673 pounds/acre left 1997 production marginally lower at 9020.64 million pounds. However, total supply still increased 3.75% over 1997 to 10932.96 million pounds. The 1997 season witnessed low ending stocks on account of higher demand for U.S. cotton and increased trade under the NAFTA [35]. In view of the low beginning stocks for the 1998 season, U.S. cotton imports jumped to their highest level recorded since 1965 to 212 million pounds [3]. This spike came on account of the low beginning stock level of 1865 million pounds, further exacerbated by declines in, planted acreage to 13.3 million acres, and yield to 625 pounds/acre resulting in a huge 25.94% decline in production to 6680 million pounds. Cotton acreage continued to be under pressure as producers shifted acreage to competing crops in the face of higher net returns and declining cotton prices at 1998 planting time [36]. The fluctuations in cotton production over 1996-1998 stabilized during the 1999-2001 period under the FAIR Act.

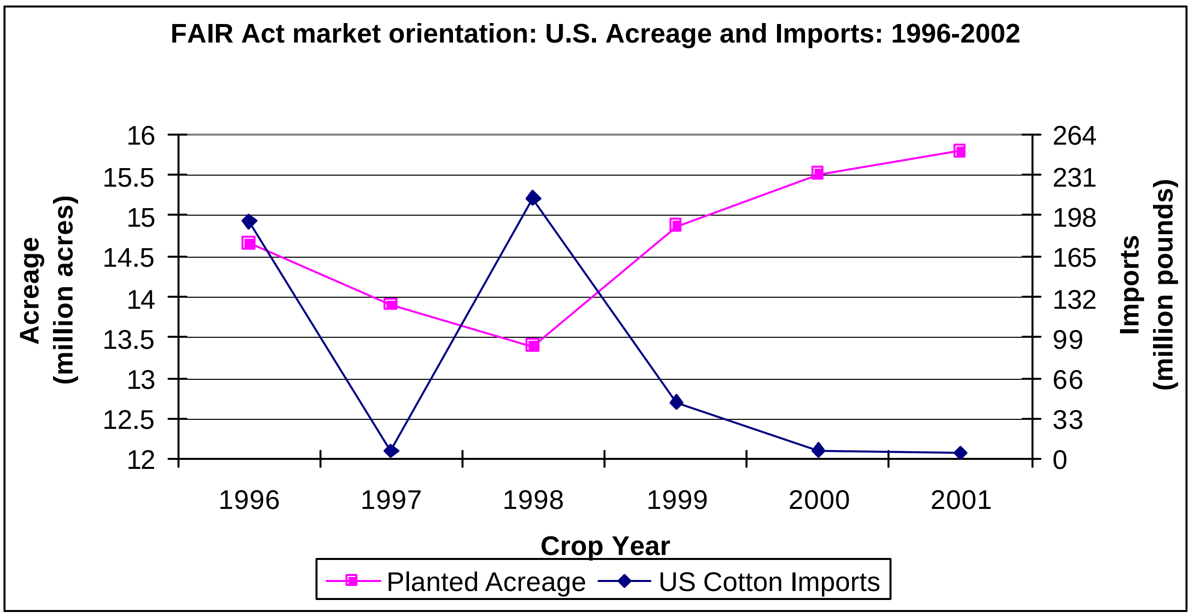
At planting time for the 1999 cotton crop, prices continued to slide from 1998 levels (see figure 3.15). The U.S. mill delivered price for cotton, declined 8.03cents/pound from 67.52 to 59.49 cents/pound in this period. World cotton pricing as reflected by the Cotlook A index also declined about 6.04 cents/pound over 1998 to 52.84 cents/pound. Cotton acreage increased 11.05% over 1998 to 14.874 million acres despite the price decline owing to concerns of aflatoxin in corn, depressed prices of competing crops and compensatory marketing loan program payments [36]. Cotton production for the 1999 crop year, thus registered a 21.91% increase over 1998 to reach 8144.64 million pounds.



Source: National Cotton Council (NCC) of America

FIGURE 3.15: COTTON PRICING DURING THE FAIR ACT: 1996-2001

The increasing trend in planted acreage into the 2000 crop year, though influenced by the higher net returns over competing crops especially corn, was bolstered due to the substantial contribution of the marketing loan program and insurance program towards crop income support in 1999 [36]. Cotton managed to add a modest 0.28 million acres or a 1.82% higher acreage over 2000 on account of depressed price conditions in the competing corn and soybeans market. This addition came despite U.S. mill delivered cotton prices declining 17.26 cents/pound. Amidst this declining price environment cotton still held relative attractiveness owing to significant marketing loan program and insurance payments [3]. The 2001 crop, which is the final cotton planting under the FAIR Act, 1996 combined a 11.55% yield increase to 705 pounds/acre over 2000 and the 1.82% increase in acreage to register a production of 9744 million pounds, the highest production since 1965.



Source: USDA Cotton and Wool Situation and Outlook Report: November 2001

FIGURE 3.16: FAIR ACT MARKET ORIENTATION: U.S. ACREAGE AND IMPORTS: 1996-2002

As illustrated in Figure 3.16, the 1997 and 1998 cotton crops, witnessed a successive decline in planted acreage to 13.89 and 13.39 million acres respectively. Lin et al [23] investigated this decline and attributed this decline to planting flexibility and highly competitive prices and returns for corn, wheat, sorghum and soybean in decreasing order. The important trend to note is the free market orientation of the U.S. cotton sector in the 1996-2001 periods under FAIR Act. The successive years of 1996 to 1998 showed a decline in acreage due to uncompetitive U.S. market prices relative to world prices, and this translated into the U.S. demand segments sourcing their cotton from foreign markets. With the reversal of acreage decline in 1999, the import pressure faded away to lower levels of 7.20 and 4.80 million pounds in 2000 and 2001 respectively. This trend was unprecedented in the U.S. cotton market.

3.5 U.S. Polyester fiber supply analysis

This section will provide a supply side analysis of polyester fiber, in staple and filament forms similar to the cotton supply analysis in section 3.6. The polyester fiber industry is part of the larger man-made fiber industry. The man-made fiber industry is broadly divided into the cellulosic fiber and synthetic fiber industry as illustrated in figure 3.17. In this analysis, cellulosic fiber comprises rayon and acetate fibers. On the other hand, the synthetic fiber industry is comprised of nylon, acrylic, polyester and olefins in staple and filament forms. Acrylic includes modacrylic fiber while olefin staple fiber figures includes mostly olefins and some vinyon fiber production data. Olefin filament figures include polypropylene yarn, monofilament and spun bonded as well as polyethylene monofilament filament and film.

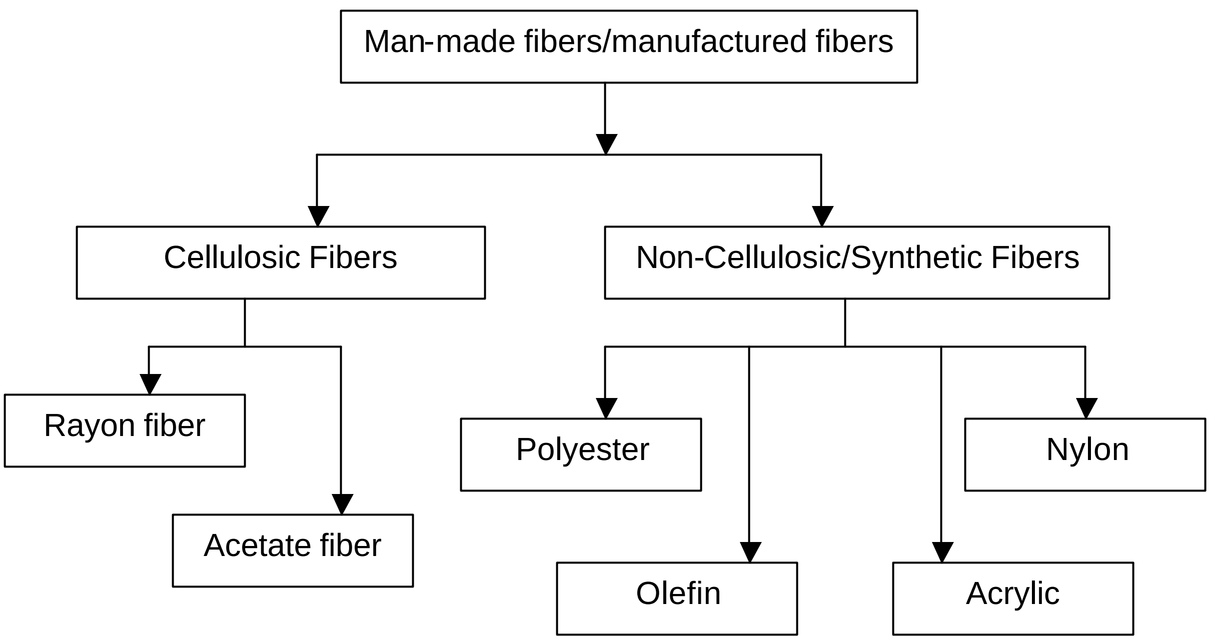
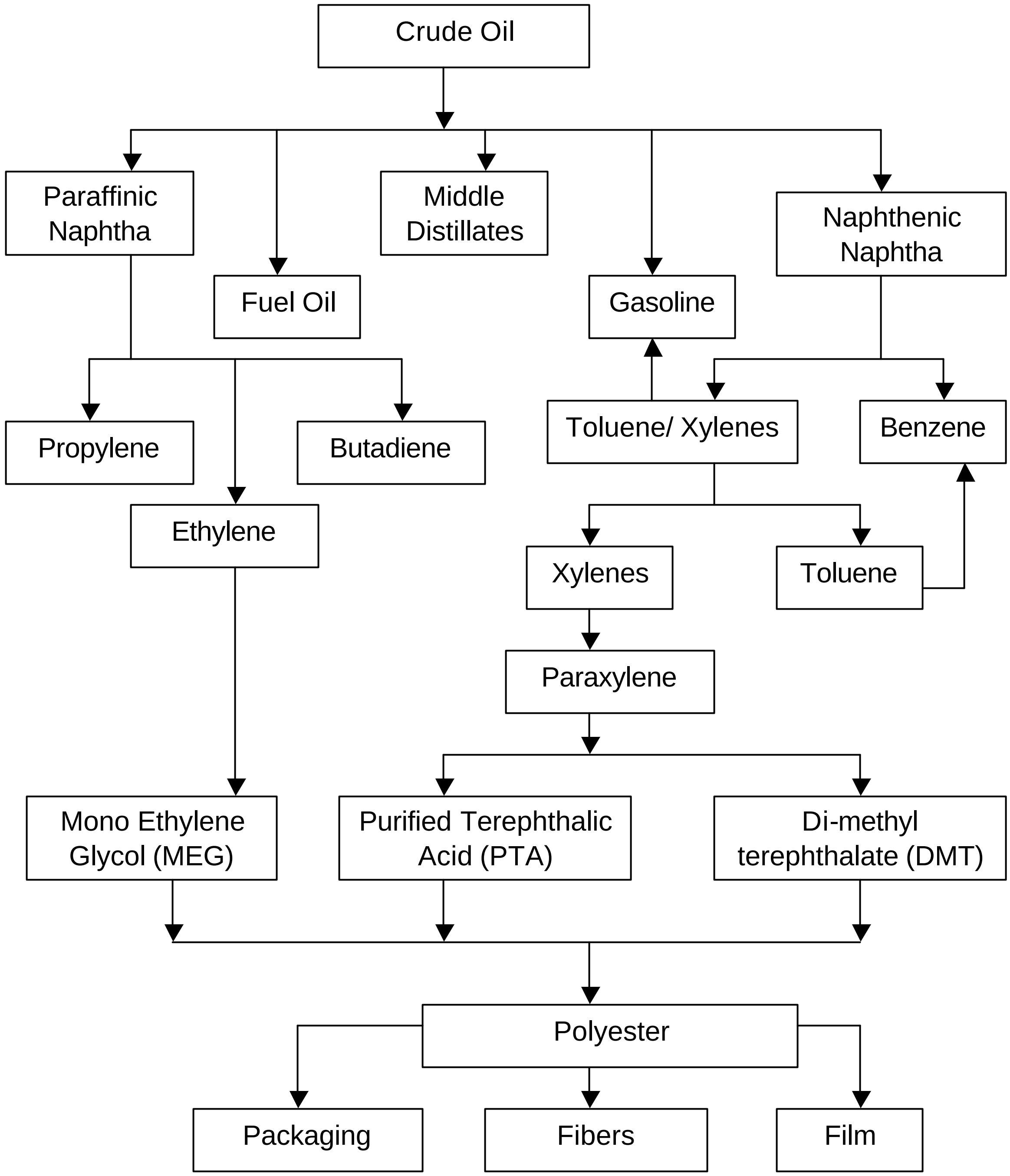


FIGURE 3.17: SCHEMATIC OF MAN-MADE FIBER CLASSIFICATIONS

Polyester fiber is a downstream derivative of crude oil, obtained after processing through several intermediates, importantly, purified terephthalic acid, dimethyl terephthalate and monoethylene glycol. This forms the polyester fiber supply chain illustrated in Figure 3.18.

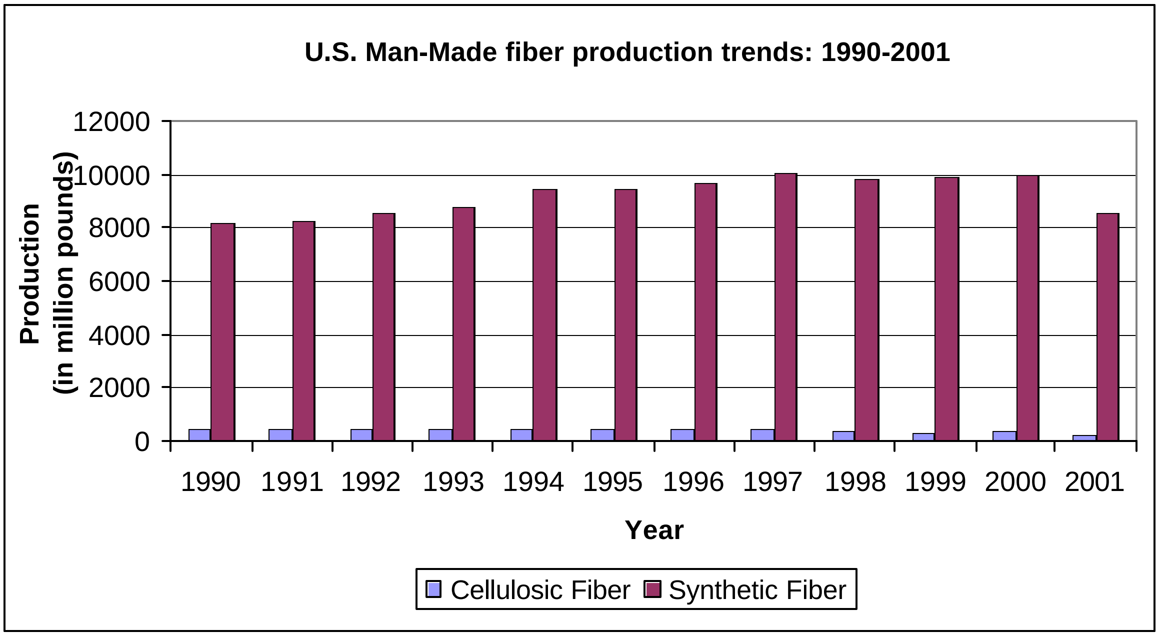


Source: Polyester: Tomorrow's Ideas and Profits, The Textile Institute, 1993

FIGURE 3.18: POLYESTER RAW FIBER SUPPLY CHAIN

3.5.1 Trends in U.S. man-made fiber production

The trends in U.S. man-made fiber production have undergone a significant change over 1990 to 2001 as illustrated in Figure 3.19. Polyester production has decreased from 3195 million pounds to 3082 million pounds in 2001, a decrease of almost 3.5%. Among the man-made fibers, cellulosic fibers have seen the highest decline in production volumes, from 505 million pounds in 1990 to 235 million pounds in 2001, a 53.4% decrease.



Source: Fiber Organon, February 2002

FIGURE 3.19: U.S. SYNTHETIC FIBER PRODUCTION TRENDS: 1990-2001

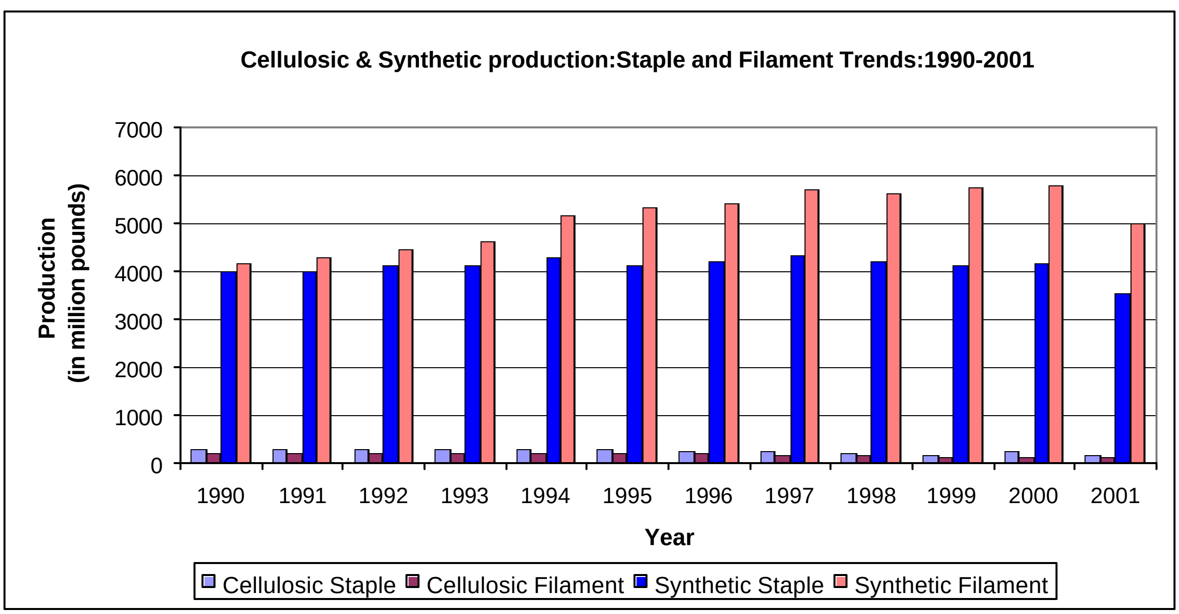
Synthetic fiber production, on the other hand has experienced fluctuating production volumes though still maintaining the 1990 level through 2001. Synthetic fiber production in 2001 was 8536 million pounds, which was an increase of 4.29% over the 1990 level of 8184 million pounds. In this analysis, cellulosic fiber production is comprised of rayon and acetate in filament and staple forms. Synthetic fiber production is the sum of the nylon, polyester, acrylic and olefin fibers in filament and staple form.

Considering the cellulosic and synthetic fiber production in terms of staple and filament individually can provide a further understanding of the trends in man-made fiber production as presented in Table 3.1. The average annual growth rates of cellulosic and synthetic staple and filament are reflective of year-to-year changes and hence provide a trend. While cellulosic fibers have witnessed all-round decline in both staple and filament, synthetic fibers have witnessed increasing growth of 1.6% in yarn and filament over the preceding ten-year period as illustrated in Figure 3.2. However, polyester staple production experienced increasingly slowing growth rates in 1990-2001 compared to 1981-1991.

Table 3.1: Average annual growth rates in man-made fibers

	1981-1991	1991-2001
Cellulosic Filament Yarn	-3.5%	-7.7%
Cellulosic Staple	-5.2%	-6.5%
Synthetic Filament Yarn	1.2%	1.6%
Synthetic Staple	-0.5%	-1.2%

Source: Fiber Organon, February 2002



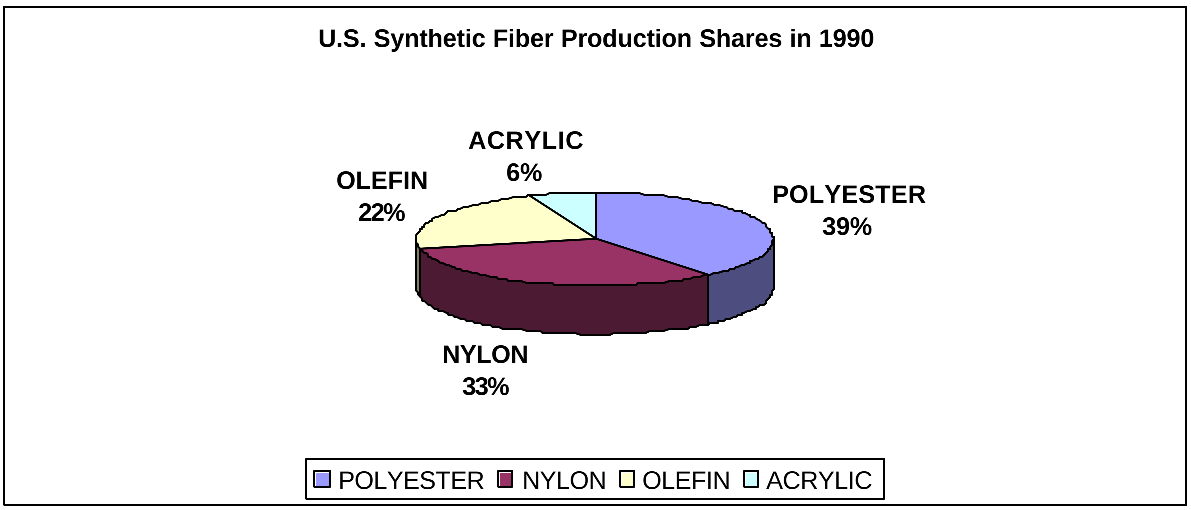
Source: Fiber Organon, February 2002

FIGURE 3.20: U.S. CELLULOSIC AND SYNTHETIC FIBER: STAPLE AND FILAMENT PRODUCTION TRENDS

Synthetic fibers experienced a strong average annual production growth of 2.97% during the first half of the decade touching the decades' highest increase in growth of 7.6% in 1994. On a volume basis, 1997 production of 10067 million pounds was the highest.

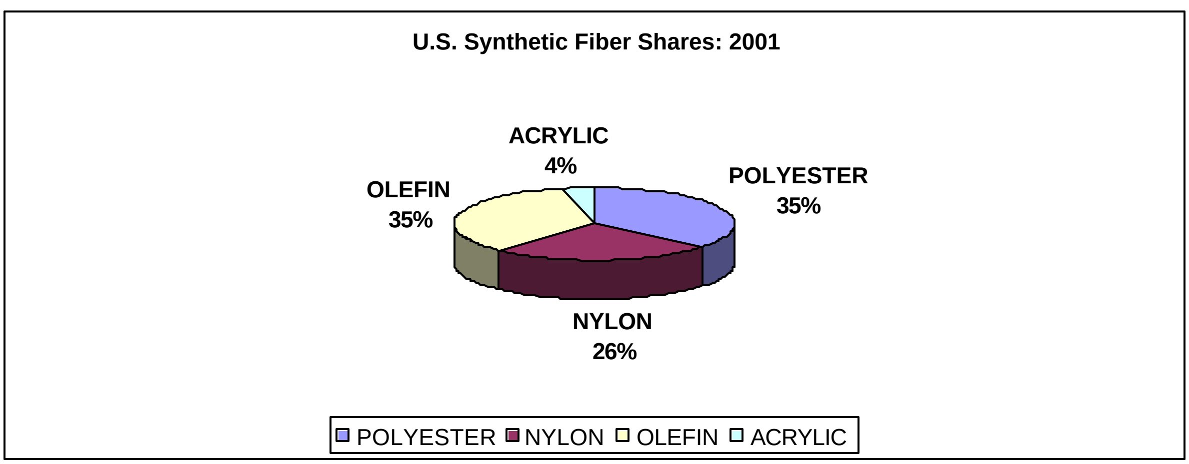
3.5.2 Trends in U.S. synthetic fiber production

The U.S. synthetic fiber production scenario has witnessed a shift in production share towards olefin fiber. The effect of this shift is illustrated and quantified by the Figures 3.21 and 3.22 illustrating the production shares of synthetic fiber, by fiber type in 1990 and 2001.



Source: Fiber Organon, February 2002

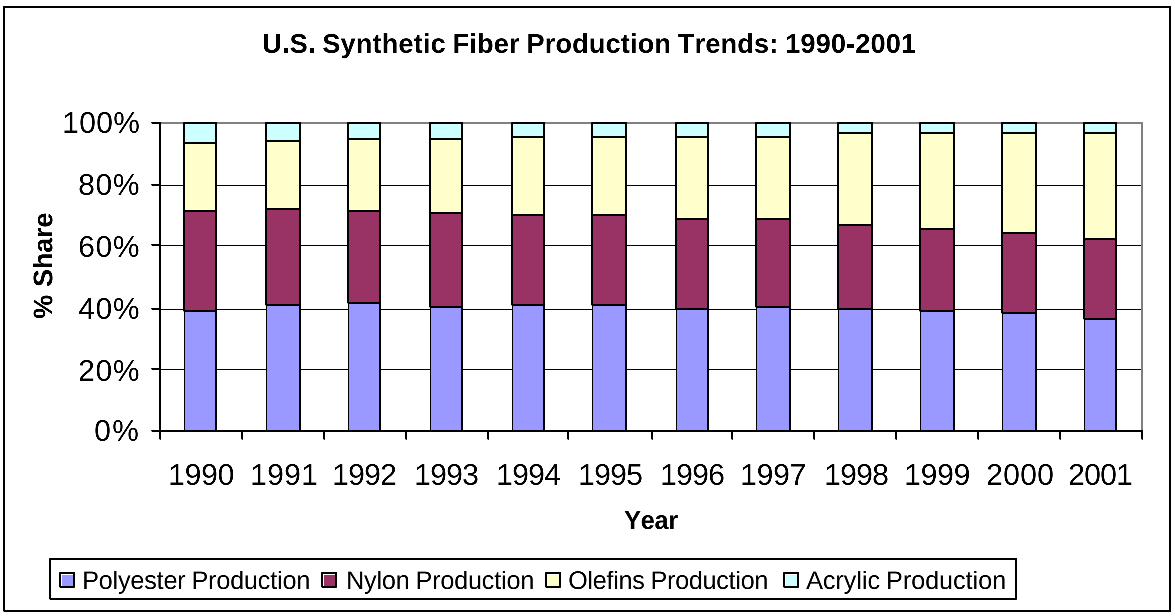
FIGURE 3.21: SYNTHETIC FIBER PRODUCTION SHARES BY FIBER TYPE: 1990



Source: Fiber Organon, February 2002

FIGURE 3.22: SYNTHETIC FIBER PRODUCTION SHARES BY FIBER TYPE: 2001

Figures 3.22 and 3.23 illustrate the gradual decline in polyester's share of U.S. man-made fiber production though its decline was second only to nylon fiber. The 13% increase in olefin fiber production volume can be attributed to the growing demand for olefin fibers from the non-woven industry. With the current share distribution, polyester along with olefin fibers are currently the largest produced fibers.



Source: Fiber Organon, February 2002

FIGURE 3.23: U.S. SYNTHETIC FIBER PRODUCTION SHARE TRENDS: 1990-2001

Table 3.2 further highlights the observation made above about polyester's declining production growth rate and the rise in olefin fiber production growth rate.

Table 3.2: Annual U.S. production growth of synthetic fibers by fiber type

	Polyester	Nylon	Olefin	Acrylic
Staple	-0.58%	-0.25%	5.73%	-4.15%
Filament Yarn	1.01%	-4.13%	4.35%	N.A.
Total	-0.05%	-1.57%	4.62%	-4.15%

Source: Fiber Organon, February 2002

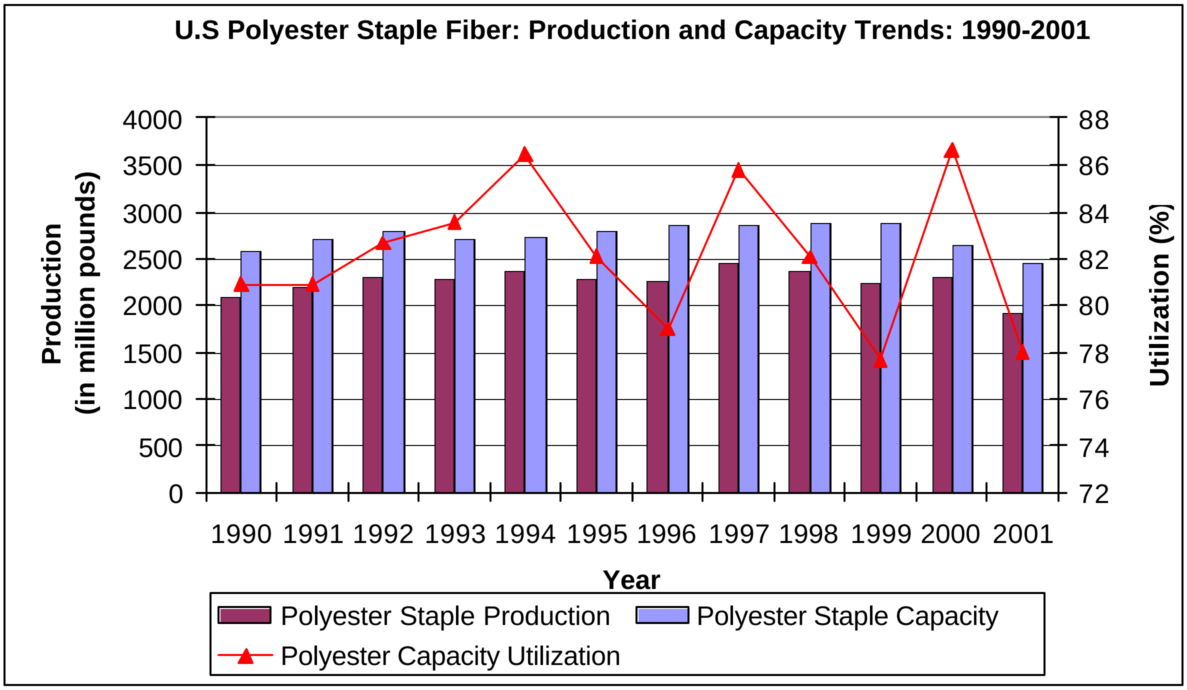
3.5.3 U.S. polyester staple and filament production analysis from 1990 to 2001

The supply of U.S. polyester is analyzed from two standpoints. The first is the analysis of U.S. production, capacity and utilization rates of polyester staple and filament production capacities. This provides an understanding of the fiber manufacturers response to fiber supply estimates. Secondly, total U.S. polyester supply is the sum of domestic producers shipments and the imports will provide an understanding of the extent and influence of raw fiber imports. The analysis of polyester fiber supply presented in sections 3.7.4 and 3.7.5 has been divided on the basis of polyester staple and polyester filament since the supply trends of each of these categories are unique due to their varying end use applications.

3.5.4 U.S. polyester staple fiber supply analysis from 1990 to 2001

The analysis of the U.S. polyester staple fiber supply in this section is analyzed from the standpoint of production, capacity, utilization, domestic shipments and imports**.** In this analysis, domestic producers shipments and production track each other pretty closely and hence consideration of any one of these terms is a valid substitute for the other. All of the analysis is based on data sourced from the Fiber Organon published by the Fiber Economics Bureau (FEB) of the American Fiber Manufacturers Association (AFMA) [37,38,4].

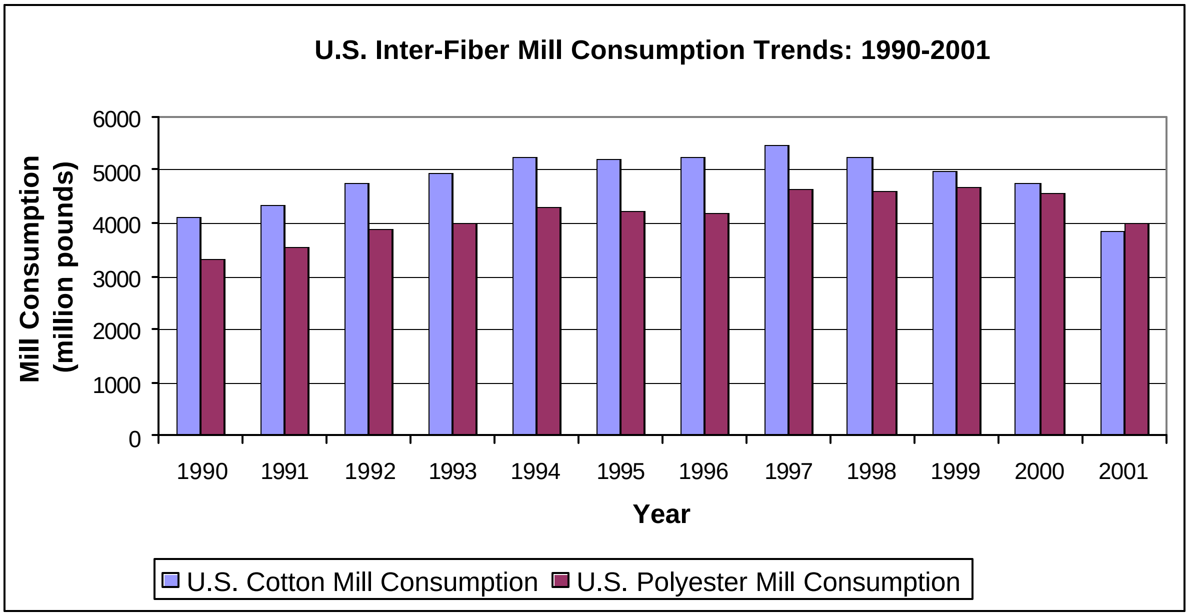
At the start of the decade in 1990, polyester production and capacity utilization showed an increasing trend as illustrated in Figure 3.24. This was in large measure due to the softening of polyester intermediate prices, right after the resolution of the Middle East crisis, due to lower crude oil and benzene prices that decide polyester pricing [39]. Polyester capacity utilization, also known as the operating rate, recorded an average annual growth rate of 82.14% over 1990 to 2001. Polyester staple capacity increased in 1991 over 1990 though utilization remained flat at 80.90%. Meanwhile, production of polyester staple jumped 5.4% and 4.7% in 1990 and 1991 respectively before flattening out in 1996. The sluggishness in polyester staple production, which primarily finds use in woven textiles, was due to greater cotton consumption in 1990 and 1991 [40,41].



Source: Fiber Organon, July 2002

FIGURE 3.24: POLYESTER STAPLE FIBER PRODUCTION AND CAPACITY TRENDS: 1990-2001

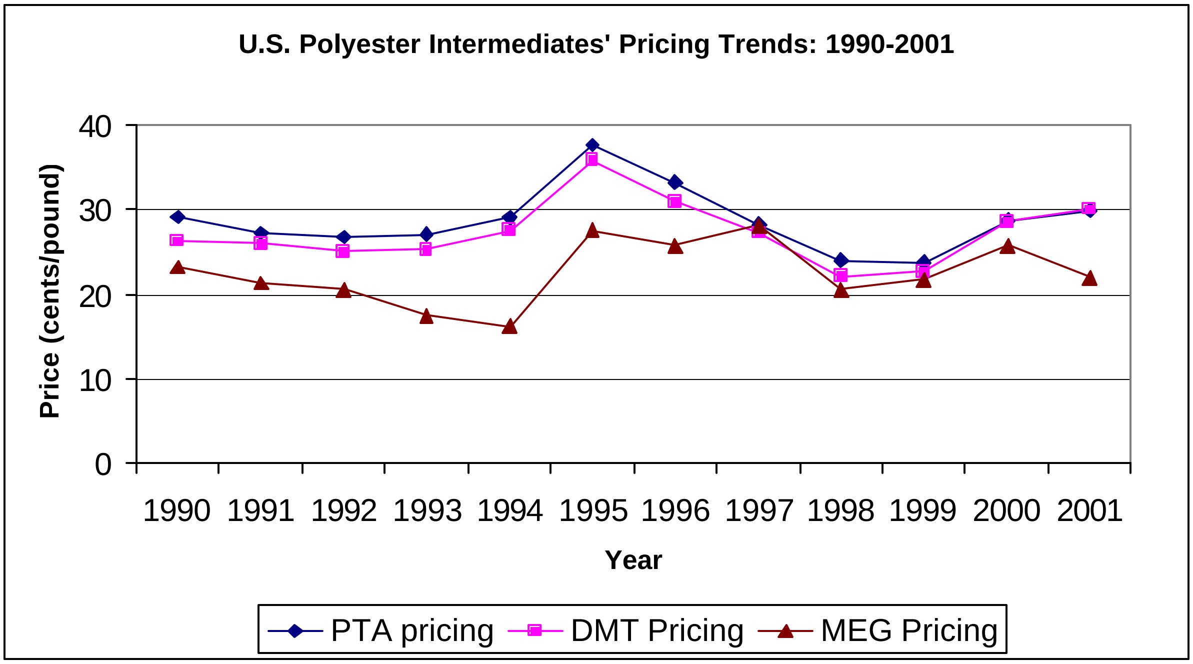
Simultaneously, cotton's share of mill consumption rose to a 20-year high of 33% in 1991 as illustrated in Figure 3.25.



Sources: Fiber Organon, February 2002 and USDA Cotton and Wool Situation and Outlook Report: November 2001

FIGURE 3.25: U.S. INTER-FIBER MILL CONSUMPTION TRENDS: 1990-2001

Polyester intermediate prices, especially mono-ethylene glycol (MEG), fell sharply to almost 20 cents/pound in 1990 from almost 42 cents/pound in 1989 as illustrated in Figure 3.26. Polyester staple capacity utilization further continued to increase from the 80.90% in 1991 to 86.42% in 1994. Declining polyester raw material prices and increasing competition from cotton for mill-use saw average staple capacity fluctuate from 2583.50 million pounds to a high of 2790.50 million pounds in 1992 to again fall to 2738 million pounds in 1994. The decline in polyester raw material prices, which are all influenced by crude-oil prices, was due to the resolution of the crisis in the Persian Gulf in 1990, further pushing prices downward until 1995 [41]. In this period, PTA and DMT pricing gradually stabilized in the 27 cents/pound and 25-cents/pound range before reaching their highest levels for the period 1990 to 2001.



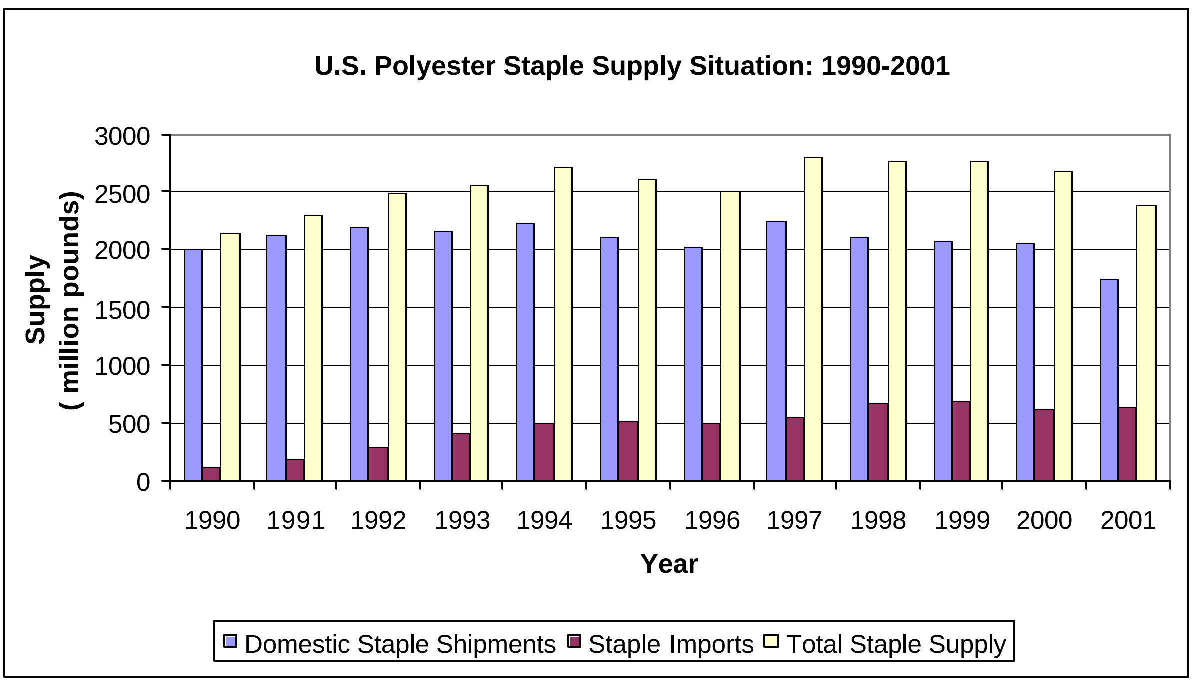
Source: Chemical Market Associates International

FIGURE 3.26: POLYESTER INTERMEDIATES PRICING TRENDS: 1990-2001

PTA prices touched 37.64 cents/pound while DMT touched a high of 35.78 cents/pound along with MEG at 27.50 cents/pound. The raw material price increases sparked off a slide in polyester staple capacity utilization to 82.10% in 1996 before touching a low of 78.98% in 1996. Corresponding to this decline, staple production declined by 3.23% and 1.32% in 1995 and 1996 over previous year levels to reach 2289.8 million pounds and 2259.6 million pounds respectively as illustrated in figure 3.32. Staple imports increased during this period to 510.26 and 490.70 million pounds respectively. Polyester staple production and utilization rebounded to record increases of 8.26% and 6.65% respectively in 1997. These increases can be accounted for by the increase in polyester share in woven textile fabric and knit fabric production [33,34].

Polyester raw material prices underwent stabilization with DMT and PTA pricing declining to 28.17 cents/pound and 27.15 cents/pound respectively while MEG prices increased slightly by almost 3 cents/pound to 28.13 cents/pound. Staple capacity utilization dropped successively in 1998 and 1999 to 82.05% and 77.67% respectively due to a 5.3% drop in production in 1998 followed by a modest 2.83%

increase in 1999. However, polyester staple capacity also increased from 2851 million pounds to 2872 million pounds in this period, and contributed partially to the drop in utilization as illustrated in Figure 3.27 [35]. Raw material prices remained stable during 1998 and 1999, though a surge in imports by 19.18% and 4.04% resulted in the largest polyester staple import levels since 1995 at 663 million pounds and 690 million pounds respectively. As such polyester staple imports had increased from just 123 million pounds in 1990 to 663 million pounds in 1999, recording a large 460% increase. The largest transformation over 2000 and 2001 was the reduction in staple production capacity by almost 1.47% and 13.76% respectively with olefin fiber capacity surpassing polyester fiber for the first time ever [33]. As is evident from Figure 3.27, domestic shipments of polyester staple increased marginally by 2.83% to 2295 million pounds in 2000 to again decrease in 2001 by 16.69% to 1912 million pounds.



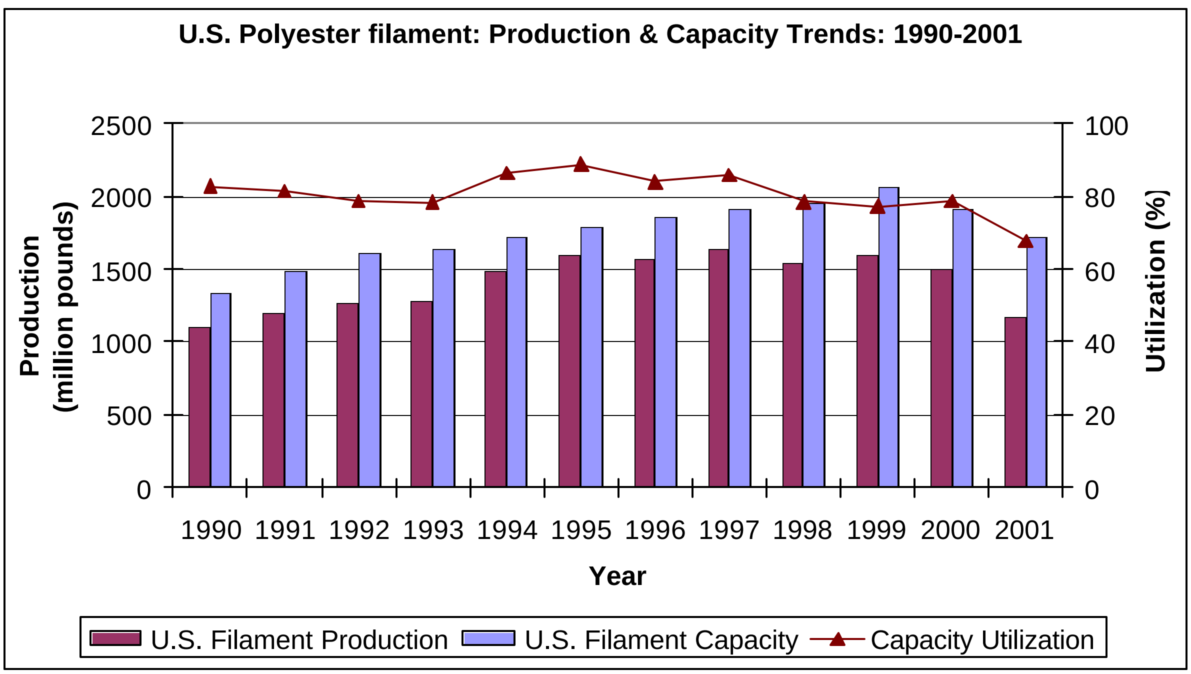
Source: Fiber Organon, February 2002

FIGURE 3.27: U.S. STAPLE SUPPLY SITUATION: 1990-2001

Correspondingly, staple imports initially declined by 10.10% and increased by 2.71% in 2000 and 2001 respectively. This fluctuation in U.S. polyester staple production and capacity utilization with import volumes proves that the competitiveness of the U.S. polyester staple industry is now largely a function of import competitiveness.

3.5.5 U.S. polyester filament supply analysis from 1990 to 2001

The U.S. polyester filament industry is smaller in production volumes compared to the polyester staple industry as seen in Figure 3.28. Average staple production for 1990-2001 was 2252.58 million pounds while polyester filament production averaged 1415.30 million pounds. Average production shares for polyester filament and staple are nearly 38% and 62% respectively.



Source: Fiber Organon, July 2002

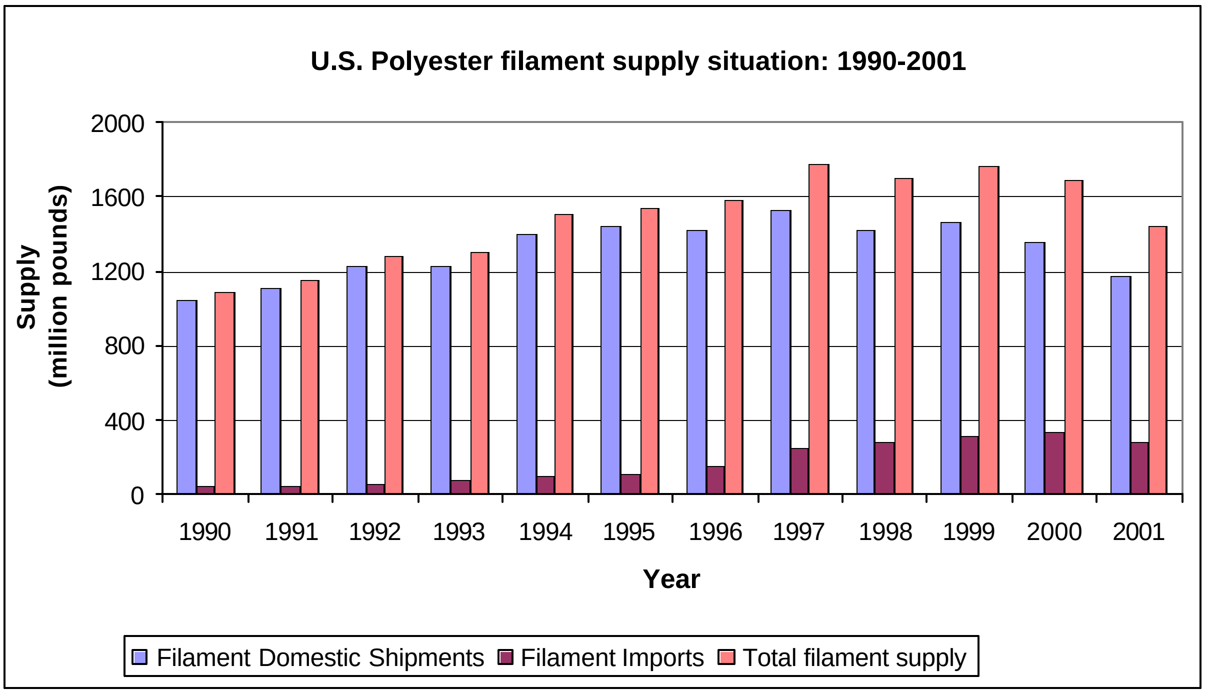
FIGURE 3.28: POLYESTER FILAMENT PRODUCTION AND CAPACITY TRENDS: 1990-2001

The most significant difference between polyester staple and filament capacity trends was the gradual capacity addition averaging a growth rate of 2.54% over 1990 to 2001. Polyester filament production is lower than staple as the largest end-use segment of apparel and clothing is dominated by staple fiber. Polyester filament demand was primarily in double knit outerwear fabric almost till 1990, even though volumes declined almost 11% in 1990 due to declining consumer preference [26]. Also, cotton's mill consumption, a reflection of increased consumer preference, in 1990 drove overall polyester fiber consumption down until 1996 when polyester consumption rebounded to eventually slightly exceed cotton consumption in 2001.

However, reversing this initial decline, polyester filament production witnessed initially moderate increases of almost 5.03% and 1.23% in 1991 and 1992 followed by a 16.17% jump in 1994 over 1993 volumes. This increase was due to major filament capacity additions in order to fulfill demand for polyester in tire cord and industrial fabrics [27,42]. Polyester filament capacity increased to 1723 million pounds in 2001, an increase of 29.06% over 1990. Polyester filament production and domestic shipments remained fairly stable over 1992 and 1993, especially in polyester textile filament due to increase in beginning stock levels by 5% and 33% respectively in 1992 and 1993 respectively [28,43]. The polyester utilization rate touched a peak of 85.58% causing a 16.17% jump in production, reflected in the 3% increase in polyester share among man-made fibers of its largest end-use segment of woven textile production to almost 63%. Meanwhile, polyester continued to maintain its almost 60% share among man-made fibers of the knit fabric market [28,32].

Almost flat production volumes, punctuated by a slight 1.64% decrease in 1996 followed by a 4.71% rebound into 1997, marked the U.S. polyester production situation. Polyester filament production stayed almost flat, fluctuating between 1541 million pounds and 1596 million pounds between 1995 and 1998 while capacity addition continued an increasing trend averaging an annual growth rate of 3.55% in the same period. Polyester production fluctuations could be attributed to polyester's share of man-made fibers in knit fabrics decreasing from 63% in 1995 to just 52% in 1996, primarily due to nylon's share increase from 20% to 31% in the same period. Additionally, polyester share of man-made fiber consumption in woven fabrics also dropped by 3% to 60% in 1996. In the post-1997 period, production volumes started declining and for the first time polyester capacity growth showed a decline going into

2001. In the light of this dramatic decline, it is impossible to ignore the effect of rising polyester imports. A study by Credit Suisse First Boston reveals that this situation was primarily due to rapid Asian capacity growth creating excess capacity and an unfavorable pricing situation for U.S. producers [44]. FEB data on imports of Polyester filament supports this argument, wherein average annual growth rate of polyester filament imports stood at 21.09 for 1990 to 2001, a period when imports share of total domestic polyester filament supply rose from just 3.85% to 19.20% as seen in figure 3.29.



Source: Fiber Organon, February 2002

FIGURE 3.29: U.S. POLYESTER FILAMENT SUPPLY SITUATION: 1990-2001

3.6 Summary of cotton and polyester supply analysis

The analysis of the supply situation in the U.S. cotton and polyester fibers market presented in the previous sections highlight the fact that U.S. cotton and polyester fiber production influences the U.S. cotton available supply and by consequence the U.S. cotton prices that in turn affect U.S. mill demand. This is because a rise in U.S. cotton prices would either cause U.S. spinning mills to buy foreign cotton or minimize production and source the yarn demand through imports. This in turn poses an interesting situation for U.S. end use demand for cotton. The need to import cotton yarn would throw up the situation of directly importing finished end-use products from the same foreign suppliers, especially if Asian countries that could provide cheaper import substitutes. This aspect will be presented in chapter 4, which presents an analysis of U.S. end use demand for cotton and polyester fiber. Specifically, the inter-relationships between the widening U.S. cotton and polyester textile deficits, fiber pricing, U.S. economic conditions and U.S. mill demand (drawn from the supply analysis in chapter 3) are discussed. On the basis of these inter-relationships, the econometric model will be developed in Chapter 6.

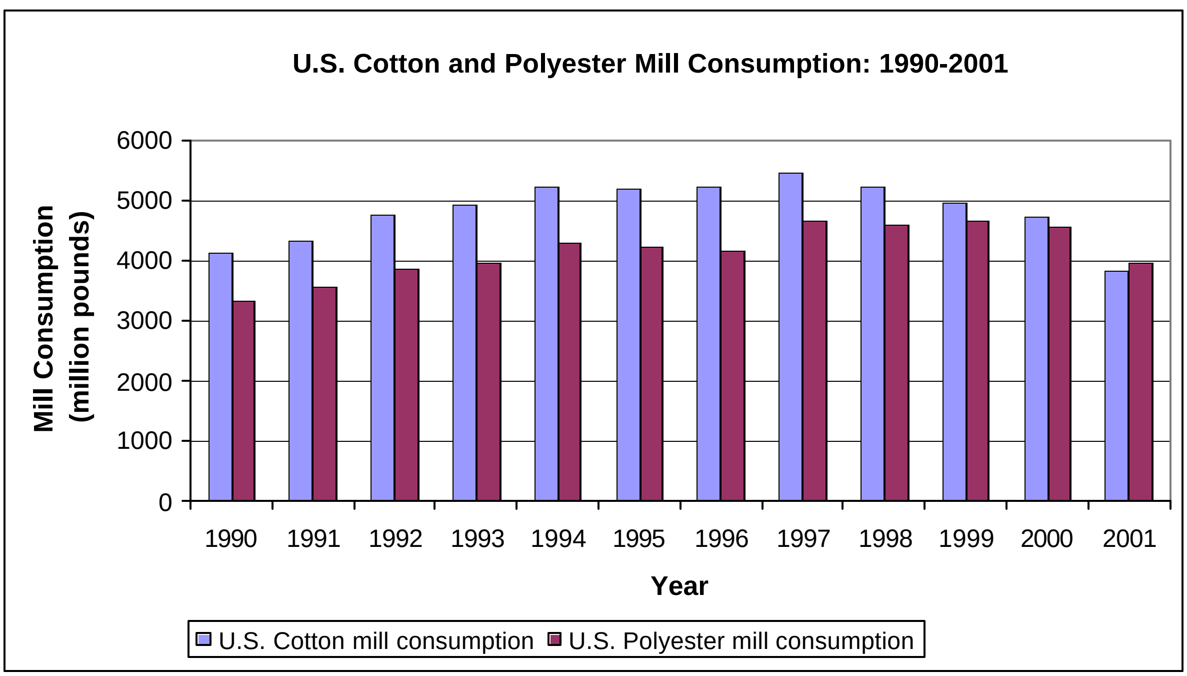
4.

U.S. Cotton and Polyester demand analysis

The aim of this study is to develop an econometric model to estimate cotton and polyester demand at mill use and end use consumption levels. Chapter 3 discussed the supply situation for cotton and polyester fibers that in turn feeds the demand for these two fibers. Chapter 4 discusses cotton and polyester fiber demand and the factors influencing them from 1990 to 2001. These determinants of cotton and polyester fiber demand will later provide the basis for developing the demand estimation models in Chapter 5.

4.1 Inter-fiber mill demand analysis

This section analyzes the trends in U.S. cotton and polyester fibers mill use from 1990 to 2001 illustrated in Figure 4.1.

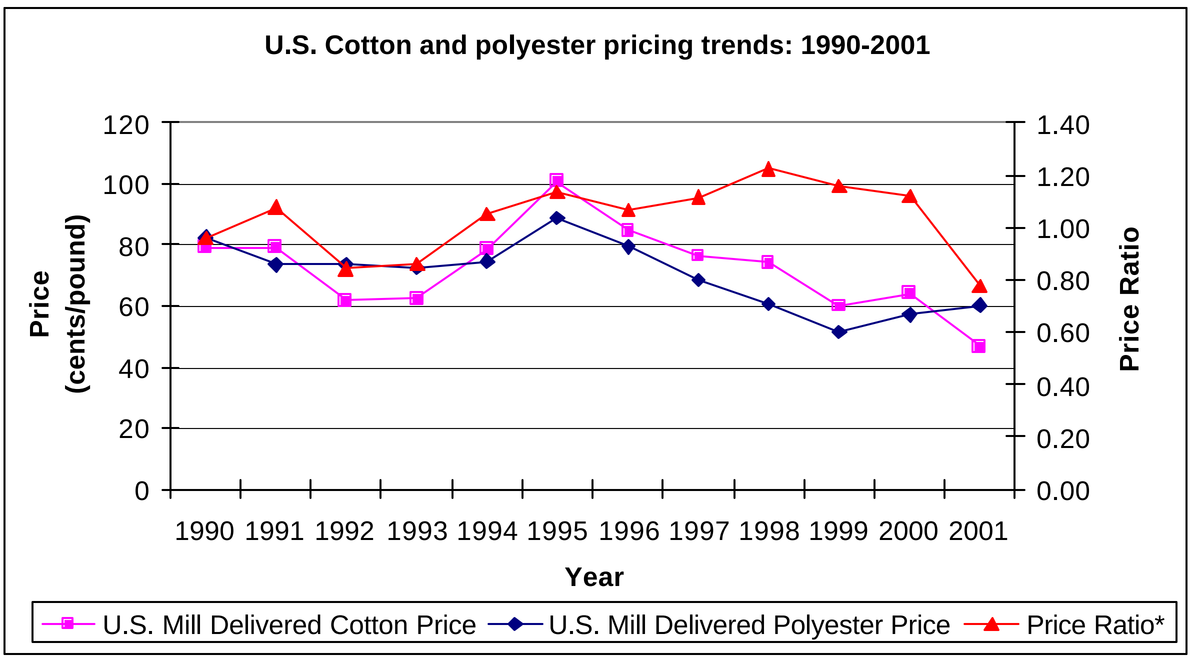


Sources: Fiber Organon, March 2002, Manufactured Fiber Producers Handbook and USDA Cotton and Wool Situation and Outlook Report: November 2001

FIGURE 4.1: U.S. COTTON AND POLYESTER MILL CONSUMPTION TRENDS: 1990-2001

During the period from 1990 to 2001 cotton share of mill use declined from 33.3% to 27.6% in 2001 [3]. U.S. cotton mill use in 1991 increased by 5.64% to reach 4347 million pounds over 1990 levels. Similarly, polyester mill-use also registered a 6.62% rise, increasing from 3335 million pounds to 3555 million pounds. The rise in cotton mill consumption, in this period was primarily due to cotton supply increasing almost 8% from 8884 million pounds in 1990 to 9586 million pounds in 1991 and continued consumer preference for cotton fibers [45].

Competitive increases in polyester mill use were due to polyester mill delivered prices declining almost 11% to 73.50 cents/pound in 1991 from 1990 as seen in Figure 4.2. More importantly, the cotton to polyester mill delivered price ratio, which is considered an index for measuring inter-fiber substitution declined from 1.04 to 0.93, reflecting polyester fibers' increasing competitiveness [45].



* Price ratio is cotton mill delivered price divided by polyester mill delivered price for a given year

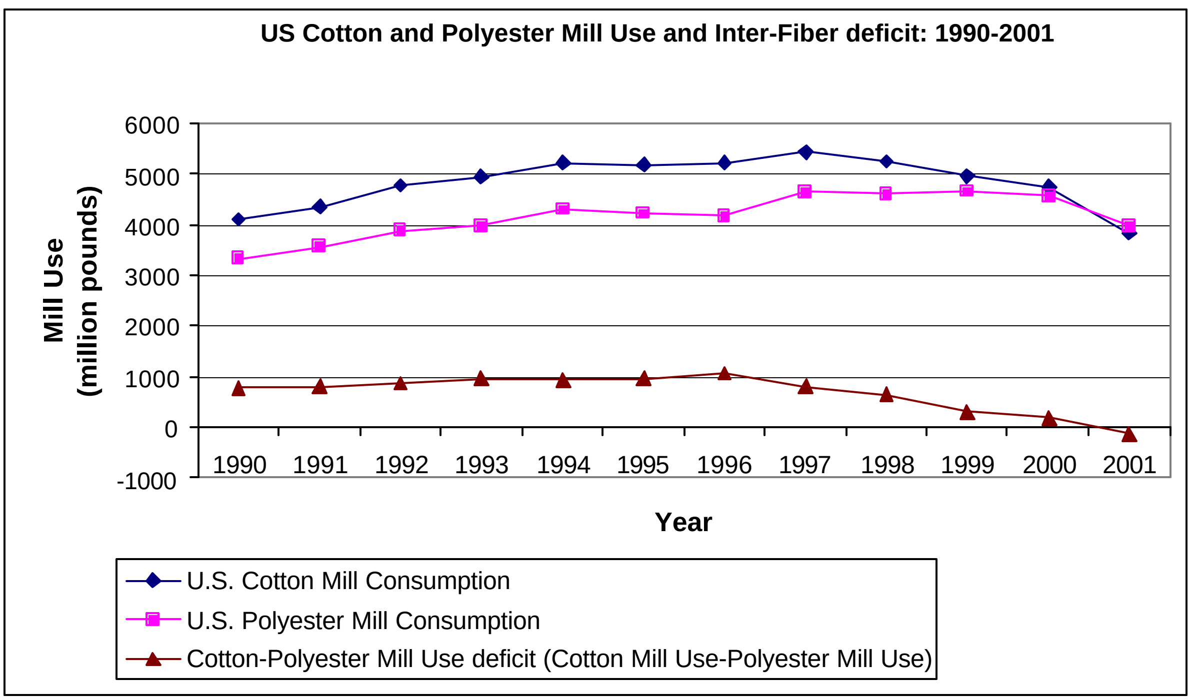
Source: National Cotton Council (NCC) of America

FIGURE 4.2: U.S. COTTON AND POLYESTER PRICING TRENDS: 1990-2001

Cotton mill use further continued its increasing trend into 1992 rising 9.53% over 1991 to 4761 million pounds. This increase was primarily due to strong demand for upland cotton for denim manufacture and decline in U.S. mill delivered cotton prices from 79.07 cents/pound in 1991 to 61.92 cents/pound in 1992. On the other hand, polyester prices stood firm at the 1991 level of 73.50 cents/pound thereby retaining its price competitiveness to boost its mill-use by 9.20% to reach 3883 million pounds in 1992. Further, the price ratio increased despite cotton price declines due to polyester staying steady at 73.50 cents/pound in 1992. Polyester fiber mill consumption increases were derived mostly due to share increases in the woven textile products and knitted fabric end-use segments [28,46]. In 1993, cotton mill use increased by 3.70% while polyester mill-use growth was a modest 2.49% primarily due to continued strong demand from denim and foreign demand for U.S. cotton products [31]. Continuing with this trend, cotton mill-use surged by 5.93% to 5231 million pounds in 1994, recording the highest U.S. mill consumption since 1980. This combined with record raw cotton exports of 4512 million pounds sharply increased cotton prices from the previous year level of 62.41cents/pound to 78.69 cents/pound. Corresponding to this increase, the cotton-to-polyester price ratio surged from 0.86 in 1993 to 1.05 in 1994. Polyester mill use also increased 7.99% to 3979 million pounds. The simultaneous increase in cotton and polyester mill use could be attributed to the overall rise in economic activity reflected in U.S. real GDP growth of 3.7% over 1993 [30].

U.S. mill-delivered cotton prices hit a peak of almost 100 cents/pound, the highest since 1980, largely due to raw cotton demand more than offsetting production [33]. U.S. polyester mill-delivered prices increased to their highest levels since 1980 to 88.83 cents/pound reflecting increased raw material prices as seen in Figure 4.2. This marked the continuation of a new trend beginning 1994 when, polyester fiber prices slipped below cotton prices. This new development extended into a long 7-year trend up to 2000. Further, U.S. final domestic demand growth on a year-to-year basis fell to 2.5% from 2.9% in 1994 [30]. Owing to the cotton price increase and general slowdown in final domestic demand, cotton mill-use in 1995 declined almost 1% to 5183 million pounds [21]. The overall slowdown in demand was reflected in polyester mill-use declining 1.82% to 4219 million pounds. U.S.

economic demand in 1996 reversed its decline in 1995 to record 3% GDP growth and 3.2% rise in final domestic demand [30]. Cotton mill use increased marginally by 0.84% due to strong demand for denim products and U.S. textile exports [34]. The cotton and polyester mill use in 1997 recorded increases of 4.11% and 11.63% respectively as seen in Figure 4.3. The increase in cotton demand was largely due to strong expansion in the U.S. economic growth reflected in the 3.4% GDP growth and increased trade under the North American Free Trade Agreement (NAFTA) [30,35]. Polyester growth was even better due to its price competitiveness, which was reflected in the increase of the price ratio (ratio of cotton fiber price to polyester fiber price) from 1.07 to 1.11. The consumption of cotton and polyester fibers by the mill sector from 1998 to 2001 presents significant differences from the previous 7-year period from 1990 to 1996.



Sources: Fiber Organon, March 2002 and USDA Cotton and Wool Situation and Outlook Report: November 2001

FIGURE 4.3: U.S. COTTON AND POLYESTER MILL USE AND INTER-FIBER DEFICIT: 1990-2001

This period was marked by an uninterrupted decline in cotton mill consumption and increasing polyester mill use and increased widening in the textile trade deficit for both fibers. Correspondingly, U.S. cotton mill use in 2001 declined by 26.4% to 3848 million pounds over 1998 levels. As seen in Figure 4.3, polyester mill use relative to cotton increased as reflected in the decreasing inter-fiber deficit to finally overtake cotton consumption in 2001. Correspondingly, polyester share of mill-use relative to cotton narrowed over 1998 to 2000 and finally overtook cotton share in 2001 for the first time since 1990. In actual mill use consumption terms polyester fiber fluctuated around 4600 million pounds from 1998-2000. In 2001, cotton mill use plunged to its lowest level since 1990 to reach 3848 million pounds while polyester declined to 3979 million pounds. In percentage terms, cotton declined 18.93% over 2000 while polyester's slide was lesser at 12.64%. In 2001, polyester mill consumption at 3979 million pounds ended ultimately higher than cotton mill consumption that was 3848 million pounds thus firmly establishing polyester's competitive edge over cotton at the mill level.

4.2 Determinants of U.S. cotton and polyester fiber mill demand

From the analysis of cotton and polyester inter-fiber mill demand presented in section 4.1, it would be possible to derive certain key determinants that influence cotton and polyester mill demand. Drawing from this discussion, past research literature (see chapter 2) and the added dimension of cotton promotion effects, this section will provide an understanding of the underlying drivers of U.S. cotton and polyester demand.

The analysis of mill demand from the review of previous literature (see chapter 2) demonstrated a consistent pattern of quantifying cotton mill demand (CMD) relative to competitive man-made fibers, of which polyester was the leading direct substitute for cotton at the mill level. However, not a single model found in the literature estimated polyester mill demand, despite its recognition as the direct substitute, as reflected in the inclusion of polyester price in cotton mill demand (CMD) models rather than nylon or olefin synthetic fibers. Evans [8] hypothesized that cotton mill demand was influenced by total domestic fiber consumption as well as cotton and polyester fiber prices for the period 1955 to 1976. Two separate equations were developed to test the hypothesis. The first equation that estimated total fiber consumption (all fibers) is presented below (with t-values in parentheses).

$$LDFP = 1.18 - 0.92\ L\ (PTX/PCEP) - 0.104\ LT$$
$$(14.6) \qquad (9.1) \qquad\qquad (3.4)$$

where,

L denotes natural logarithm,

DFP denotes total fiber consumption in pounds per capita,

PTX denotes wholesale price index of textile and apparel products,

PCEP denotes total per capita personal consumption expenditures, and

T denotes time (where 1955 =1).

Evans estimated U.S. cotton mill demand separately with a second set of equations using an Ordinary Least Squares (OLS) regression technique. Evans [8] presented three satisfactory equations for estimating U.S. cotton mill demand. From the equations presented below it is evident that that Evans' hypothesized that U.S. cotton mill demand was influenced by total fiber consumption, cotton fiber price and polyester fiber price. However, both price ratio (cotton price divided by polyester price) as well as prices were found to produce satisfactory models.

$$LQCMP = 1.55 \ + 0.33\ L\ DFP - 0.35\ L\ \frac{(PCT_{t-1})}{(PPOL_{t-1})}$$
$$(2.8) \qquad (2.3) \qquad\qquad (8.1)$$

$$LQCMP = 0.70 \ + 0.46\ L\ DFP - 0.32\ L\ (PCT_{t-1}) + 0.40\ (PPOL_{t-1})$$
$$(0.7) \qquad (2.3) \qquad\qquad (5.9) \qquad\qquad (5.9)$$

$$QCMP = 10.2 + 0.17\ DFP - 0.13\ (PCT_{t-1}) + 0.09\ (PPOL_{t-1})$$
$$(2.0) \qquad (2.1) \qquad\qquad (5.4) \qquad\qquad (5.9)$$

where,

L denotes natural logarithm,

QCMP denotes mill consumption of cotton per capita for the calendar year,

DFP denotes domestic fiber consumption in pounds per capita,

PPCT denotes the price of middling 1(1/16) inch cotton price at Group B mill points in cents per pound, and

PPOL denotes the reported average price for 1.5 denier polyester staple for cotton blending in cents per pound.

Evans hypothesized total fiber consumption to be influenced by the ratio of the wholesale price index of textile products and apparel to total per capita personal consumption expenditures (PCE) and a trend variable to represent technological and cultural change. Sanford [7] retained the two-equation approach of Evans, but he added some variation into the explanatory variables of his demand equations to estimate U.S. cotton mill demand from 1960 to 1986.

$$LTFPC = \underset{(-3.5)}{-9.32} - \underset{(-3.7)}{0.18}\ LRCOTP + \underset{(5.0)}{1.78}\ LRCS - \underset{(-2.4)}{0.19}\ LYR$$

R-squared = 0.88, Durbin-Watson d-statistic = 1.85

where,

L indicates natural log,

LTFPC denotes total fiber consumption in pounds per capita,

LRCOTP denotes real cotton price,

LRCS denotes real per capita personal consumption expenditure, and

LYR denotes a trend variable YR, where 1960 =1.

In Sanford's model presented above, the total fiber consumption equation included a price factor to reflect real cotton prices and the income variable was replaced with real PCE per capita while retaining the same time trend variable. Real cotton prices were chosen as a proxy for total fiber price on the assumption that cotton's increased 30% share of total fiber consumption made it representative of general fiber price levels. However, this solution was tried after unsatisfactory attempts to develop a fiber price index that failed due to a positive coefficient for the index. Income was represented by PCE, though disposable personal income (DPI) was initially considered. In the period of that study from 1960 to 1986, consumers had decreased savings and increased borrowing, favoring the use of PCE over DPI as the income variable for a more accurate reflection of total fiber demand.

$$QCMP = 17.17 + 0.191\,(TFPC) - 12.68\,(RATIO) - 0.557\,(YR)$$
$$(12.03) \quad (5.69) \quad (-\,4.87) \quad (-\,2.4)$$

R-squared = 0.98, DW d-statistic = 1.35

where,

QCMP denotes mill consumption of cotton per capita for the calendar year,

TFPC denotes total domestic fiber consumption in pounds per capita,

RATIO denotes cotton price lagged one year divided by polyester price lagged one year, and,

YR is a trend variable where 1961 = 1.

Sanford's mill demand equation presented above was successful in accounting for 98% of the variation in annual per capita U.S. cotton mill demand. This equation provided an improvement over Evans' equations presented earlier that was could account for just over 90% of the variation. However, U.S. cotton mill demand underwent upward revision due to the North American Free Trade Agreement (NAFTA) rising mill-use volumes in 1994-1997 before the onset of consistent decline brought about by a surge in cotton textile imports and widening textile deficit.

Meyer [6] sought to capture these two changes by developing a cotton mill demand model including these two changes. The equations (with t-values in parentheses below) developed are presented below.

Total Fiber Demand Estimation equation:

$$\text{Ln (TFD)} = 2.121 + 0.980 \text{ Ln (DPI)} - 0.178 \text{ Ln (Fiber Price)} + 0.128 \text{ (NAFTA)}$$

$$(12.21) \qquad (-4.68) \qquad (3.85)$$

Adjusted R-squared = 0.9096, DW d-statistic = 1.253

where,

TFD denotes total fiber demand (Sum of total demand for U.S. cotton, man-made and wool fibers) in pounds per capita,

DPI denotes per capita real U.S. disposable personal income,

Fiber Price, denotes nominal U.S. mill delivered cotton price (chosen as proxy for cotton, wool and man-made fiber prices), and

NAFTA is dummy trend variable equal to one in 1994 (NAFTA inception) and zero in prior years.

Cotton Mill Demand Estimation equation:

$$\text{Ln (CMD)} = -2.448 + 1.315 \text{ Ln (TFD)} - 0.494 \text{ Ln (Ratio)} - 0.252 \text{ Ln (Deficit)}$$

$$(7.05) \qquad (-14.31) \qquad (-10.68)$$

$$+ 0.136 \text{ (1 + TradeLib)}$$

$$(5.38)$$

Adjusted r-squared = 0.9312, DW d-statistic = 1.672

where,

CMD denoted U.S. per capita cotton mill demand in pounds per capita,

TFD denotes U.S. total fiber demand in pounds per capita,

Ratio denotes the ration of nominal U.S. cotton mill delivered price lagged by one year divided by the nominal U.S. polyester mill delivered price lagged by one year,

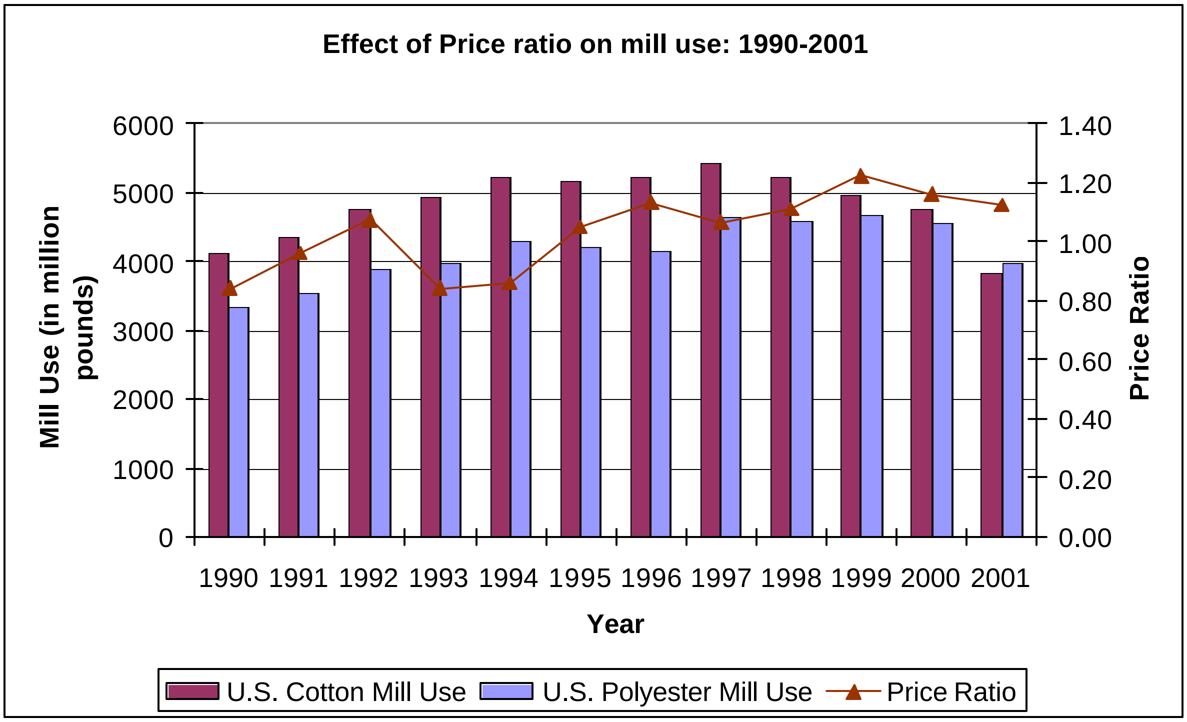
Deficit denotes U.S. per capita cotton textile deficit in pounds per capita (deficit equals U.S. cotton imports minus U.S, cotton exports in raw fiber equivalent), and

TradeLib is a trend variable (1984 = 1 and zero in previous years) multiplied by a dummy equal to one in 1984 and zero in previous years.

Cotton mill demand was hypothesized to be influenced by total fiber demand, ratio of cotton-to-polyester price, cotton textile deficit (represented by cotton textile imports minus cotton textile exports), and a time-trend variable to reflect trade liberalization. Additionally, total fiber demand was hypothesized to be influenced by income, fiber price and exogenous variables which in this case was a trend variable representing the effect of NAFTA. The following section discusses the role of the explanatory variables of price ratio and textile deficit already used by Evans [50], Sanford [7] and Meyer [6]. In addition the effect of technological change in polyester and cotton promotion efforts are investigated. The review of past literature shows no single model that includes the effect of cotton promotion in particular and given its importance it will be included in this study [18].

4.2.1 Cotton to polyester price ratio

In this analysis, price ratio is defined as the ratio of U.S. cotton mill delivered price to polyester mill delivered price. An increase in the ratio indicates that cotton is becoming expensive relative to polyester. Conversely, a decrease in the ratio indicates that polyester is becoming expensive relative to cotton. As seen in figure 4.4, over the study period of 1990 to 2001, an increase in the price ratio shows an increase in U.S. polyester mill demand. In an econometric analysis of textile fiber demand, Lewis [15] established the existence of substitution relationships between synthetic fibers and other fibers. On further analysis of inter-fiber price relationships by Shui et al [9], the existence of significant cross-price elasticity between natural and man-made fibers established the presence of substitution effect between them. This observation was confirmed and further narrowed down by Zhang et al [10] in their analysis of inter-fiber competition in mills over time using a time varying parameter model for 1961-1990. In the models developed in chapter 5, substitution effects are studied in further detail than Shui et al did, since man-made fiber demand was divided into synthetic fiber and cellulosic fiber categories. The estimated coefficients in the model for cotton and rayon fiber prices, were statistically insignificant at the 5% level, which proves that cellulosic fiber was neither a substitute nor a complementary fiber to cotton except during the period of 1982-1985. On the other hand, the consistently, positive coefficient for polyester prices indicated that non-cellulosic or synthetic fiber shares a statistically significant substitution relationship with cotton.



Sources: USDA Cotton and Wool Situation and Outlook Report: November 2001, Fiber Organon, March 2002 and National Cotton Council (NCC) of America

FIGURE 4.4: EFFECT OF PRICE RATIO ON MILL USE: 1990-2001

In volume terms, a change in polyester price by 10 cents per pound would result in a change in cottons share of mill-use by 1.9 to 3.2 percent. Based on this premise three different mill demand models by Evans [8], Sanford [7] and Meyer [6], analyzed the impact of price ratio on cotton mill demand. Meyer [6], states that the price ratio specification measures the competitiveness of cotton with respect to polyester. In his analysis of factors affecting U.S. mill demand for cotton and apparel wool, Sanford [7] arrived at the following equation for cotton mill demand.

$$QCMP = 17.17 + 0.191\ TFPC – 12.68\ RATIO – 0.557\ YR$$

where,

QCMP, denotes U.S. mill consumption per capita

TFPC, denotes total fiber consumption per capita

RATIO, denotes the cotton price lagged by one year divided by the polyester price lagged by one year, and

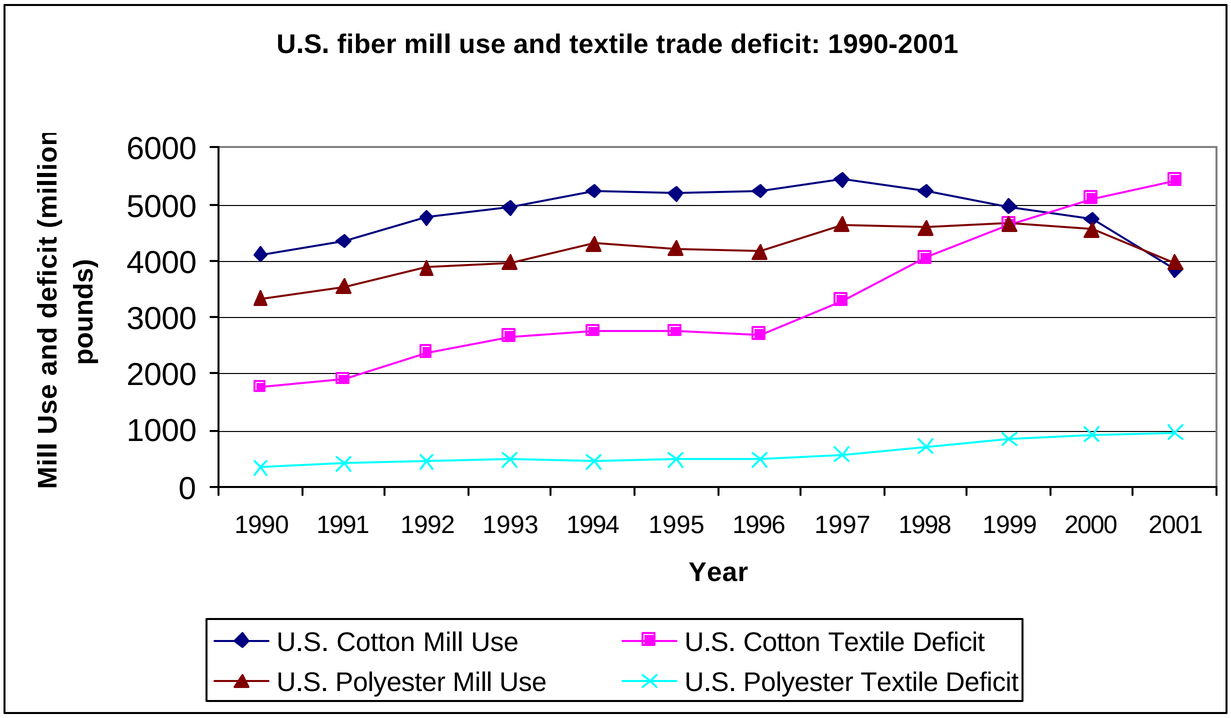
YR is a trend variable.

The negative coefficient of price ratio versus cotton mill demand indicates that as cotton price increases relative to polyester price mills would use lesser cotton. Further, he established that a 10% change in the polyester price would change per capita cotton mill consumption by 3.5 to 4.0 percent over 1955-1976 [8]. The effect of relative fiber price and its influence on cotton mill use was further tested and proven by Meyer [6] in a two stage least squares analysis of U.S. total fiber and cotton mill demand. In this analysis, it was observed that a 10% increase in the price ratio would lower per capita cotton mill demand by nearly 5%. Review of the literature described above revealed the absence of a similar polyester mill demand model. Therefore, this study will develop an additional polyester mill demand OLS model in addition to a cotton mill demand model over the period of 1990 to 2001.

4.2.2 Cotton and polyester textile trade deficit

During the early 1990's the effect of textile imports on cotton and polyester mill use was modest. This trend changed significantly after 1996 especially for cotton mill use due to the surge in the textile deficit as seen in Figure 4.5. This is evidenced by the fact that average annual growth in mill use of cotton was 4.12% from 1990 to 1996. In contrast, the value declined to –8.07% over the next four years. As is evident from Figure 4.5, cotton textile deficit significantly jumped from 3291.69 million pounds in 1997 to 5421.47 million pounds in 2001, representing a 64.7% increase. Polyester on the other hand experienced a 69.9% increase in the same time period from 574.65 million pounds in 1997 to 976.82 million pounds in 2001

[8,26]. This significant change experienced in the 1990's was included in Meyer's model for total fiber and cotton mill demand over 1962 to 1997 [6].



Sources: USDA Cotton and Wool Situation and Outlook Report: November 2001 and Fiber Organon, March 2002

FIGURE 4.5: U.S. FIBER MILL USE AND TEXTILE TRADE DEFICIT: 1990-2001

The following equation from Meyer's analysis for cotton mill demand highlights the impact of cotton textile deficit on cotton mill demand. The t-vales and standard error for this equation are presented in Table 4.1.

Cotton Mill Demand:

$$\text{Ln (CMD)} = -2.448 + 1.315\ \text{Ln (TFD)} - 0.494\ \text{Ln (Ratio)} - 0.252\ \text{Ln (Deficit)} + 0.136\ \text{Ln}(1 + \text{TradeLib})$$

Adjusted R-squared = 0.9312

where,

CMD denotes Cotton Mill Demand,

TFD, denoted total fiber demand,

Ratio, denotes cotton-to-polyester mill delivered prices lagged by one year,

Deficit, denotes cotton textile deficit, and

TradeLib is a trend variable (1984 = 1).

Table 4.1: T-values and Standard error for Meyer's cotton mill demand model

	t-value	Standard Error
TFD	7.05	0.186
Ratio	-14.31	0.035
Deficit	-10.68	0.024
TradeLib	5.38	0.025

Source: Cotton and Wool Situation and Outlook Yearbook, USDA, November 1999

According to this model, a 10% rise in the cotton textile deficit would reduce per capita mill demand by 2.5 percent. This model establishes the influence of textile deficit on cotton mill use as a necessary explanatory variable for a cotton model like the one sought to be developed in this thesis study as it spans from 1990 to 2001.

4.2.3 Cotton promotion initiatives and its impact on mill-level consumption

Past literature on U.S. cotton demand, divides its competitiveness into price and non-price competition [18,47]. Price competition stems from cottons relative pricing with polyester fibers, its chief competitor in mill use. Barlowe et al observed that the established consumption drivers of U.S. cotton are domestic mill use and textile trade deficit. On the other hand, the study points out that non-price competitiveness of cotton stems from cotton promotion activities and continuous technological developments in man-made fibers.

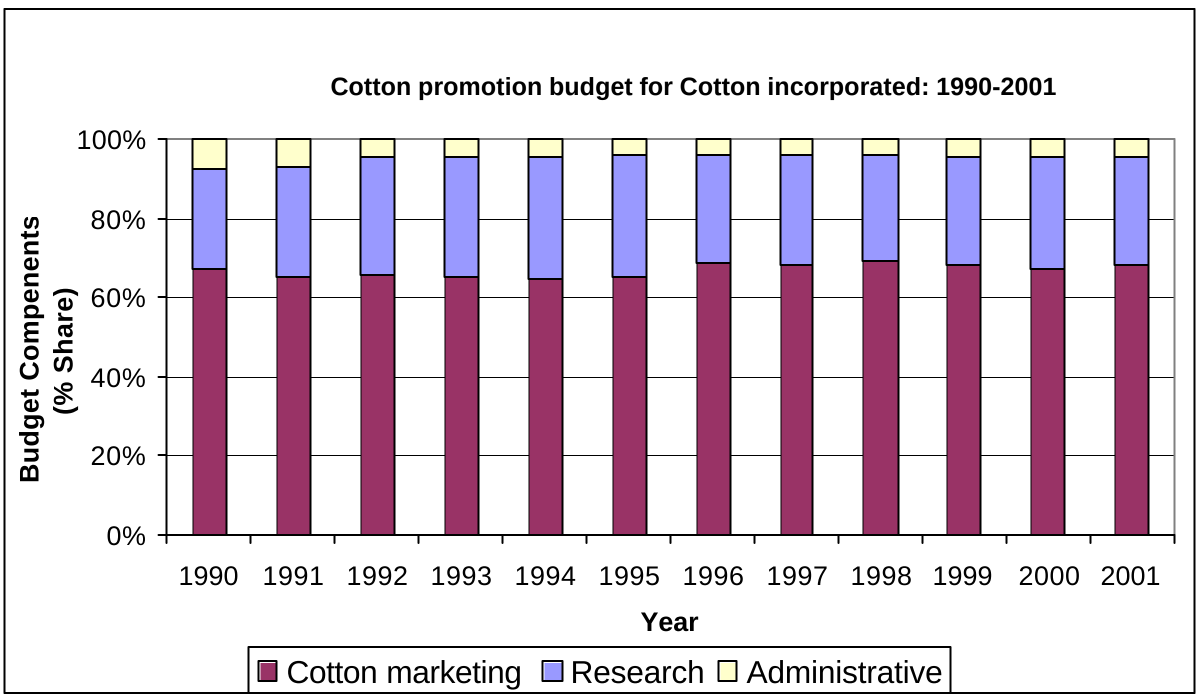
Cotton promotion as an instrument to counter increasing synthetic fiber consumption was initiated with the passage of the Cotton Research and Promotion Act of 1966 [19]. Under this Act, the Cotton Board contracted cotton marketing and promotion programs to Cotton Incorporated, with a fund allocated for promotion and research drawn entirely from cotton producers and importers. Jacobson et al describe the 'push-pull' strategy adopted by Cotton incorporated for cotton promotion activities [23]. As a part of this approach the push for cotton consumption would come from the textile mills or mill use consumption. This 'push' was necessary to counter the intensive marketing and promotion by chemical fiber manufacturers at retail level that in turn forced the mills to favor synthetic use over cotton. Valderrama, points out that cotton promotion might help explain the portion of demand not explained by just income and prices [18].

4.2.4 Threat to cotton mill-consumption from synthetic fibers

The advent of synthetic fibers began with the invention of nylon in the late 1930's by Dupont. Unsatisfactory attempts at blending nylon staple fiber with cotton led to the need for a fiber with better blend characteristics. A solution was found when, John Whinfield and James Dickson in Britain invented polyester before its commercial manufacture was started by ICI [48]. Polyester promotion was almost single handedly and powerfully promoted by Dupont, which was then working in collaboration with ICI. Dupont promoted its 'Dacron' branded polyester using a push-pull strategy as described above and this section will deal with the push component [14]. Dupont modified existing industrial processes as well as modified existing textile machinery for polyester inclusion since most textile spinning and weaving machinery were geared towards cotton textile production [19].

A part of this effort included education and training to textile mill employees to effectively work under the changed operation standards and machine parameters for polyester blends. Cotton Incorporated (CI) was faced with the task of combating this threat after its inception in 1970. Cotton Incorporated adopted a strategy closely matching the Dupont strategy of retail 'pull' through advertising, strategic marketing, and brand consciousness through the 'Seal Of Cotton' campaign.

The National Cotton Council (NCC) and Cotton Incorporated's predecessor, the Cotton Producers Institute (CPI), had attempted promotion efforts earlier but were largely unsuccessful. The failure was because most of their campaign focused on promoting 100% cotton products. Cotton Incorporated recognized the selective superiority of polyester in areas like easy care and shrink resistance that provided little incentive for mills to pursue cotton share increases in blends and instead focused on a more realistic goal of increasing cotton's ratio of blends to a dominating level. This need was fulfilled through the establishment of research in fibers, fabrics and agriculture at its research center in Raleigh, North Carolina. The importance of CI's research-led initiative for generating the necessary push for mill consumption is illustrated by the fact that research forms its second largest promotion budget component as illustrated in Figure 4.6.



Source: Cotton's Renaissance: 'A Study in Market innovation', Cambridge University Press, 2001

FIGURE 4.6: COTTON PROMOTION BUDGET COMPONENTS FOR COTTON INCORPORATED: 1990-2001

This led to its co-operated efforts with USDA to develop a 60-40 cotton polyester blend and promoted it as the now-popular ‘cotton-rich’ blend [59]. The centerpiece of direct mill-level promotion for Cotton Incorporated is through its research and development initiative. However, retail promotion through advertising and brand campaigns provide an indirect trickle down effect on U.S. cotton mill consumption. Some of these research-driven promotion efforts to U.S. mill include:

- Development of the Engineered Fiber System (EFS), used by the USDA as a tool for bale classification. EFS enables mills to select cotton mixes based on the desired yield of the spinner. Further, EFS has spurred sub-systems such as GinNet™ for gin operation, MillNet™ for mill management from mix selection to property evaluation and finally QRNet™ for cotton merchants for enabling cotton trading through data exchange
- Technical assistance through laboratory testing and technicians who work with, mills to resolve cotton-processing issues such as fabric barre effects, shrinkage control and dyeability
- Cotton property enhancement through the development of a metered addition system for a measured finish application for wrinkle-free cotton fabrics that can effectively rival polyester’s wrinkle resistance while leveraging cottons advantages of softness and absorbency

4.2.5 Technological development and innovation in polyester fibers

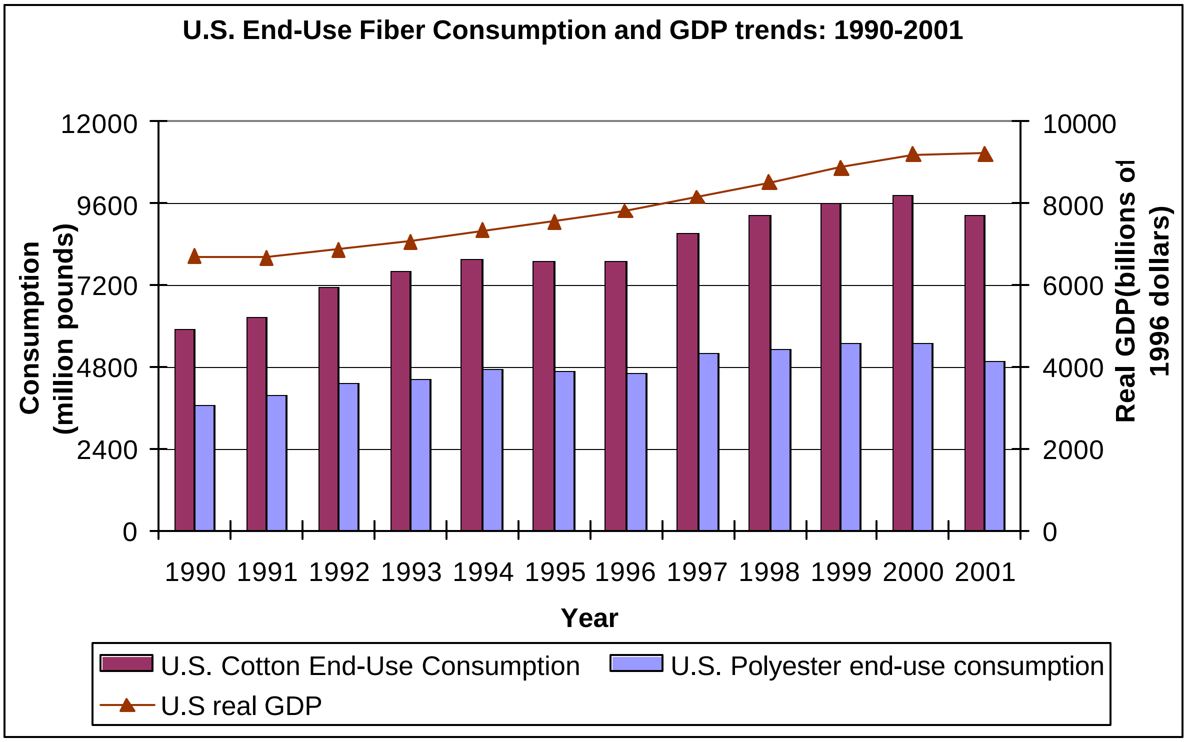
The substantial gains in polyester share and use can be attributed to its superior performance characteristics and the ability to blend with cotton in a suitable ratio [14,47]. Polyester fibers when converted into fabric offered advantages such as durable press, that significantly increased polyester consumption by offering consumers easy care properties. From a mill use standpoint, it provided a significant opportunity to optimize product costs and leverage inter-fiber price advantages by altering blend ratios accordingly. Non-price competitiveness according to Barlowe et al [47] was largely interplay of cotton promotion programs and technological advances in man-made fibers. Developments in polyester fiber technology translates to increased mill use of polyester due to ultimate consumer demand for polyester attached to its attributes such as rapid drying and crease resistance. The next section will carry a more detailed discussion on the impact of advances in polyester technology on inter-fiber consumption trends.

4.3 U.S. cotton and polyester end-use demand analysis

In order to isolate the determinants of U.S. cotton and polyester end use demand for the econometric model in Chapter 5, an analysis of the trends in their demand situation would provide an insight into the factors influencing demand during the period from 1990 to 2001. Once these factors are isolated it would prove simpler to formulate a hypothesis for the econometric model formulation. Further, a discussion of each of the demand determinants and their influence on consumption are discussed. In this analysis, U.S. end-use fiber consumption for cotton and polyester fiber are defined as the sum of the annual mill consumption plus the net textile trade deficit (in this case imports minus exports expressed in raw fiber equivalent) in cotton and polyester. In the survey of literature, it was found that fiber consumption was interchangeable referred to as fiber demand. Further, the terms apparent consumption, total fiber consumption, retail fiber consumption and end-use fiber consumption were also used interchangeably. In this analysis, end-use consumption is used uniformly to represent all of the above variations.

4.3.1 Trends in cotton and polyester end-use consumption from 1990 to 2001

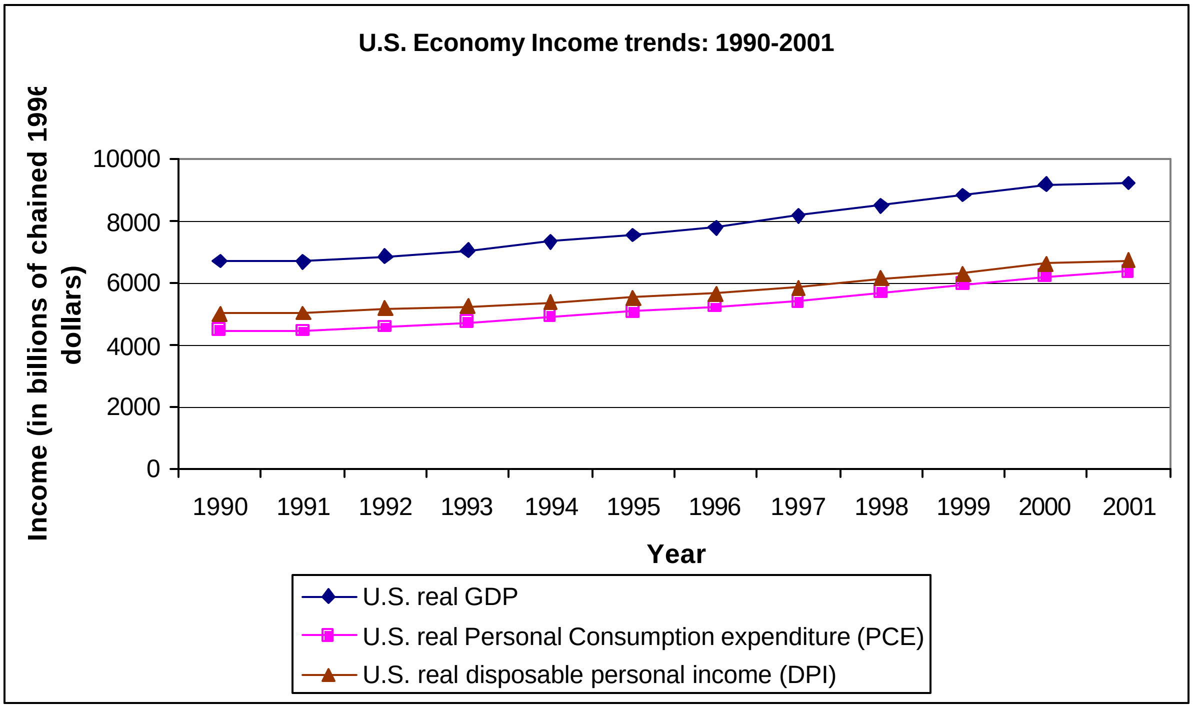
The U.S. cotton and polyester end-use consumption presents a sharp contrast to the trends in mill consumption. First, polyester consistently dominated cotton with almost 70% share of mill fiber consumption with cotton at only 21.17% in 2001. On the other hand, cotton dominated over polyester with a 40% share in end-use consumption, while polyester had only a 22% share in 2001. Second, while cotton share of mill use declined from 30.6% in 1990 to 27.1% in 2001, its end-use share increased from 35.84% to 40.56% over the same period. On the other hand, polyester was the opposite with a mill-use increase from 67.3% in 1990 to 71.4% in 2001 while its end-use share declined from 22.37% to 21.68% over the same period as illustrated in Figure 4.7.



Sources: USDA Cotton and Wool Situation and Outlook Report: November 2001, U.S. Census Bureau and FEB Internal Data

FIGURE 4.7: U.S. COTTON AND POLYESTER END-USE CONSUMPTION: 1990-2001

Previous literature reviewed consider end-use fiber demand to be influenced by fiber prices, income (GDP, DPI or PCE), and a trend variable for capturing any change in consumer preferences or technological change as in the case of synthetic fiber competition. The analysis in chapter 5 will incorporate these factors into the year-by-year analysis of cotton and polyester end-use consumption. The growth in real GDP of the U.S. economy in 1991 showed a 3.05% increase over 1990 as the U.S. economy slowly recovered from a recession [39,40]. In real 1996 dollars, GDP declined by –0.47% from 6707.9 billion dollars in 1990 to 6676.4 billion dollars in 1991. Growth in cotton and polyester end-use consumption grew modestly by just 6.29% and 7.69% respectively, owing to a recovery in consumer spending on non-durable goods that reflects textile product related expenditures as well [41]. U.S. end-use fiber consumption of cotton and polyester rose by 14.20% and 9.35% respectively in 1992 largely due to the 3.05% increase in GDP growth. U.S. fiber consumption generally tracks GDP growth, especially the PCE component. This was reflected in the 2.86% increase in real PCE in 1992 (see Figure 4.9).



Source: U.S. Census Bureau

FIGURE 4.8: U.S. ECONOMY INCOME TRENDS: 1990-2001

The overall fiber consumption increases were primarily due to increased apparel retail sales [49]. Real GDP growth increased by 2.56% in 1993 over 1992 levels resulting in consumption increases of 6.34% and 3.02% for cotton and polyester respectively. The strong increases in GDP in 1993 were due to strong growth in industrial production by 5.8% over 1993, exports, government spending and employment levels. Cotton and polyester fiber end-use consumption were driven by strong apparel sales at retail as well as increases in cotton and polyester mill consumption by 3.70% and 2.49% over 1992 respectively [31]. The strong 4.04% GDP growth in 1994, the highest annual GDP growth since 1990, resulted in strong gains of 4.95% and 6.21% in cotton and polyester end-use consumption, significantly impacted by the rising textile deficit following NAFTA's inception in 1994 [49]. Under its influence, the U.S. textile trade deficit in cotton rose 3.14% to 2745.64 million pounds. This proves the strong influence of U.S. income as represented by GDP, PCE or DPI and its impact on textile deficit and end-use consumption from 1990 to 1995, which will be later, employed in chapter 5 in formulating a hypothesis for econometric modeling.

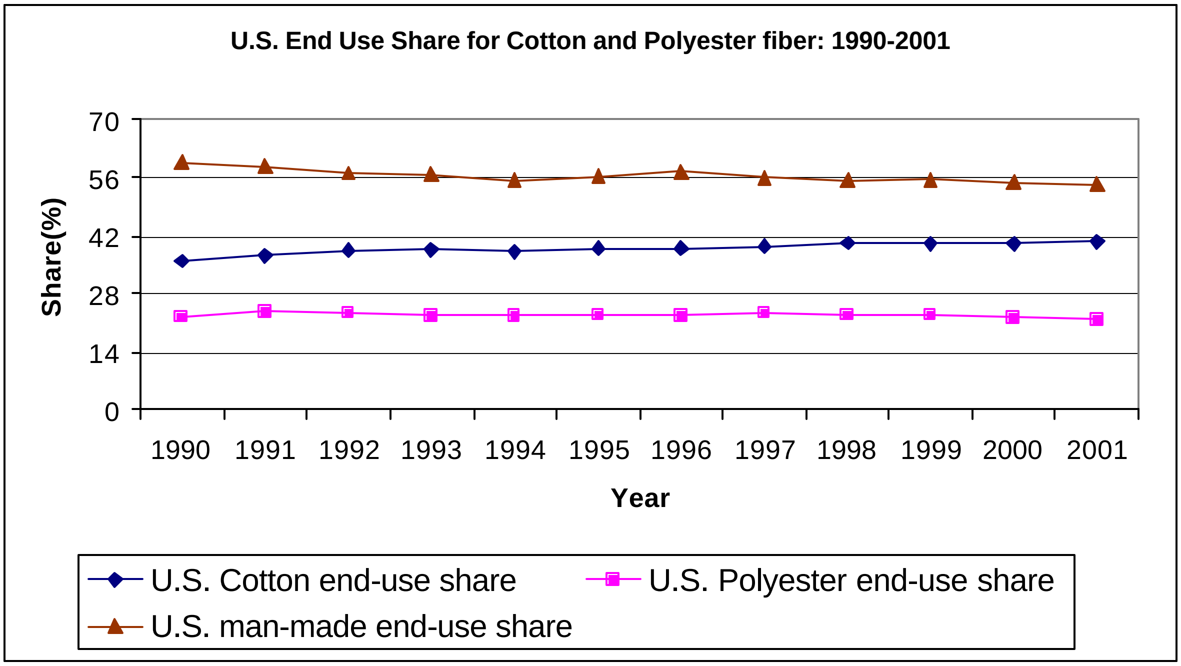
The U.S. economic growth in 1995 slowed as reflected in the GDP growth of just 2.67%, down from the 4.04% in 1994. As a result U.S. total domestic demand growth declined from 3.4% to 2.7% in the same period. [30]. Cotton end-use consumption declined by –0.43% as a result from 7976.24 million pounds to 7942.14 million pounds. Similarly, polyester end-use consumption too declined by –1.82% from 4734.07 million pounds to 4686.99 million pounds. However, the decline in growth of cotton and fiber consumption was due to decreased consumer spending. This is evidenced by the fact that the growth in disposable personal income (DPI) increased from 2.58% in 1994 to 2.63% in 1995 while growth in personal consumption expenditure declined from 3.77% to 2.99% over the same period. U.S. GDP growth staged a slight recovery of 0.9% in 1996 to 3.57% from 2.67% in 1995. However, PCE in 1996 grew by just 0.2%, resulting in a slight decrease in cotton and polyester end-use consumption by 0.22% and -1.2% respectively.

The continued influence of U.S. income, textile trade deficit and fiber pricing on U.S. cotton and polyester demand from 1997 to 2001 is analyzed in the following paragraphs. The U.S. cotton and polyester fiber consumption in 1997 was strongly influenced by the Asian financial crisis combined with the largest economic expansion of the U.S. economy in history [12]. Since exchange rate effects typically have longer lags than price effects, Asian economies would be affected to the extent of their import dependence for cotton and polyester and its related pricing [34]. Opportunities for cost optimization through fiber substitution were limited as most Asian economies except for Thailand and Malaysia produce polyester feedstock domestically. On the other hand, cotton textile manufacture, where China possesses a lion's share has been import dependent, especially China that turned into a net importer from a net exporter since 1989 [50]. Thus, dollar denominated cotton imports were not able to fulfill fiber demand for textile manufacture. Meanwhile, the U.S. economic expansion marked by a 4.4% GDP growth, increased PCE growth by 0.37% to 3.56% and final domestic demand grew by 0.2% to 3.2% in real terms. This transformed economic situation coupled with increased textile trade witnessed under NAFTA boosted U.S. domestic mill demand [35]. In 1980, 83% of U.S. clothing imports originated in the Far East while Mexico and Canada constituted a combined 3%. Within two years of NAFTA's inception in 1994, Mexico emerged as the largest importer and exporter of textiles and apparel to the U.S. [51].

Correspondingly, U.S. mill consumption of cotton rose by 4.11%, while polyester rose even higher by 11.63% over 1996. The net result of the above situation resulted in end-use consumption of cotton and polyester by 10.20% and 12.77% respectively. The exceptional expansion of the U.S. economy witnessed in 1997 continued into 1998 and 1999 with annual GDP growth of 4.28% and 4.11% respectively. Inter-fiber competition underwent a significant change during this period. This translated into continued increases in cotton and polyester end-use consumption. In 1998 cotton end-use consumption increased 6.53% to 9303.41 million pounds over 1997 while mill-use declined by 3.81% to 5234.30 million pounds. On the other hand polyester end-use consumption increased by 1.53% over 1997 to 5301.87 million pounds. This was due to the raw fiber equivalent of cotton imports, used in arriving at the final U.S. end-use consumption, exceeding U.S. mill consumption due to the effects of trade liberalization [36].

Meanwhile, polyester showed sustained competitive advantage over U.S. cotton due to significantly lower prices as well as lower exposure to mill demand. This is reflected by the fact that despite the increasing onslaught of imports polyester mill demand remained steady at an average of 4603.8 million pounds, fluctuating by just 1% either way, while cotton mill use declined successively by 3.8%, 5.2% and 4.34% over 1998, 1999 and 2000. In 2001, polyester mill consumption at 3979.42 million pounds ended ultimately higher than cotton mill consumption that was

3848.40 million pounds thus firmly establishing polyester's competitive edge over cotton at the mill level.



Sources: USDA Cotton and Wool Situation and Outlook Report: November 2001 and FEB Internal Data

FIGURE 4.9: U.S. END-USE SHARE FOR COTTON AND POLYESTER: 1990-2001

The three-year streak of above-4% GDP growth from 1997 to 1999 ended in 2000 with growth slowing to 3.75% over 1999 levels. This slowdown in the U.S. economy resulted in cotton end-use consumption growth declining to 2.55% from the 3.19% growth witnessed in 1999. Polyester end-use consumption witnessed comparatively steeper declines, registering a –0.35% growth in 2000 compared to 3.83% in 1999. The slowdown in the U.S. economy that began in 2000 worsened in 2001, with GDP growth dipping to an abysmal 0.25%. Consumer spending too declined with real personal consumption expenditure growth slowing to 2.46% in 2001 from 4.35% in 2000. As a result, cotton end-use consumption declined by 5.85%, from 9845.40 million pounds in 2000 to 9269.87 million pounds in 2001. On the other hand polyester showed a greater decline of 9.65% to 4956.24 million pounds. USDA forecasts a marginal rebound in world cotton consumption in 2002 followed by even better consumption in 2003 when the world economy is expected to return to average levels of expansion. Additionally, with cotton prices having reached the decade's lowest levels of under 40 cents/pound, USDA forecast that the advantage of lagged price effects would translate to a forecasted world cotton consumption growth of 2.1 percent. From the above consumption trend analysis from 1990 to 2001 it is evident that U.S. end use demand for cotton and polyester are influenced by fiber pricing and U.S. national income as well as an indirect influence on U.S. mill demand and trade deficit for these two fibers.

4.3.2 Determinants of inter-fiber demand of cotton and polyester

Review of past literature on estimation of end-use fiber consumption reveals that most of the regression models have concentrated upon total fiber demand that is essentially representative of grouped trends rather than individual end-use consumption by fiber type. However, since cotton and polyester account for almost 70% of end-use fiber consumption, the earlier hypotheses would still apply. In addition, factors specific to cotton and polyester fibers' end-use consumption would also have to be considered to account for their dominating market shares. This would also seek to explain the reason for the lack of a substitutive relationship for the other fibers such as wool, flax and silk. Valderrama [18] of the International Cotton Advisory Committee (ICAC), in his analysis of cotton's competitiveness states that the world cotton consumption in the 1990's has not kept pace with the growth in the overall textile market [18]. Consequently, while cotton expansion was a mere 500,000 tons, overall fiber consumption rose by 8 million tons. A further observation is that 95% of this growth has been captured by non-cellulosics, mostly polyester on account of its price and property advantage.

Earlier research into cotton demand mostly explained total fiber demand as being influenced by income and prices. Evans [8], in his estimation of cotton and apparel wool mill demand from 1955-1976, considered total fiber demand as being influenced by income represented by the ratio of the wholesale price index of textile products to total per capita real personal consumption expenditure and a trend variable to capture technological or cultural changes. Sanford [7], developed a variation of this model by considering U.S. total fiber demand to be influenced by real fiber price, real income and a trend variable to capture technological or cultural changes over 1960 to 1986. The model treated real cotton fiber price as a proxy for all fibers on the basis that cotton with its 30% share of total fiber consumption reflected general price levels. Income was represented by real PCE. As described in the analysis of the U.S. fiber end-use consumption from 1990 to 2001 in the previous section, U.S. cotton textile imports in raw fiber equivalent terms stood at 7545 million pounds overtaking mill consumption at 3848 million pounds. This vast change was due to trade liberalization under NAFTA and WTO resulting in rising imports. This effect was captured in Meyer's research on U.S. total fiber and mill demand [6]. Meyer expanded on Sanford's work by considering total fiber consumption as being influenced by fiber price, income and a dummy variable to reflect increased trade due to NAFTA. This model also considered cotton price as a proxy for all fiber prices, though nominal prices were used as past research using real prices proved unsatisfactory. Income, in this case, was represented by real per capita disposable personal income (DPI) while the trend variable was equal to one beginning 1994 and zero for earlier years.

Valderrama [18] of ICAC, points out that cotton demand can be broadly classified into price and non-price competitiveness. While the past research focused almost exclusively on price factors such as income and fiber pricing, non-price factors have been largely ignored. The key non-price factors are listed as quality and promotion. Valderrama further states that, strong non-price competitiveness of cotton in North America prevented loss of cotton market share. The ICAC cotton demand model for estimating world cotton demand does not include the non-price factors in its econometric model due to lack of available data. However, ICAC points out that Cotton Incorporated has created a retail cotton market of 4.4 million tons in 2000, up from just 2.8 million tons in 1990. This increase has been attributed to its cotton promotion efforts [12]. Based on this argument, the analysis in this thesis will consider cotton promotion's impact on end-use consumption as quantified by the cotton promotion budget of Cotton Incorporated.

Barlowe et al [47] in their analysis of cotton demand point out that technological developments in man-made fibers are a major factor contributing to non-price competition for cotton. Based on this analysis and the fact that cotton's competition in the 1990's essentially came from polyester, polyester end-use demand will be estimated using technological change as the third factor in addition to income and prices.

4.3.3 Influence of U.S. national income on cotton and polyester end-use consumption

National income has been used as an explanatory variable in most previous estimation models. Barlowe and McDonald [47], point out in their analysis of total fiber demand in 1971, that an increase by one-third in the disposable income would increase cotton consumption by one-fourth. In his estimation of total fiber consumption, Evans [8] used real per capita personal consumption expenditure to represent income as a ratio of the wholesale textile price index for textile and apparel products. Sanford [7] included real per capita personal consumption expenditure in his estimation of total fiber consumption. Further, Sanford points out that PCE usually remains stable over time, while its internal allocation amongst durable goods, non-durable goods and services changed. The choice of an income parameter could be arrived at by statistical analysis. Meyer in his model, on the other hand chose real per capita disposable personal income to represent income [6]. The USDA reports observe that real GDP generally tracks fiber consumption, especially following changes in the personal consumption expenditure [52].

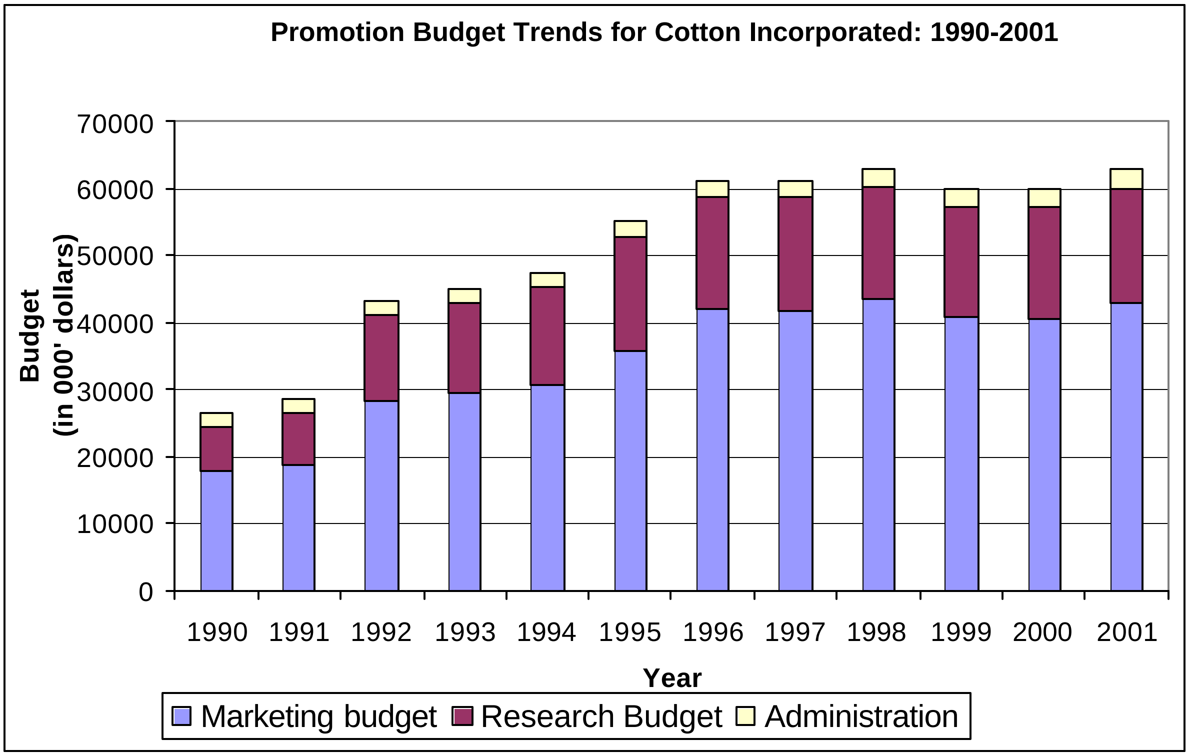
4.3.4 Fiber pricing and its impact on end-use consumption

Fiber pricing would be a logical choice for inclusion in fiber demand estimation, on the basis that a lower priced fiber would result in a more competitive textile product. Barlowe and McDonald, explain shifts in blend ratios as a reflection of inter-fiber substitution effects arising out of price competition [47]. However, at the end-use level, the fraction of the textile product cost represented by fiber price is very low. Valderrama, points out that this argument poses a practical limitation to evaluation of fiber consumption and market shares [18]. Additionally, he points out the fact that the lack of a single price index is the reason for the inability to capture true fiber price changes. However, all the models discussed above estimate a total fiber demand figure in order to further estimate mill demand in turn [6,7,8]. In this analysis, cotton and polyester fiber demand are specifically determined and hence their specific prices can be conveniently applied for estimation of their end-use demand. Since, U.S. mill delivered prices offer a good proxy for the price dynamics of cotton and polyester fiber, these prices would be used in this analysis.

4.3.5 Cotton promotion initiatives and end-use cotton consumption

The effect of cotton promotion as a positive non-price competitive factor driving cotton end-use consumption and market share has been established by past research [47,12,53]. Cotton promotion in the U.S. has been almost single handedly driven by Cotton incorporated and the steps leading to its formation are discussed in section 4.2.3. This section provides an analysis of retail level promotion initiatives and the resultant impact on cotton end-use consumption.

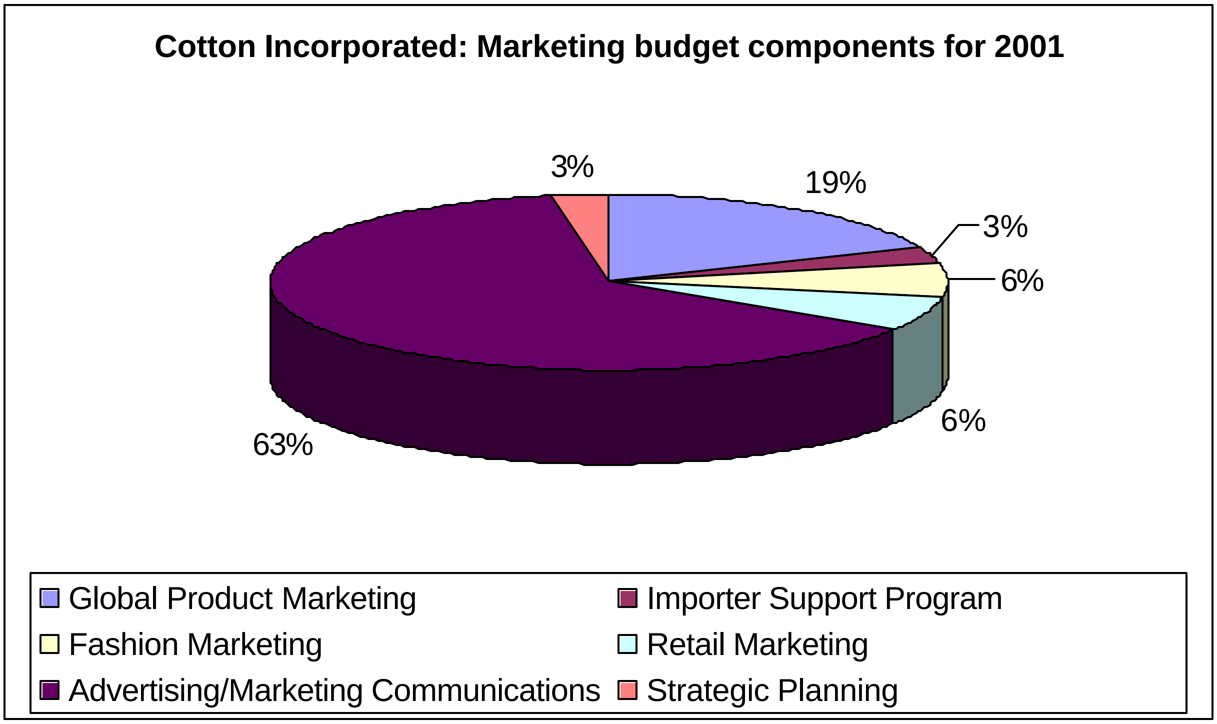
Retail level promotion forms the ‘pull’ component of the push-pull strategy. The push component is mostly generated through mill level promotional activities of Cotton incorporated, focusing on research in fibers, fabric and processing as seen in the earlier section on mill level promotion. On the other hand, retail level pull is generated through advertising, retail marketing, product marketing and fashion marketing [54]. The importance of marketing has increased tremendously over the years. In 1971, Cotton Incorporated's divided its $10 million budget roughly equally between research and promotion [47]. This has undergone a significant change in the 1990's with marketing, mostly retail level directed, assuming the dominant share of promotion funding as seen in Figure 4.11.



Source: Cotton's Renaissance: A Study in Market innovation', Cambridge University Press, 2001

FIGURE 4.10: TRENDS IN COTTON INCORPORATED PROMOTION BUDGET: 1990-2001

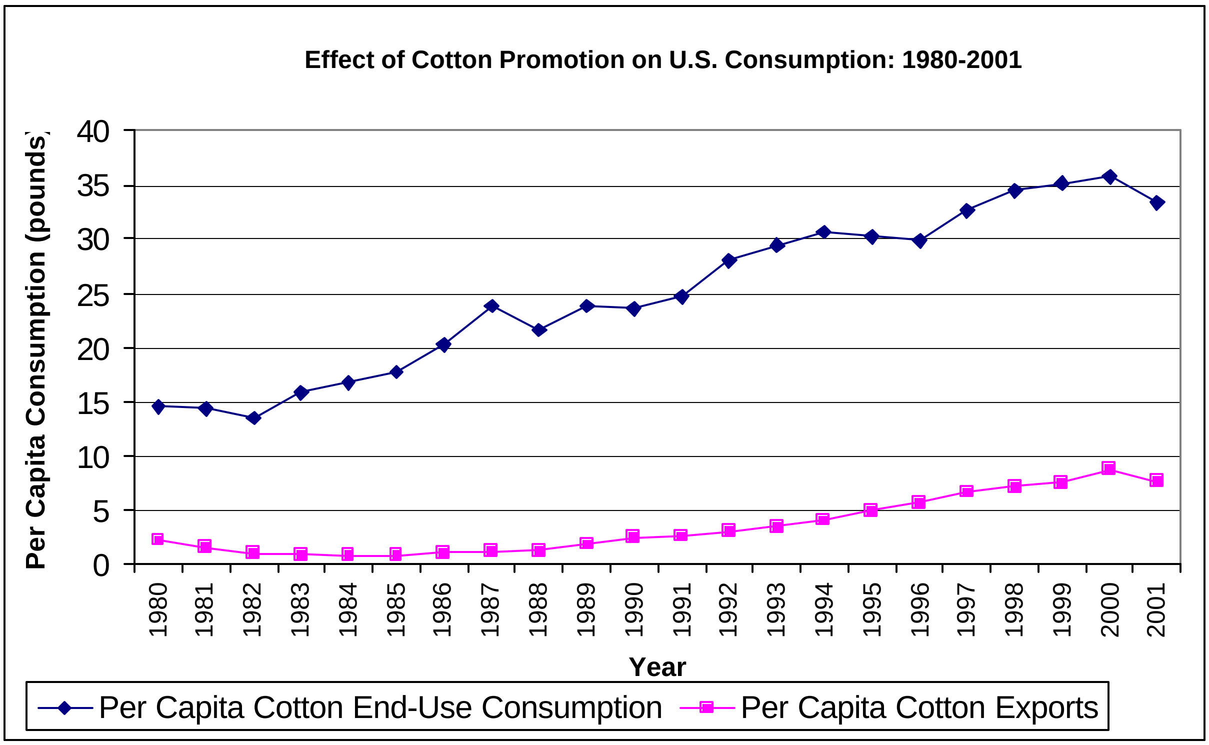
The emphasis of Cotton Incorporated's (hereafter referred to as CI) efforts in the 1990-2001 period have clearly centered on the retail promotion of cotton consumption with research following second. Barlowe [47] points out that in 1971, CI decided to place greater emphasis on research. This approach seems to have changed dramatically, with mill consumption (which drives research funding mostly), declining and retail consumption of U.S. cotton being the largest in the world [12]. CI's marketing budget is composed of 6 components, namely: global product marketing, importer support program, fashion marketing, retail marketing, advertising and strategic planning (see Figure 4.12 for comparison). With a dominant 63% share of marketing expenses, advertising clearly seems to have been the main thrust for retail promotion. Finnie [19] in his analysis of CI, states that the "Seal of Cotton" built to rival Dupont's similar certification efforts for Dacron, engaged network television extensively to develop consumer image and eventual demand.



Source: Cotton's Renaissance: A Study in Market innovation', Cambridge University Press, 2001

FIGURE 4.11: COTTON INCORPORATED: MARKETING BUDGET COMPONENTS FOR 2001

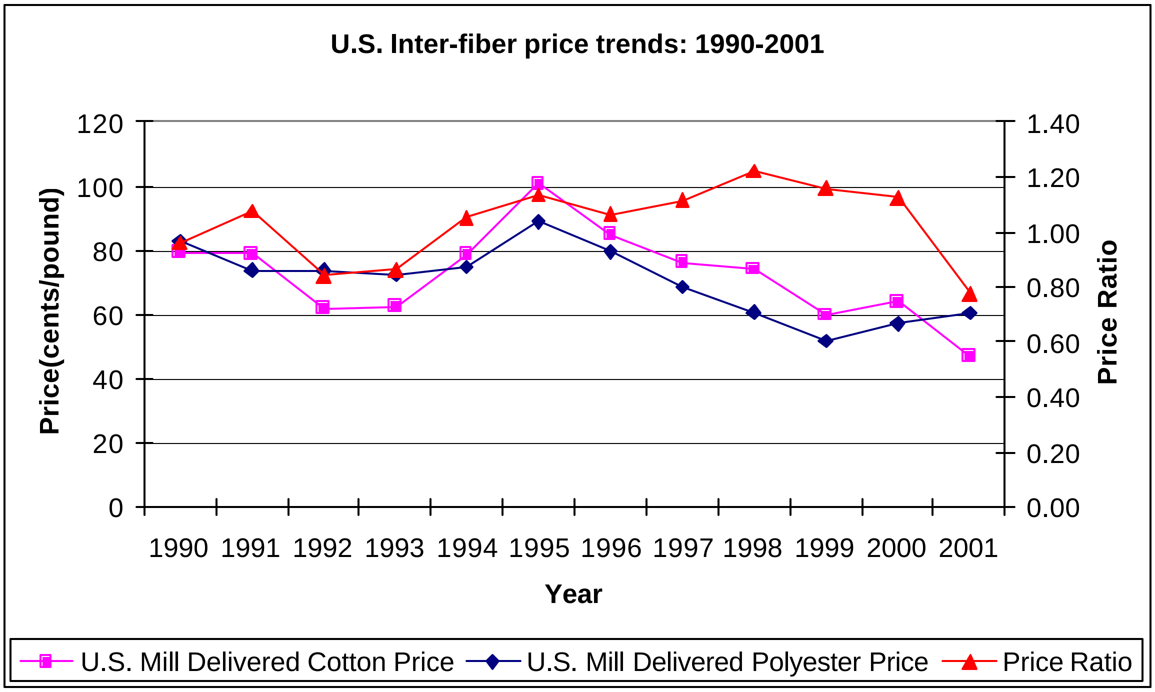
In addition to pure retail marketing, CI also initiated efforts to co-ordinate retail stores' product line with product development efforts at mills. This emphasis started with the early efforts in 1970's to jointly develop with ICI, wrinkle-free cotton fabrics to challenge polyester's similar attribute [13]. CI collaborated with WestPoint Stevens to promote 'cotton-rich' fabrics, which essentially was a blend variant with dominant cotton component. Another industry-CI partnership, was the 'True-Performance" campaign to highlight cotton's property advantages, culled after a nationwide survey of synthetic fiber consumer complaints [19]. The major CI effort of the 1990's was the 'Fabric of our lives' campaign that is successfully continuing till today. CI's current efforts are to improve cotton use in end-use segments other than apparel, namely, floor coverings and nonwovens [54]. In this effort, CI has tried to replicate its certification-driven strategy to boost cotton consumption. The "Carpet Blend" and "Rug Blend" seals have been introduced. In terms of cotton end-use consumption, CI's efforts have translated into an increase in the per capita consumption of the U.S. consumer. The Figure 4.12 illustrates the effect of cotton promotion of CI. Using Valderrama's observation of price and non-price competitiveness, this trend would be better explained with a price comparison [18].



Source: USDA Cotton and Wool Situation and Outlook Report: November 2002

FIGURE 4.12: IMPACT OF COTTON INCORPORATED'S PROMOTION EFFORTS ON END-USE COTTON CONSUMPTION: 1980-2001

Figure 4.13 illustrates that despite cotton prices remaining above polyester prices for a major part of the period between 1990 and 2001, non-price effects have played a major role. Further, non-price effects with regards to the U.S. are largely generated from cotton promotion and quality aspects.



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Source: National Cotton Council (NCC) of America

FIGURE 4.13: U.S. POLYESTER AND COTTON FIBER PRICING TRENDS: 1990-2001

The effect of promotion on U.S. cotton end-use consumption becomes evident considering the fact that in 2001, the retail consumption of man-made fibers at 93.1 million bales exceeded that of cotton at 91.8 million bales [55]. The reversal of this trend points to the significance of non-price competitiveness, of which promotion is a major component.

4.3.6 Technological developments in polyester fibers

In his analysis of fiber competitiveness, Valderrama [18] argues that despite the low contribution of fiber price towards the final textile product it plays a key role in the econometric modeling of fiber consumption due to the lack of a reliable price index. The presence of any other factor driving consumption other then income and fiber prices would be non-price competitiveness like promotion or property attributes. Using this argument, polyester would derive its non-price competitiveness from its continuous technological development to deliver superior attributes like no-iron, wrinkle free, and quick drying. Barlowe and McDonald [47] in their analysis of cottons competitive threats observe that significant technological developments in man-made fibers, especially polyester, have driven their consumption levels. A case in point was the development of the popular 65:35 polyester-cotton blend by Dupont [19]. Finnie [19] points out that Dupont developed the textile processes and production systems to deliver this blend of its 'Dacron' branded-polyester with cotton. Celanese developed a competing 50:50 polyester-cotton blend with its branded polyester called 'Fortrel'. However, polyester derived much of its success from the scope it provided for technical developments. The development of pill-resistant polyester, which was a major consumer complaint about polyester fabrics, was a step in that direction. The partial substitution of the terephthalic acid component by sulfoisophthalic acid in its sodium slat form reduced the pilling tendency [48]. The development of another polyester fiber called poly-butylene terephthlate (PBT), with its high elasticity has been central to the current development of core-sheath yarns [56]. These yarns find application in sportswear and apparel. Hoechst with its 'Trevira' polyester yarns led the development of flame-retardant polyester for safety-critical home textiles. Further, polyester yarn has emerged in the form of bi-component yarns. With this development polyester's versatility increases due to the combined effect of two different fiber components [57]. The 'Trevira' bi-component yarn combines flame-retardancy while the second component provides increased strength. Enka Limited had developed a variant of their 'Diolen' polyester for circular knit fabrics by texturing the polyester yarn to provide bulk along with its traditional easy-care properties.

Based on the technological developments of the nature described above, polyester fibers retained their competitiveness in the face of weak profit margins and cotton promotion efforts [58,59]. During the 1990's polyester promotion, which was, intensive during its introductory phase in the 1960's all but ceased. This change in polyester's competitive positioning versus cotton will be included in the econometric model in chapter 5.

5.

Econometric modeling of U.S. cotton and polyester inter-fiber competition

In the previous chapter the determinants of U.S. cotton and polyester demand for mill use and end use were discussed. In this chapter, the choice of these determinants is discussed in the background of previous models developed for the same purpose. Using these new determinants, ordinary least squares regression models are developed for U.S. cotton and polyester, mill and end use demand.

5.1 Econometric model: Data sources and modeling methodology

Cotton and polyester inter-fiber competition involves the shifting or substitution effects in fiber consumption between these two fibers. Valderrama [18] defines textile fiber consumption as a three-tier structure. The first tier of consumption is raw fiber consumption by mills, i.e. mill demand. Further, the second tier is represented by the semi-processed fiber in yarn or fabric form, consumed by the fabric and/or textile product manufacturer. Finally, the third tier is the retail level fiber consumption of finished textile goods by the consumer. In this study, fiber consumption is defined as a two-tier fiber demand structure (refer Figure 3.5). The first tier is the mill level consumption that in this study and following models is referred to as mill demand. The second tier is the end-use level consumption or retail-level fiber consumption that in this study and following models is referred to as end-use demand. The two-tier structure of mill demand and end-use demand used in this study eliminates the semi-processed fiber demand tier that Valderrama [18], defines as the second tier. The rationale for using a two-tier structure instead of the three-tier structure lies in the method employed by USDA and FEB in reporting as well as computing the end-use fiber consumption. USDA and the FEB define end-use consumption as the sum of the annual mill consumption and the net textile trade balance (n raw fiber equivalent). Within this, the net textile trade balance is defined as the textile trade deficit of textile semi-manufactures and manufactures. The availability of data as a composite of semi-manufactures and manufactures makes it necessary and possible to consider fiber demand only as a two-tier structure [4].

The following section will present the rationale and subsequently four statistical models for total cotton demand (TCD), total polyester demand (TPD), cotton mill demand (CMD) and polyester mill demand (PMD). The consumption data for cotton fiber was derived from the United States Department of Agriculture's (USDA) cotton and wool situation and outlook reports as well as Fiber Economics Bureau's (FEB) 'Fiber Organon' while polyester fiber consumption data was derived exclusively from the 'Fiber Organon'. The relevant tables are listed in the appendix section (see Appendix section 8.1 to 8.18). The period of time chosen for study was from 1990 to 2001. This choice of time period was limited by the data available for polyester end-use demand (refer Appendix Table 8.9). The polyester end-use demand data is not publicly available since polyester is clustered with nylon and olefins and presented as a single man-made/manufactured fiber category. The FEB provided internal data for this study that could date back only until 1990.

This study uses ordinary least squares (OLS) regression as was the case with the earlier demand studies conducted by Sanford [7], Evans [8] and Meyer [6]. The modeling could be performed using either direct regression methods such as OLS or indirect regression methods such as two stage least squares (TSLS). The parameters for evaluating model effectiveness will be the R-squared values, *t*-statistic, *p*-statistic and the Durbin-Watson (DW) *d*-statistic for serial auto correlation.

5.1.1 The Durbin-Watson (DW) test for serial auto correlation

The correlation between the error terms arising in time-series data, of the kind used in this fiber demand estimation model, would give rise to a possibility for autocorrelation or serial correlation [60]. In order to eliminate the possibility of such autocorrelation effects the Durbin-Watson test is performed. Studenmund [20] observes that the Durbin-Watson 'd' test is the most common test to detect serial correlation.

The most commonly used model for evaluating autocorrelation is one where the errors μ_t and μ_{t-1} have a correlation ρ. This model can be thought of as one in which the hypotheses is tested about ρ on the basis of ρ' which is the correlation between the least square residuals μ_t' and μ_{t-1}'. A commonly used statistic for this purpose is the Durbin-Watson statistic denoted by '*d*' that is defined as,

$$d = \frac{\sum_{2}^{n} (\mu'_t - \mu'_{t-1})^2}{\sum_{1}^{n} (\mu'_t)^2}$$

where μ'_t is the estimated residual for period t. 'd' may also be expressed as,

$$d = \frac{\sum (\mu'_t)^2 + \sum (\mu'_{t-1})^2 - 2 \sum (\mu'_t * \mu'_{t-1})}{\sum (\mu'_t)^2}$$

In case of large samples $\sum (\mu'_t)^2$ and $\sum (\mu'_{t-1})^2$ are approximately equal. Hence, d is almost equal to $2(1-\rho')$. If the correlation term $\rho = +1$, then $d=0$. On the other hand if $\rho = -1$ then $d = 4$. However, if the correlation between the error terms $\rho = 0$, then $d=2$. Thus, if d is close to 0 or 4, the residuals are highly correlated. The sampling distribution of '*d*' depends upon the values of the explanatory variables and in turn the derived upper limit (d_u) and lower limit (d_l) for the significance levels of 'd'. The d_u and d_l values can be obtained from the Durbin-Watson tables by comparing the number of observations against the number of explanatory variables. After determining the upper and lower limits, the DW statistic is tested based on the hypothesis for first-order positive serial autocorrelation described below.

Hypothesis test for zero autocorrelation against first-order positive autocorrelation:

1. If $d < d_l$, the null hypothesis of no autocorrelation is rejected.
2. If $d > d_u$, the null hypothesis is not rejected.
3. If $d_l < d < d_u$, the test is inconclusive.

With this background of the DW test it would be easier to interpret the results of the OLS regression for cotton and polyester mill-use and end-use demand.

5.2 U.S. Cotton demand estimation model

The determinants of U.S. cotton mill demand and end-use demand were derived from the discussion in Chapter 4. In this section, U.S. cotton end-use demand and the choice of determinants for the total cotton demand (TCD) OLS model are discussed followed by the selected model and its analysis. The following section presents a similar discussion for U.S. cotton mill demand (CMD).

5.2.1 U.S. Cotton end-use demand: Background and variable selection

The cotton end-use demand refers to the total U.S. cotton demand (TCD). The TCD is representative of the total U.S. cotton fiber consumption at the retail level. The formula to determine U.S. total cotton demand in million pounds is:

$$TCD = CMD + (Imports – Exports)$$

where,

TCD denotes U.S. end-use/retail cotton demand in million pounds,

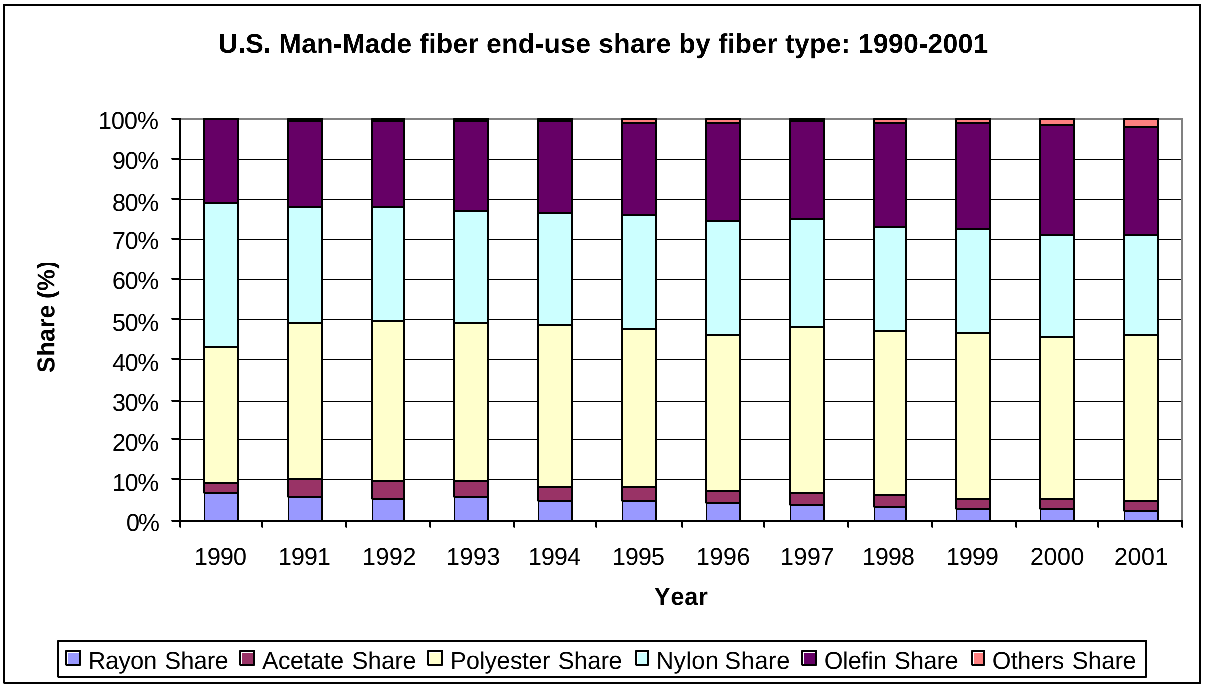
CMD denotes U.S. cotton mill demand in million pounds,

Imports denotes the raw fiber equivalent of U.S. cotton imports in million pounds, and

Exports denotes the raw fiber equivalent of U.S. cotton exports in million pounds.

U.S. cotton end-use demand equations were developed as a twin set of equations. The first set estimates demand in actual cotton fiber quantity consumed in million pounds while the second set of equations estimates the per capita cotton demand. The rationale for this approach is the unique value provided by the actual and per capita demand estimates. The actual demand is useful in interpreting the effect of demand supply forces discussed in chapters 3 and 4 since most cotton policy data, import and export data and WTO-related trade and quota literature report the actual fiber consumption in million pounds. However, most of the specific research literature on fiber demand estimation, especially Meyer [6], Sanford [7] and Evans [8], employ per capita demand in their estimation equations.

Barlowe [5], developed direct estimation equations for U.S. cotton and man-made fiber aggregate demand. In this study, Barlowe hypothesized U.S. cotton end-use demand to be influenced by cotton fiber price, polyester price, disposable personal income (DPI), annual change in DPI and man-made fiber promotional expenditure. This hypothesis is in line with the observation made by Glade [61], et al that total domestic fiber consumption is influenced by fiber prices, income, population growth and consumer preferences. Barlowe [5] and Valderrama [18] classify fiber prices and income as factors contributing to the price competitiveness of the fiber. However, they both point out to a second category of non-price factors including research, promotion and fiber quality that contribute to total fiber consumption. At the time of Barlowe's [5] study in 1967, synthetic fibers rose in popularity due to consumer preference for its easy care and property uniqueness. Consequently, Barlowe's OLS model employed real man-made fiber promotion expenditure (deflated by consumer price index) in determining U.S cotton and man-made fiber end-use consumption. Additionally, this model 'clustered' all man-made fibers under a single category, thereby masking the underlying fundamentals of individual man-made fibers (see Figure 5.1).



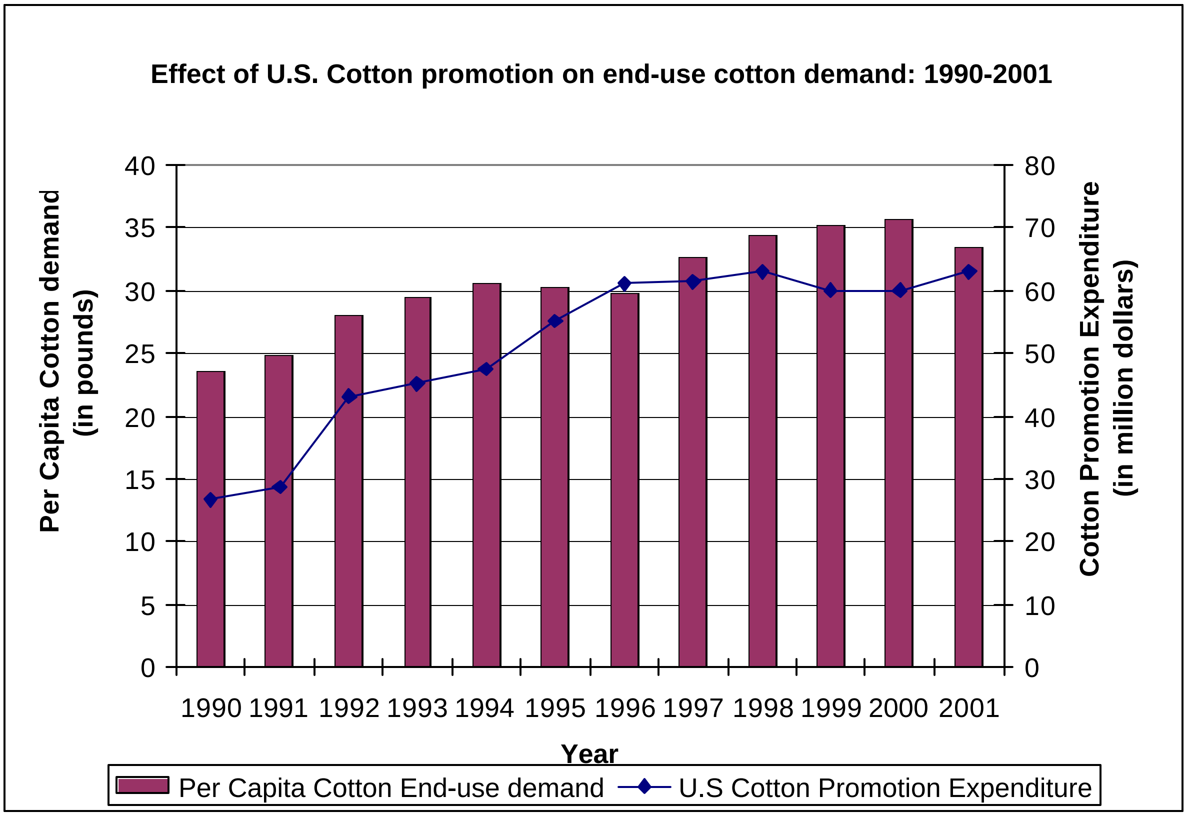
Source: Internal data from Fiber Economics Bureau and Fiber Organon, March 2002

FIGURE 5.1: U.S. MAN-MADE FIBER END-USE SHARE BY FIBER TYPE: 1990-2001

Figure 5.1 clearly illustrates that polyester commands the largest market share among man-made fibers of almost 40%. Thus polyester poses the largest substitutive threat to cotton in the U.S. inter-fiber competition scenario. Valderrama [18] observes that the largest increases in non-cotton fiber consumption has come form polyester essentially during the 1990's. While polyester retained its majority share of almost 40% a notable development was the rise of olefin fiber consumption to overtake nylon as the second largest synthetic fiber consumed in the U.S. in 1999. This further highlights a significant structural change in the U.S. fiber market witnessed during 1990 to 2001. This further highlights the need to study the underlying dynamics of individual fibers rather than cluster all fibers under man-made fibers and study its competition against cotton. The fundamental disadvantage of Barlowe's [5] approach is that it largely ignores the underlying fundamentals of individual man-made fibers.

Another significant change between the time period of Barlowe's study in 1967 and the period of 1990 to 2001 has been the turnaround in the non-price competitiveness of cotton and polyester. Barlowe's study concludes that inter-fiber competition between cotton and polyester was influenced by cotton price and man-made fiber promotion [5]. This study claims that during the period of 1948 to 1964, man-made fiber promotion expenses increased geometrically and outstripped promotion expenditure by the cotton industry. Jacobson [14] et al corroborate this observation and further state that synthetic fiber manufacturers especially Dupont promoted their polyester ‘Dacron’ and acrylic ‘Orlon’ intensively starting in the 1950’s.

However, this scenario changed with the passage of the Cotton Research and Promotion Act in 1966 [19]. Valderrama [18], observes that cotton promotion alone could explain the strength of non-price competitiveness of cotton in the U.S. Figure 5.2 illustrates and confirms the fact that cotton promotion efforts have contributed to per capita cotton demand rising from just 23.55 pounds in 1990 to 33.48 pounds in 2001. In summary, U.S. cotton end-use demand is a composite influence of price competitiveness influenced by fiber pricing and income on the one hand. On the other hand, non-price competitiveness has witnessed a turnaround from aggressive synthetic promotion activities between the 1960’s and 1980’s to the 1990-2001 period when cotton promotion has gained prominence while the synthetic fiber companies have all but suspended promotion due to poor margins for polyester fibers. Since there was no literature available to corroborate the above statement, independent sources were utilized that confirmed the lack of any organized U.S. polyester promotion. The sources were, Mr. Frank .J. Horn, editor of the Fiber Organon publication of the Fiber Economics Bureau (FEB) and Mr. Leslie Meyer, Agricultural economist in charge of cotton at the Economic Research Service (ERS) at the United States Department of Agriculture (USDA). In this regard, Horn [58], observes that there has never been an organized polyester promotion effort. The only polyester industry program was the U.S. Polyester Council that existed between 1982 and 1992. However, this program was largely restricted to public relation efforts rather than actual fiber promotion. In comparison to Cotton Incorporated’s (that administers the U.S. cotton promotion efforts) budget that ranged from 26.55 million dollars in 1990 to 63.00 million dollars in 2001 the U.S. polyester council budget ranged from less than 100,000 dollars to 300,000 dollars. This council has not been in existence since 1992. Meyer [59], confirms the above observation and states in addition that whatever promotion exists for polyester would be attributed to the research and marketing expenditures of a few large chemical companies whose polyester specific budgets are confidential.



Source: USDA Cotton and Wool Situation and Outlook Report, November 2002 and Jacobson. T. C. and Smith. G. D., 'Cotton's Renaissance: A Study in Market innovation', Cambridge University Press, 2001

FIGURE 5.2: EFFECT OF COTTON PROMOTION ON U.S. TOTAL COTTON DEMAND: 1990-2001

5.2.2 U.S. Cotton end-use demand model specification

The models developed for this analysis are based on the Ordinary Least Squares (OLS) regression technique. The review of earlier research on U.S fiber demand estimation models revealed that Barlowe's [5] model was the only demand estimation model that focused exclusively on U.S cotton and man-made fiber end-use consumption. Meyer [6], Sanford [7] and Evans [8], developed models whose focus was essentially U.S. cotton mill demand estimation. However, in doing so they developed a Total Fiber Demand (TFD) model from which the U.S. cotton mill demand was derived. Though this TFD represented U.S. fiber end-use consumption, it was considered as a sum of cotton, man-made and wool fibers' end-use consumption. In contrast, this study focuses on inter-fiber competition between and cotton and polyester specifically. Hence this study will develop specific cotton and polyester fiber end-use demand models similar to Barlowe's [5] study though under a new hypothesis to reflect and account for the structural changes discussed in section 5.2.1. However, the models developed by Meyer [6], Sanford [7] and Evans [8] will be described since the explanatory variables employed would still provide an insight into the factors influencing fiber end-use consumption.

Barlowe [5], hypothesized total cotton demand (TCD) to be influenced by cotton fiber price, polyester fiber price, disposable personal income (DPI), change in DPI and man-made fiber promotion expenditure. However, after eliminating unsatisfactory effects of signs and statistically insignificant terms the final model for U.S. cotton end-use demand was found to be influenced by change in DPI and man-made fiber promotion. The final equation (with t-values in parentheses) was:

$$C_{tc,t} = 28.2717 + \underset{(+3.45)}{0.0138\, I_{\Delta}} - \underset{(-10.26)}{33.1473\, M_{p,t}}$$

$$R\text{-squared} = 0.89, \text{ DW statistic} = 1.63$$

where,

$C_{tc,t}$ denotes pounds of cotton consumed in the production of aggregate end uses, divided by the population of the U.S. on July 1, including armed forces overseas,

I_{Δ} denotes change from preceding year in real per capita DPI, and,

$M_{p,t}$ denotes the real per capita man-made fiber industry promotion expenditure.

The above equation explained 89% of the variation in U.S. cotton end-use demand for the period 1948 to1964. The DW statistic indicates no positive serial correlation. Based on the structural changes in the U.S. fiber demand and consequently the price and non-competition factors discussed in the previous sections a new hypothesis would be necessary to reflect those changes. This study hypothesizes U.S. total cotton demand (TCD) in the period 1990 to 2001(same as end-use consumption of previous studies and referred to as TCD throughout this study to reflect consistency) to be influenced by cotton fiber price, income and cotton promotion. The general form of the new equation is:

$$TCD = a + b\,(Income) - c\,(COTPRICE) + d\,(COTPROM)$$

where,

TCD represents U.S. total cotton demand,

COTPRICE represents U.S. cotton price

Income represents U.S. national income, and

COTPROM represents real annual cotton promotion expenditure.

The OLS regression was performed using the above general form using the MINITAB statistical software. Several simulations were performed with various variations of the above-mentioned general form. The OLS simulations with the best results alone are presented in this section. However, the results of all the other simulations are provided for reference in the appendix from section 8.21 to 8.47.

5.2.3 OLS regression models for U.S. cotton end-use demand

Two sets of simulations were performed for the U.S. cotton end-use demand equations. The first set of OLS models employed actual fiber demand in million pounds and income in billions of dollars. The second set of OLS models included population growth effects as; its influence on fiber demand is significant [61] and past models by Barlowe [5], Meyer [6], Sanford [7] and Evans [8]. Consequently, the per capita fiber demand is expressed in pounds, per capita income in dollars and cotton promotion expenditure in dollars. The final models selected from the simulations were chosen on the basis of their r-squared value, Durbin-Watson (DW) *d*-statistic, *t*-values and overall fit. Based on the above criterion the models chosen to estimate U.S. cotton end-use demand and their MINITAB statistical outputs are presented below.

5.2.4 Model 1: MINITAB output of U.S. total cotton demand OLS model

Regression Analysis: Ln(TCD) versus Ln(COTPRICE), Ln(REALDPI), ...

```
The regression equation is
Ln(TCD) = 1.74 - 0.167 Ln(COTPRICE) + 0.749 Ln(REALDPI) + 0.380 Ln(REALCOTPROM)

Predictor        Coef     SE Coef          T        P       VIF
Constant        1.737       1.509       1.15    0.283
Ln(COTPR     -0.16705     0.08248      -2.03    0.077       1.3
Ln(REALD       0.7494      0.1781       4.21    0.003       2.8
Ln(REALC      0.38036     0.07595       5.01    0.001       2.7

S = 0.03681            R-Sq = 96.4%         R-Sq(adj) = 95.0%
PRESS = 0.027818       R-Sq(pred) = 90.67%

Analysis of Variance
Source            DF          SS          MS         F        P
Regression         3    0.287383    0.095794     70.72    0.000
Residual Error     8    0.010837    0.001355
Total             11    0.298220

No replicates. Cannot do pure error test.
Source       DF      Seq SS
Ln(COTPR      1    0.013025
Ln(REALD      1    0.240388
Ln(REALC      1    0.033970

Unusual Observations
Obs   Ln(COTPR    Ln(TCD)         Fit      SE Fit    Residual    St Resid
 12       4.16     9.1345      9.1955      0.0229     -0.0610       -2.11R
R denotes an observation with a large standardized residual
Durbin-Watson statistic = 1.60

No evidence of lack of fit (P > 0.1)
```

5.2.5 U.S. total cotton demand model analysis

The Model 1 is successful in explaining 95% of the variation in U.S. total cotton demand for the period 1990 to 2001. All the explanatory variables, namely, cotton fiber price (*t*-value = -2.03), real disposable personal income (*t*-value = 4.21) and real cotton promotion expenditure (*t*-value = 5.01) are statistically significant as indicated by their *t*-values. The Durbin-Watson d-statistic of 1.60 shows no sign of first order serial autocorrelation, as it is greater then the dL value of 0.658 (see Appendix table 8.18). At the time of this study there were no prior models available for comparison for estimating U.S. TCD using actual demand and income (rather than per capita).

In the process of choosing the model presented in section 5.2.4 other model variations were also considered. The models other than the one chosen represent OLS models created by variations of certain explanatory variables. In the case of U.S. TCD the three explanatory variables were fiber price, cotton promotion expenditure and U.S. income. With regard to cotton fiber price, two variations were performed using nominal U.S. mill delivered cotton price (see section 5.2.4) and real U.S. mill delivered cotton price (see Appendix section 8.19). This OLS model produced a possible lack of fit as well as a lower Durbin-Watson statistic and thus not chosen. With regard to U.S. cotton promotion expenditure, two simulations were performed using real and nominal expenditure. The model using nominal expenditure produced a possible lack of fit as well as a lower Durbin-Watson statistic (see Appendix section 8.20). In the case of U.S. income, three simulations were performed using nominal U.S. gross domestic product (GDP), personal consumption expenditure (PCE) and disposable personal income (DPI) and three using real GDP, real PCE and real DPI. With nominal DPI, the model produced a possible lack of fit (see Appendix section 8.21), while the simulations with nominal PCE and nominal GDP produced very low Durbin-Watson statistic (see Appendix sections 8.22 and 8.23). In the case of real U.S. income, both real GDP and real PCE simulations produced lower Durbin-Watson d-statistic values than the chosen model (that uses real DPI) while real GDP also showed an overall lack of fit (see Appendix sections 8.23 and 8.25).

5.2.6 U.S. total cotton demand model performance evaluation

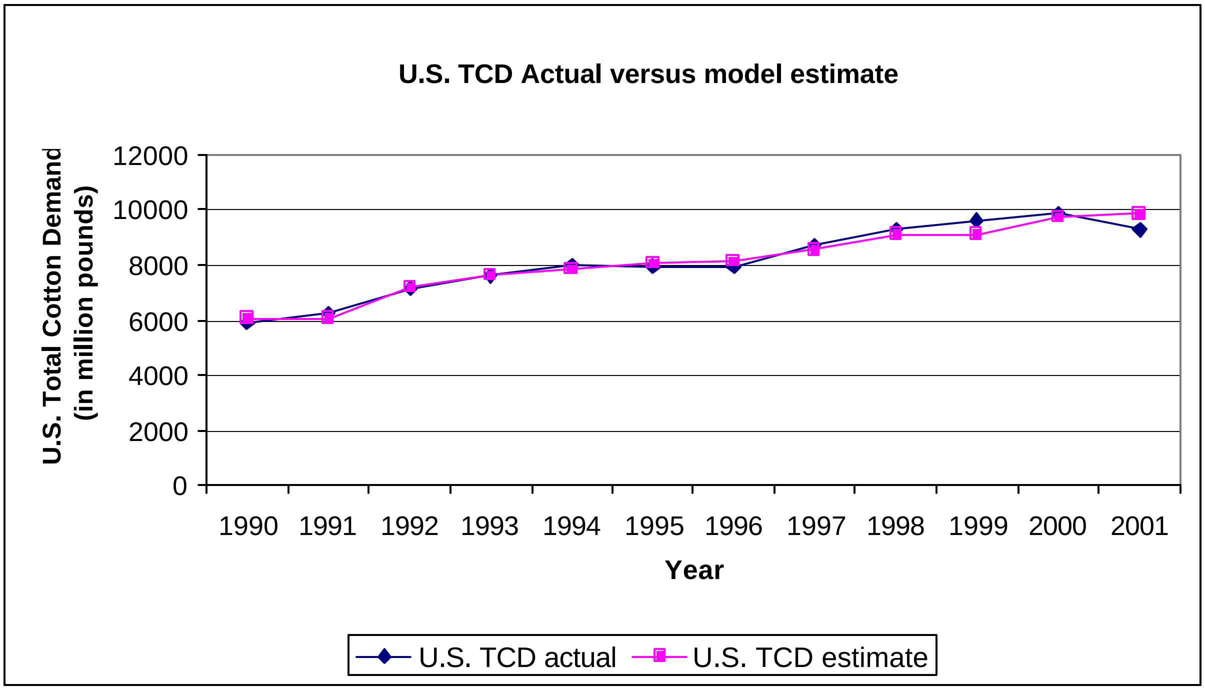


FIGURE 5.3: U.S. ACTUAL TCD VERSUS ESTIMATED TCD

The actual U.S. TCD was plotted against estimated U.S. TCD from the equation in section 5.2.4. (see figure 5.3). The estimated values closely tracks actual TCD throughout the period of study from 1990 to 2001. The average difference in estimated demand and actual demand was within 200 million pounds. However, large differences arose in 1999 and 2001. During 1999, cotton fiber prices fell to their lowest point of 59.85 cents per pound since 1990 (and also the lowest point in the study period of 1990 to 2001). This price decline coupled with the high 1998 ending stocks of 1890 million pounds could have triggered a rise in U.S. cotton consumption and hence. In 2001, the model overestimates the actual U.S. by 570.70 million pounds. During 2001, the U.S. economy witnessed a slowdown in growth and this was reflected in dramatic declines in U.S. cotton mill demand and imports. This overestimation may be due to the fact that though real DPI (which is employed in the estimation equation) increased 1.8 % in 2001 over 2000, the U.S. real GDP, which is reflective of overall economic activity grew a mere 0.25% over the same period (see

Appendix table 8.14). Thus, the general economic slowdown might be causing the overestimation in 2001.

Sensitivity Analysis

A sensitivity analysis was performed to observe the effects of changing income, cotton promotion expenditure and cotton fiber price on U.S. total cotton demand.

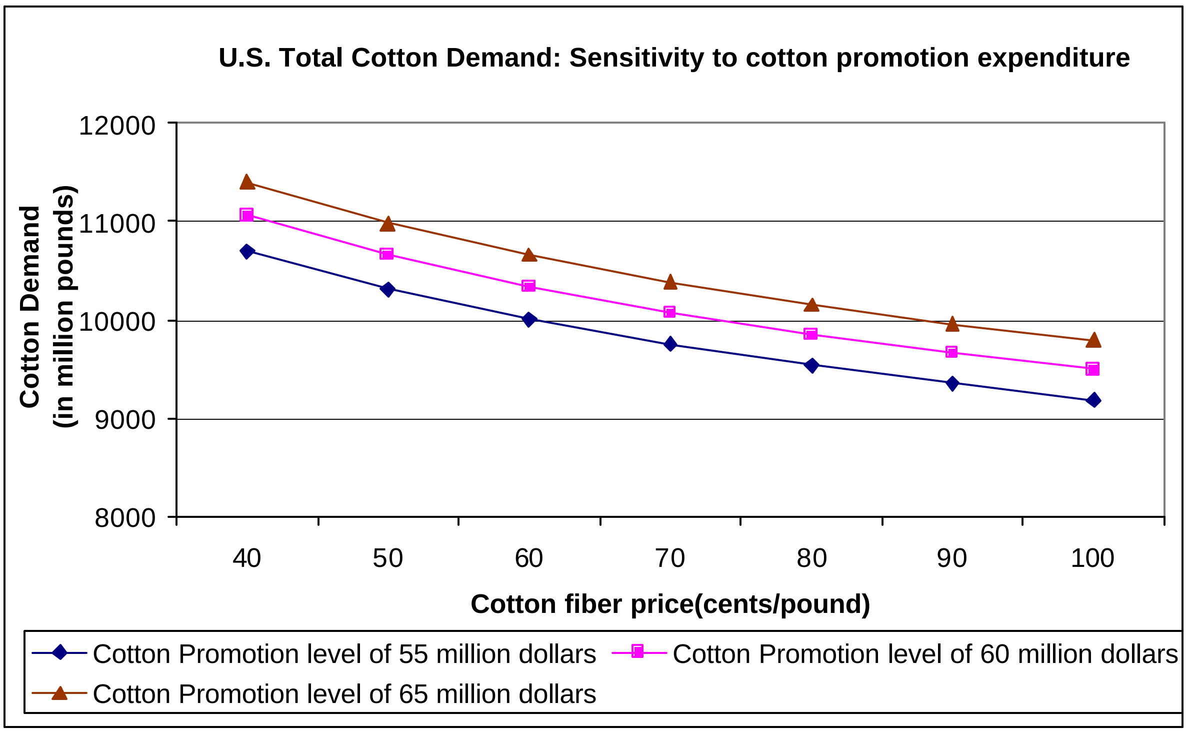


FIGURE 5.4: U.S. TCD: SENSITIVITY TO COTTON PROMOTION EXPENDITURE

Figure 5.4 illustrates the effect of three cotton promotion expenditure levels of \$55 million, \$60 million and \$65 million on U.S. total cotton demand under a constant real disposable personal income of \$ 7000 billion. From this illustration it is evident that as cotton promotion expenditure increases U.S. total cotton demand increases correspondingly. For example U.S. total cotton demand was 9183 million pounds at a cotton promotion expenditure of \$55 million, while at cotton promotion expenditures of \$60 million and \$65 million U.S. TCD was 3.3% (9491.79 million pounds) and 6.5% (9784.93 million pounds) higher respectively, under a constant real DPI of $7000 billion and a cotton fiber price of 100 cents per pound. The effect of varying income is illustrated in figure 5.5 by plotting U.S. TCD against cotton fiber price under three real DPI levels of $6500 billion, $7000 billion and $7500 billion and a constant cotton promotion expenditure of $60 million.

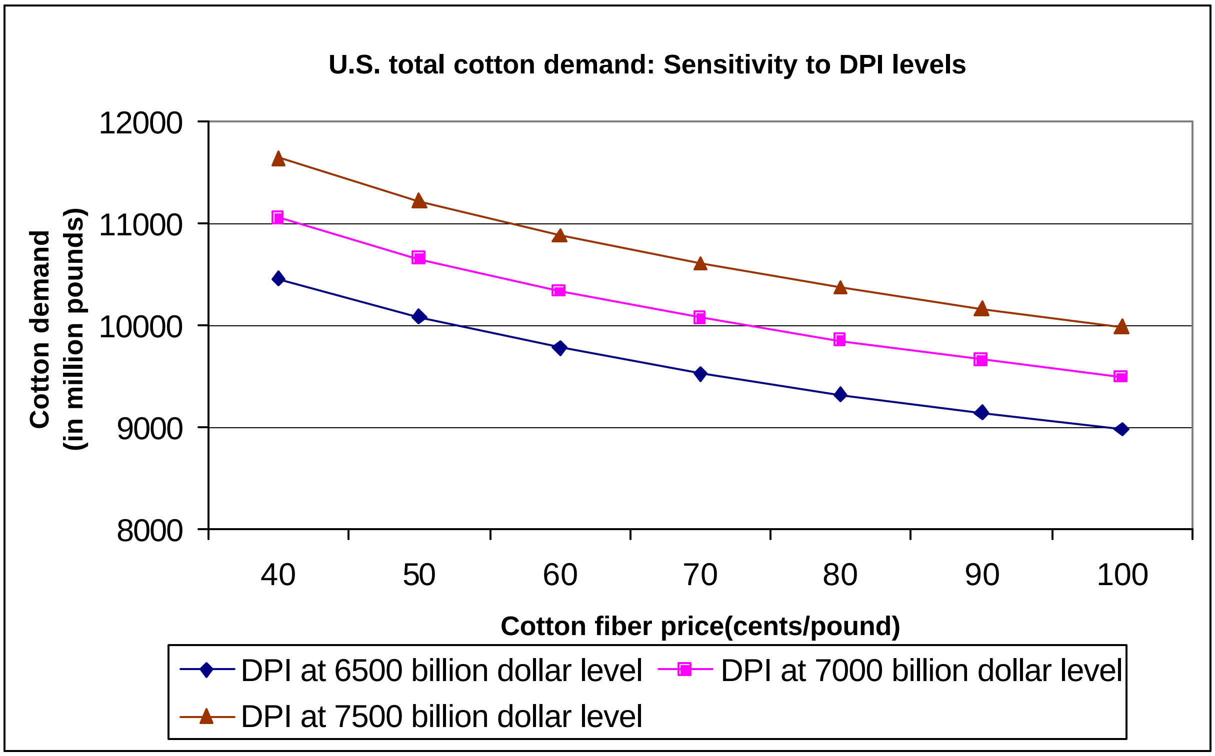


FIGURE 5.5: U.S. TOTAL COTTON DEMAND: SENSITIVITY TO U.S. REAL DPI

From Figure 5.5 it is evident that as real DPI increases, U.S. TCD also increases. For example, at a real DPI of $6500 billion, U.S. TCD was 8979 million pounds, while at real DPI levels of $7000 billion and $7500 billion; U.S. TCD increased by 5.7% (9491 million pounds) and 11.31% (9995 million pounds) respectively.

Out-of-sample forecast

All the models developed in this section are for the period 1990 to 2001, which in turn was limited by FEB's ability to provide polyester consumption figures only as far back as 1990. Consequently, the out-of-sample forecast was limited to the year 2002. However, it must be stated that at the time of this study the mill use and end use consumption data for 2002 for both cotton and polyester were nine-month consumption data for 2002. This was due to the fact that USDA's annual Cotton and Wool Situation and Outlook Yearbook was released in November 2002 as in all previous years. Further, FEB draws its imports and exports data for polyester from the above-mentioned USDA report. With this limitation, the nine-month data were converted into annualized 2002 consumption data for comparison with the model estimate. The nine-month total U.S. cotton demand for 2002 as reported by USDA was 7534.00 million pounds [2]. The annualized U.S. TCD was determined as in the following equation:

U.S. TCD (for 2002) =[U.S. nine-month TCD/ 9)] x 12

By the above formula, the annual (12-month) U.S. TCD for 2002 was 10045.33 million pounds. The estimated U.S. TCD for 2002 was 10630.39 million pounds. A 90% confidence interval for this estimate would range from 9567.35 million pounds to 11693.42 million pounds.

5.2.7 Model 2: MINITAB output of per capita U.S. total cotton demand model

Regression Analysis: Ln(TCD) versus Ln(COTPRICE), Ln(REALGDP), ...

```
The regression equation is
Ln(TCD) = - 3.16 - 0.166 Ln(COTPRICE) + 0.769 Ln(REALGDP) + 0.370 Ln(RCOTPROM)

Predictor        Coef     SE Coef          T        P       VIF
Constant       -3.163       1.975      -1.60    0.148
Ln(COTPR     -0.16612     0.06519      -2.55    0.034       1.2
Ln(REALG       0.7692      0.1726       4.46    0.002       2.2
Ln(RCOTP      0.37030     0.06217       5.96    0.000       2.1

S = 0.03023            R-Sq = 96.2%        R-Sq(adj) = 94.8%
PRESS = 0.019423       R-Sq(pred) = 89.90%

Analysis of Variance

Source            DF          SS          MS         F        P
Regression         3    0.185000    0.061667     67.50    0.000
Residual Error     8    0.007309    0.000914
Total             11    0.192308

No replicates. Cannot do pure error test.

Source       DF      Seq SS
Ln(COTPR      1    0.009295
Ln(REALG      1    0.143298
Ln(RCOTP      1    0.032406


Durbin-Watson statistic = 1.63

No evidence of lack of fit (P > 0.1)
```

5.2.8 U.S. per capita total cotton demand model analysis

The model 2 is successful in explaining 94.8% of the variation in U.S. per capita total cotton demand (TCD) for the period 1990 to 2001. Further, the Durbin-Watson d-statistic of 1.63 shows no evidence of autocorrelation effects (see Appendix section 8.18). All three explanatory variables namely, cotton price (*t*-value = -2.55), real GDP (*t*-value = 4.46) and cotton promotion expenditure (*t*-value = 5.96) are significant as reflected in their t-values. This compares favorably over Barlowe's [5] U.S. TCD model (which was exclusively a per capita model) that could explain only 89% of the variation in U.S. per capita TCD. Further, this model accounts for the change witnessed during 1990 to 2001 wherein, polyester promotion all but ceased with cotton promotion acquiring greater promotion expenditure (see section 5.2.1).

In case of the fiber prices, two variations were performed. The first variation directly used the actual U.S. mill delivered fiber price lagged by one year while the second variation used fiber price ratio. This price ratio was calculated by dividing U.S. mill delivered cotton fiber price lagged by one year by the U.S. mill delivered polyester fiber price lagged by one year. Meyer [6] observes that the use of such a price ratio provides the ability to capture the competitiveness of cotton with respect to polyester. The rationale of using lagged price is due to the fact that most fiber purchase for eventual mill use or end-use consumption is undertaken in the previous cotton crop season. Thus lagged prices would reflect the actual fiber purchase price and consequently the impact of that cost on final retail and mill demand.

Past research indicates varying approaches to quantifying fiber prices in the estimation of U.S. per capita total fiber demand. Sanford [7], employed real cotton prices since efforts to develop a fiber price index were unsatisfactory. Meyer [6], in his estimation of TFD employed nominal cotton prices since results using real fiber prices proved inadequate. In this study, both real and nominal U.S. cotton mill delivered prices were employed. The OLS model using nominal U.S. cotton mill delivered price produced as good an r-squared value as the chosen model in section 5.2.7, though its Durbin-Watson statistic of 1.55 was lower than the final model that had a Durbin-Watson statistic of 1.63 (see Appendix section 8.26).

In case of the income variable, Barlowe [5] employed real disposable personal income (DPI) as the income variable. In their total fiber demand models (whose overall hypothesis was structurally comparable to the cotton or polyester specific end-use models), Meyer [6] obtained satisfactory results with real DPI while Sanford [7], obtained satisfactory results by employing real personal consumption expenditure (PCE) as the income variable. In this study, simulations of all three income variables namely, per capita gross domestic product (GDP), per capita disposable personal income (DPI) and per capita personal consumption expenditure (PCE), in both nominal and real dollars (chained 1996 dollars) were performed. Based on the r-squared, values, Durbin-Watson statistic and test of overall fit; the model shown in section 5.2.4 that uses U.S. real per capita GDP as the income variable was chosen as the best estimation model. These simulations have been included in the Appendix from section 8.27 to 8.31. The third variable, namely, cotton promotion expenditure, was simulated with nominal dollars (se Appendix section 8.32) and real dollars (see section 5.2.7). The variations described above were included in the OLS regression for all four models namely, TCD, TPD, CMD and PMD.

5.2.9 U.S. per capita total cotton demand model performance evaluation

The performance of the OLS model developed in this study was evaluated for its effectiveness through three tests. The actual U.S. TCD values were plotted against estimated U.S. TCD values as seen in Figure 5.6. This plot would help in understanding of the model's estimation power. Further, a sensitivity analysis was performed, to highlight the effect of a change in an independent variable on U.S. per capita TCD. Finally, an out-of-sample forecast was performed by estimating U.S. per capita TCD, for a year not contained in the study sample (1990 to 2001), for comparison against the actual value of U.S. per capita TCD for the same year.

From figure 5.6 it is evident that the estimated U.S per capita U.S. TCD tracks actual U.S. per capita TCD except for the years 1999 and 2001. This indicates that the model estimate provides an effective prediction value of actual U.S. per capita TCD. The underestimation in 1999 and the overestimation in 2001 could be due to the unusual economic activity in these two years (see section 5.2.6.). In the case, of 1999 the underestimation could be due to the fact that the real per capita GDP in 1999 (over 1998) rose 4% though real personal consumption expenditure rose almost equally high by 3.8%, resulting in higher than expected fiber consumption (see Appendix section 8.15).

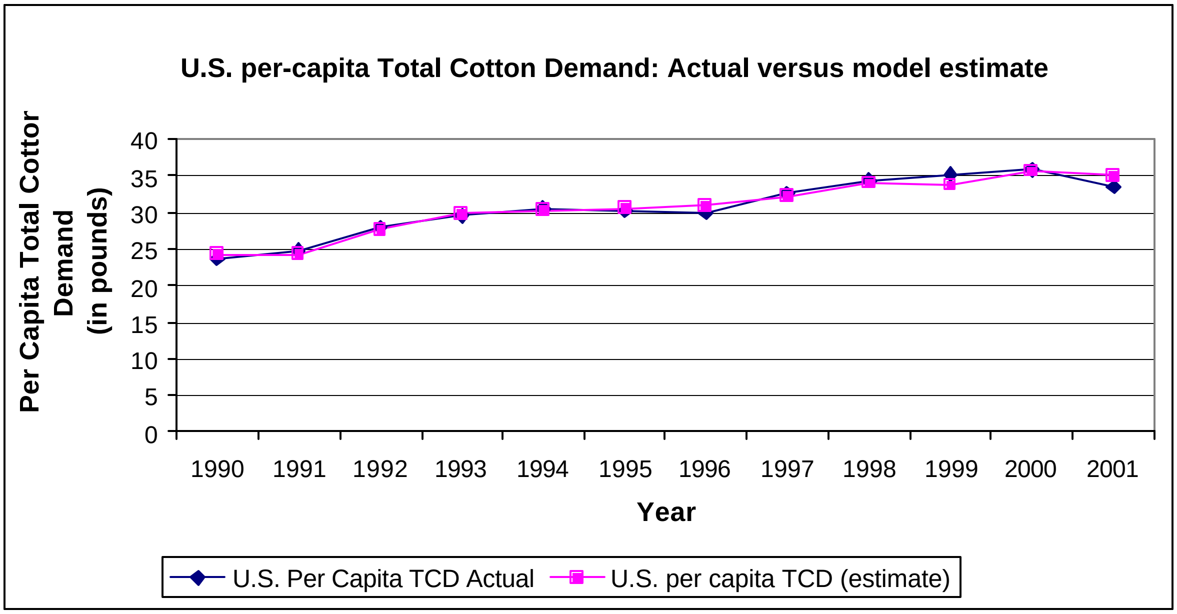


FIGURE 5.6: U.S. PER CAPITA TOTAL COTTON DEMAND: ACTUAL VERSUS MODEL ESTIMATE

In 2001, though real per capita GDP (which is used by the estimation model) declined by 0.69%, both real per capita DPI and PCE rose by 0.81% and 1.49% respectively over 2000 levels. This might be the reason for the total per capita demand being higher than estimated by the equation, which employs real per capita GDP.

Sensitivity Analysis

A sensitivity analysis was performed to observe the effects of changing income, cotton promotion expenditure and cotton fiber price on per capita U.S. total cotton demand for the period from 1990 to 2001. Figure 5.7 illustrates the effect of three per capita cotton promotion expenditure levels of $0.20, $0.25 and $0.30 on U.S. per capita total cotton demand under a constant real gross domestic product of $ 30,000. From this illustration it is evident that as per capita cotton promotion expenditure increases U.S. per capita total cotton demand increases correspondingly. For example per capita U.S. total cotton demand was nearly 30 pounds at a per capita cotton promotion expenditure of $0.20, while at cotton promotion expenditures of $0.25 and $0.30, U.S. per capita TCD were 8.6% (32.79

pounds) and 16% (35.08 pounds) higher respectively, under a constant real GDP of $30,000 and a cotton fiber price of 100 cents per pound.

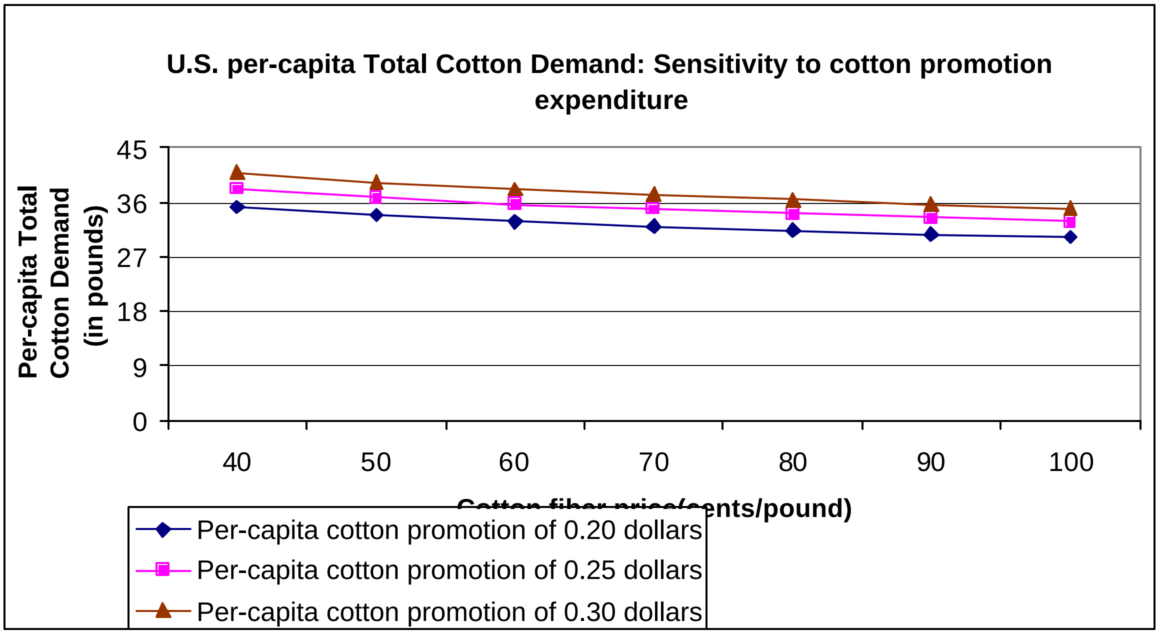


FIGURE 5.7: U.S. PER CAPITA TOTAL COTTON DEMAND: SENSITIVITY TO COTTON PROMOTION EXPENDITURE

The effect of varying income is illustrated in Figure 5.8 by plotting U.S. per capita TCD against cotton fiber price under three real GDP levels of $25,000, $30,000 and $35,000 and a constant per capita cotton promotion expenditure of $0.25. From figure 5.8 it is evident that as real GDP increases, U.S. per capita TCD also increases. For example, at a real per capita GDP of $25,000, U.S. per capita TCD was 28.50 pounds, while at real per capita GDP of $30,000 and $35,000; U.S. TCD increased by 15% (32.79 pounds) and 29% (36.92 pounds) respectively.

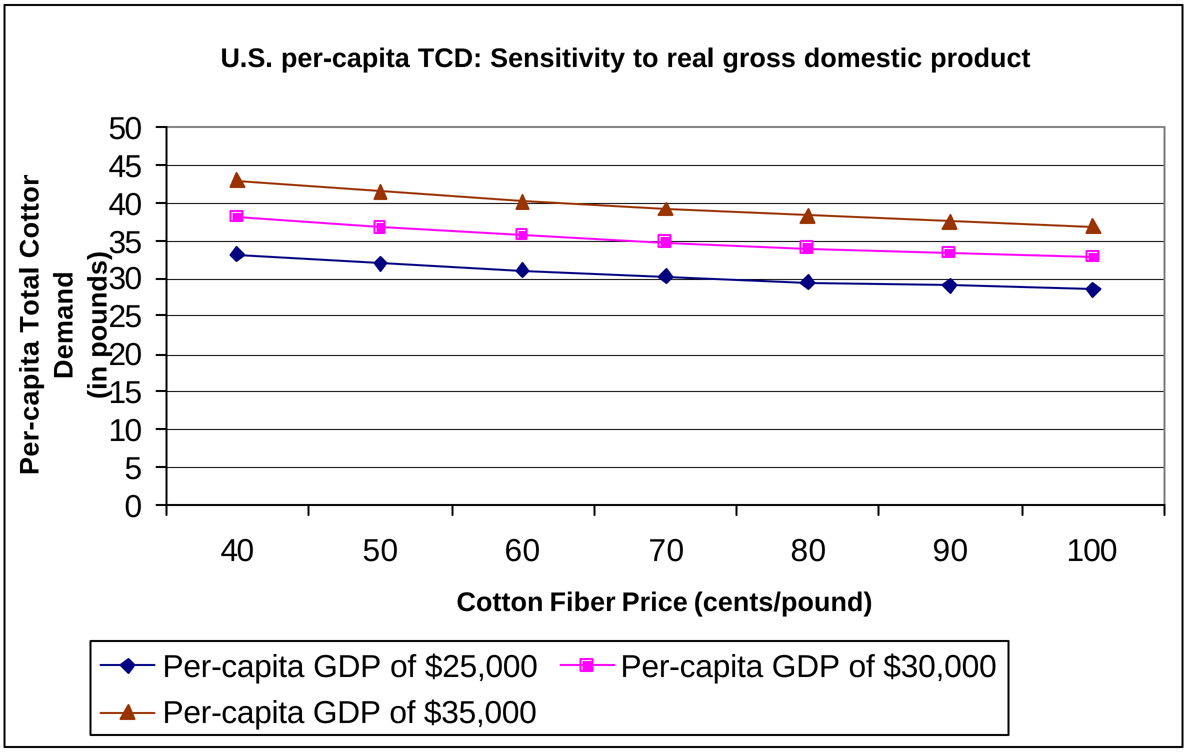


FIGURE 5.8: U.S. PER CAPITA TOTAL COTTON DEMAND: SENSITIVITY TO REAL GROSS DOMESTIC PRODUCT

Out-of-sample forecast

The annualized U.S. TCD was arrived at by the formula given below. A detailed discussion on the need for this estimation method is presented in section 5.2.6.

U.S. per capita TCD (for 2002) =[U.S. nine-month per capita TCD/ 9)] x 12

The annualized per capita U.S TCD for 2002 using the above formula was 35.84 pounds [57]. The model estimate for U.S. TCD was 36.95 pounds. A 98% confidence interval for this estimate would range from 36.21 pounds to 37.68 pounds. Hence, the above model can predict U.S. CMD within a 98% confidence level.

5.3 U.S. Cotton mill demand estimation: Background and variable selection

The modeling of U.S. cotton mill demand has been the topic of maximum research in the past in comparison to the other three models namely, U.S total cotton demand (TCD), U.S total polyester demand (TPD) and U.S polyester mill demand (PMD). Evans [50] hypothesized that U.S. cotton mill demand (CMD) was influenced by U.S. total fiber demand (TFD), cotton fiber price and polyester fiber price over the period 1955 to 1976. From a set of simulations Evans selected three equations based on the statistical significance of estimated coefficients and explanatory power.

The selected equations were:

$$LQCMP = 1.55 + 0.33\ L\ DFP - 0.35\ L\ \frac{(PCT_{t-1})}{(PPOL_{t-1})}$$

$$(2.8) \qquad (2.3) \qquad (8.1)$$

$$LQCMP = 0.70 + 0.46\ L\ DFP - 0.32\ L\ (PCT_{t-1}) + 0.40\ (PPOL_{t-1})$$

$$(0.7) \qquad (2.3) \qquad (5.9) \qquad (5.9)$$

$$QCMP = 10.2 + 0.17\ DFP - 0.13\ (PCT_{t-1}) + 0.09\ (PPOL_{t-1})$$

$$(2.0) \qquad (2.1) \qquad (5.4) \qquad (5.9)$$

where,

L denotes natural logarithm,

QCMP denotes mill consumption of cotton per capita for the calendar year,

DFP denotes domestic fiber consumption in pounds per capita,

PPCT denotes the price of middling 1(1/16) inch cotton price at Group B mill points in cents per pound, and,

PPOL denotes the reported average price for 1.5-denier polyester staple for cotton blending in cents per pound.

Each of the three equations was successful in explaining about 90% of the variation in U.S. cotton mill demand. From the above equations it is evident that cotton and polyester prices have the largest impacts on U.S. cotton mill demand. A 10% change in polyester fiber price can change per capita CMD by 3.5 to 4%. On the other hand, a 10% change in cotton fiber price would change per capita CMD by

3.2 to 3.5%. Sanford [7] improved on Evans' [8] model to estimate U.S. CMD in the period 1960 to 1986. Sanford hypothesized that U.S. CMD was influenced by U.S. total fiber demand (TFD), price ratio and a trend variable to reflect changes in consumer preferences and lifestyles. The equation (with t-values noted in parentheses) that provided the best statistical results was:

$$\underset{(12.03)}{QCMP = 17.17} \quad + \underset{(5.69)}{0.191\,(TFPC)} - \underset{(-\,4.87)}{12.68\,(RATIO)} - \underset{(-\,2.4)}{0.557\,(YR)}$$

R-squared = 0.98, DW d-statistic = 1.35

where,

QCMP denotes mill consumption of cotton per capita for the calendar year,

TFPC denotes total domestic fiber consumption in pounds per capita,

RATIO denotes cotton price lagged one year divided by polyester price lagged one year, and

YR is a trend variable where 1961 = 1.

The above model by Sanford was a vast improvement over Evans [50] model, since it was successful in explaining 98% of the variation in U.S. CMD for the period 1960 to 1986. The DW statistic of 1.35 shows no autocorrelation problem. However, since the period of 1960-1986 there have been fundamental changes in the U.S. trade structure with the passage of the North American Free Trade Agreement (NAFTA) in 1994. In order to account for this change that is assumed to positively impact U.S. domestic production, Meyer [6], developed estimation equations for U.S. CMD. However, Meyer adopted two stage least squares (TSLS) regression in contrast to all previous demand estimation models that where estimated using OLS regression.

The equations (with *t*-values in parentheses below) developed were:

Total Fiber Demand Estimation equation:

$$\text{Ln (TFD)} = 2.121 + 0.980 \text{ Ln (DPI)} - 0.178 \text{ Ln (Fiber Price)} + 0.128 \text{ (NAFTA)}$$

$$(12.21) \qquad (-4.68) \qquad (3.85)$$

Adjusted R-squared = 0.9096, DW *d*-statistic = 1.253

where,

TFD denotes total fiber demand (Sum of total demand for U.S. cotton, man-made and wool fibers) in pounds per capita,

DPI denotes per capita real U.S. disposable personal income,

Fiber Price, denotes nominal U.S. mill delivered cotton price (chosen as proxy for cotton, wool and man-made fiber prices), and

NAFTA is a dummy trend variable equal to one in 1994 (NAFTA inception) and zero in prior years.

Cotton Mill Demand Estimation equation:

$$\text{Ln (CMD)} = -2.448 + 1.315 \text{ Ln (TFD)} - 0.494 \text{ Ln (Ratio)} - 0.252 \text{ Ln (Deficit)}$$

$$(7.05) \qquad (-14.31) \qquad (-10.68)$$

$$+ 0.136 \text{ (1 + TradeLib)}$$

$$(5.38)$$

Adjusted R-squared = 0.9312, DW *d*-statistic = 1.672

where,

CMD denoted U.S. per capita cotton mill demand in pounds per capita,

TFD denotes U.S. total fiber demand in pounds per capita,

Ratio denotes the ration of nominal U.S. cotton mill delivered price lagged by one year divided by the nominal U.S. polyester mill delivered price lagged by one year,

Deficit denotes U.S. per capita cotton textile deficit in pounds per capita (deficit equals U.S. cotton imports minus U.S, cotton exports in raw fiber equivalent), and

TradeLib is a trend variable (1984 = 1 and zero in previous years) multiplied by a dummy equal to one in 1984 and zero in previous years.

Meyer's [6] model brought about a few important changes with respect to the other two models discussed in this section. Firstly, TSLS regression was used instead of OLS regression. The econometric argument forwarded by the author for employing TSLS regression was the interdependency of the dependent variables, namely, TFD and CMD. Secondly, the CMD estimation equation includes an added explanatory variable to capture the U.S. cotton textile deficit. The author observes that the inclusion of this term was essential to account for the large increases in imports amidst declining U.S. mill demand. This argument matches the trend observed in U.S. mill demand discussed in Chapter 4 on U.S. cotton demand. The trend variables included in the TFD and CMD equations to capture trade liberalization effects are trend variables. The lack of a better quantifying measure diminishes the explanatory power of Meyer's model. All the models discussed above ignore the effect of cotton promotion on U.S. mill demand, whose importance has been highlighted in Chapter 4. Thus the new model will seek to add the important cotton promotion dimension as well as include useful portions of previous models to explain with greater effectiveness the variation in U.S. cotton mill demand. In effect the new model would seek to develop a new U.S. cotton mill demand that is more relevant to the study period of 1990 to 2001 as well as succeed in explaining the variation in U.S. CMD.

5.3.1 U.S. Cotton mill demand model hypothesis

Based on the derived determinants in Chapter 4 and the section 5.2.1 this study hypothesizes that U.S. cotton mill demand is influenced by U.S cotton promotion expenditure, U.S. cotton textile deficit (CTD), ratio of cotton fiber price to polyester fiber price and U.S. total fiber demand (TFD). The general equation supporting the above hypothesis would be of the form:

$$CMD = a + b\,(COTPROM) - c\,(CTD) - d\,(ratio) + e\,(TFD)$$

where,

CMD denotes U.S. cotton mill demand,

COTPROM denotes the real U.S. cotton promotion expenditure,

CTD denotes U.S. cotton textile deficit, and

TFD denotes U.S. total fiber demand

Using the above general equation two OLS estimation models are proposed. The first model estimates U.S. CMD using actual real income and demand. The second model estimates U.S. CMD using per capita income and fiber demand. This section will present the models with the best statistical performance. The remaining OLS simulations with its variations are presented in the appendix section for reference.

5.3.2 U.S. Cotton mill demand Model

Minitab Output of U.S. cotton mill demand model

Regression Analysis: CMD versus CTD, RATIO, TFD, REALCOTPROM

```
The regression equation is
CMD = - 1916 - 0.903 CTD - 40 RATIO + 0.445 TFD + 9.30 REALCOTPROM

Predictor        Coef     SE Coef          T        P       VIF
Constant      -1916.2       435.8      -4.40    0.003
CTD          -0.90308     0.04838     -18.67    0.000       9.1
RATIO           -40.1       234.5      -0.17    0.869       2.4
TFD           0.44516     0.03268      13.62    0.000      16.5
REALCOTP        9.303       4.355       2.14    0.070       5.6

S = 65.17              R-Sq = 98.9%         R-Sq(adj) = 98.3%
PRESS = 93064.2        R-Sq(pred) = 96.59%

Analysis of Variance

Source             DF          SS          MS         F         P
Regression          4     2697756      674439    158.80     0.000
Residual Error      7       29730        4247
Total              11     2727486
No replicates. Cannot do pure error test.

Source       DF      Seq SS
CTD           1       24988
RATIO         1      246233
TFD           1     2407155
REALCOTP      1       19380

Unusual Observations
Obs       CTD        CMD         Fit      SE Fit    Residual    St Resid
  7      2698     5226.8      5326.0        44.3       -99.2      -2.08R

R denotes an observation with a large standardized residual

Durbin-Watson statistic = 2.32

No evidence of lack of fit (P > 0.1)
```

5.3.3 U.S. cotton mill demand model analysis

The above model is successful in explaining 98.3% of the variation in U.S. CMD for the period 1990 to 2001 (see Section 5.3.2). Further, the Durbin-Watson d-statistic of 2.32 shows no evidence of autocorrelation effects (refer Appendix Table 8.18). The explanatory variables in the above equation, namely, cotton textile deficit (*t*-value = -18.67), total fiber demand (*t*-value = 13.62) and cotton promotion expenditure (*t*-value = 2.14) are all statistically significant though the price ratio term (*t*-value = -0.17) shows low significance as indicated by their *t*-values. This significance confirms the assumption made in the previously described hypothesis.

In the process of choosing the model presented in Section 5.3.2 other model variations were also considered. The models other than the one chosen represent OLS models created by varying certain explanatory variables. In the case of U.S. CMD the explanatory variables drawn from the hypothesis presented in section 5.3.1 were fiber price ratio, cotton promotion expenditure, U.S. cotton textile deficit and U.S. total fiber demand. Since, the fiber price ratio, U.S. cotton textile deficit are fixed quantities, the variations attempted were restricted to the cotton promotion expenditure variable and the U.S. total fiber demand. With regard to U.S. cotton promotion expenditure, two simulations were performed using real and nominal expenditure. The model using nominal expenditure produced a lower R-squared value as well as a lower Durbin-Watson statistic (see Appendix section 8.33). Meyer [6], in his estimation model for U.S. cotton mill demand, calculated the U.S. total fiber demand, as the sum of the annual mill demand of cotton, wool and man-made fibers plus the net textile trade deficit (in raw fiber equivalent basis) in manufactured products for these fibers. On the, other hand the USDA Cotton and Wool Situation and Outlook Report for 2002, calculates total fiber demand using the same formula as described above, but with an additional fiber category, namely, flax and silk. Hence, two simulations, one using Meyer's definition (designated as TFD 1) and the second using the USDA Cotton and Wool Situation and Outlook Report definition (designated as TFD) were performed. The USDA definition of TFD was found to produce better results (see Appendix 8.34).

5.3.4 U.S. cotton mill demand model performance evaluation

The performance of the OLS model developed in this study was evaluated for its effectiveness through three tests. The actual U.S. CMD values were plotted against estimated U.S. CMD values. This plot would help in understanding of the model's estimation power. Further, a sensitivity analysis was performed, to highlight the effect of a change in an independent variable on U.S. CMD. Finally, an out-of-sample forecast was performed by estimating U.S. CMD for a year not contained in the sample (in this case 2002) for comparison against the actual value of U.S. CMD for the same year.

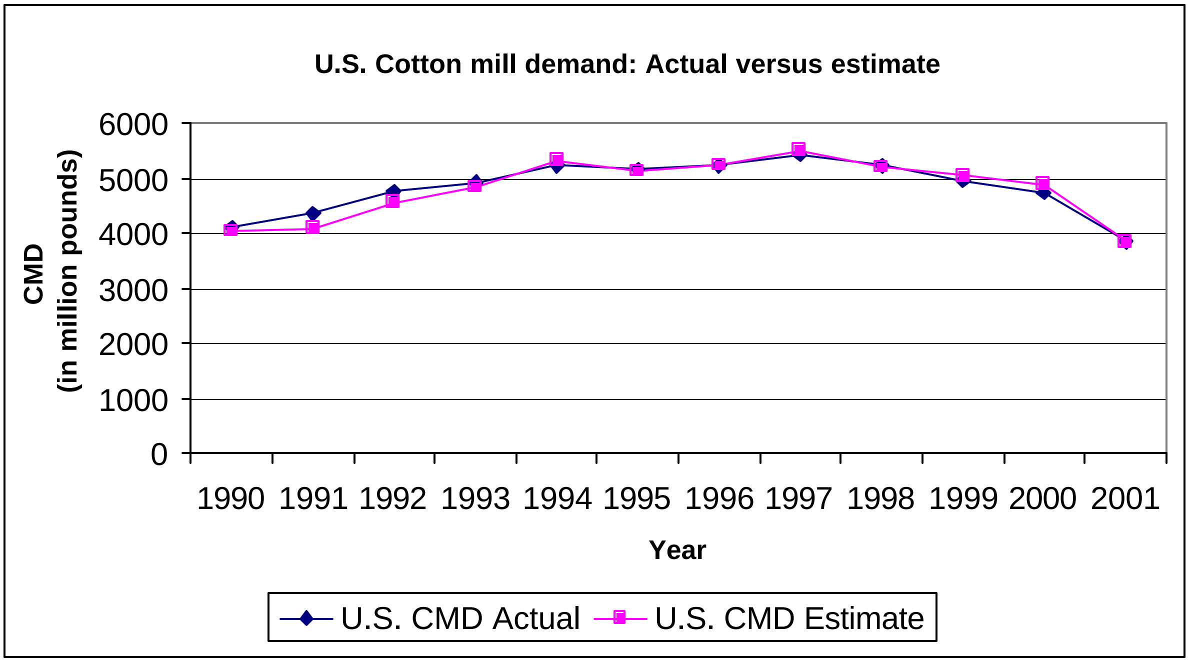


FIGURE 5.9: U.S. COTTON MILL DEMAND: ACTUAL VERSUS MODEL ESTIMATE

Figure 5.9 illustrates the actual U.S. cotton mill demand versus the model estimate of U.S. cotton mill demand. From this illustration, it is evident that the estimated U.S. CMD values track the actual values almost throughout the period of 1990 to 2001. This would be indicative of the model's high accuracy of estimation.

Sensitivity Analysis

A sensitivity analysis was performed to observe the effects of varying cotton textile deficit, cotton promotion expenditure and fiber price ratio on U.S. cotton mill demand. Figure 5.10 illustrates the effect of three cotton promotion expenditure levels of $55 million, $60 million and $65 million on U.S. cotton mill demand under a constant cotton textile deficit of 6000 million pounds and a total fiber demand of 24,000 million pounds. From this illustration it is evident that as cotton promotion expenditure increases U.S. cotton mill demand increases correspondingly. For example U.S. cotton mill demand was nearly 3817 million pounds at a cotton promotion expenditure of $55 million, while at cotton promotion expenditures of $60 million and $65 million, U.S. CMD were 1.2% (3864 million pounds) and 2.4% (3910 million pounds) higher respectively, under a constant cotton textile deficit of 6,000 million pounds and a price ratio of 1.00 (cotton price equals polyester price).

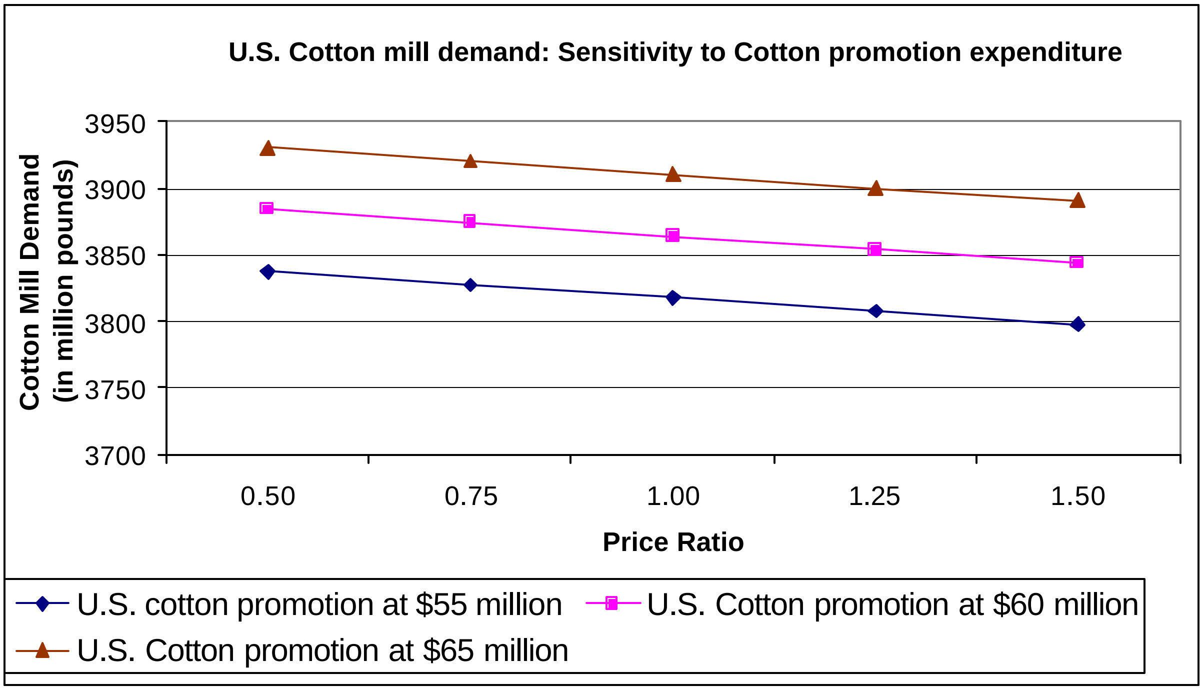


FIGURE 5.10: U.S. COTTON MILL DEMAND: SENSITIVITY TO COTTON PROMOTION EXPENDITURE

The effect of varying income is illustrated in Figure 5.11 by plotting U.S. cotton mill demand against the fiber price ratio under three cotton textile deficit levels of 5,500 million pounds, 6,000 million pounds and 6,500 million pounds under a constant cotton promotion expenditure of $60 million.

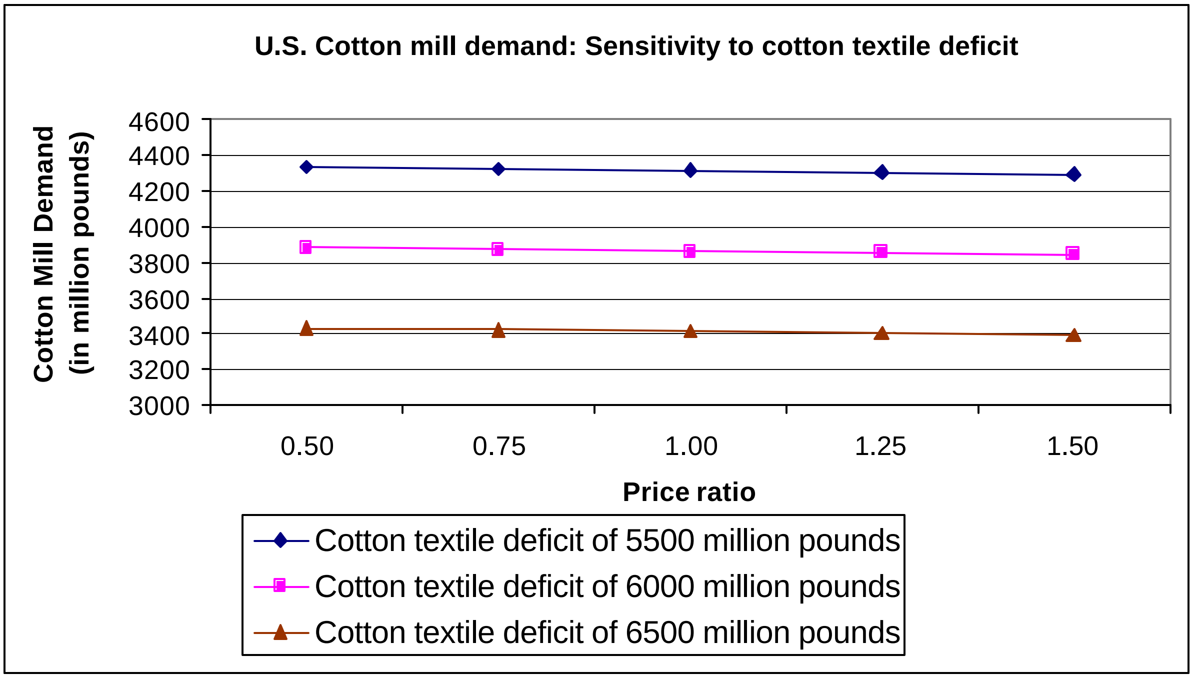


FIGURE 5.11: U.S. COTTON MILL DEMAND: SENSITIVITY TO COTTON TEXTILE DEFICIT

From Figure 5.11 it is evident that as the U.S. cotton textile deficit increases, U.S. cotton mill demand decreases. For example, at a cotton textile deficit of 5,500 million pounds, the U.S. cotton mill demand was 4315 million pounds, while at cotton textile deficits of 6,000 million pounds and 6,500 million pounds; U.S. cotton mill demand decreased by almost 10% (3864 million pounds) and 20% (3412 million pounds) respectively under a constant cotton promotion expenditure of $65 million and a price ratio of 1.00 (cotton price equals polyester price).

The effect of varying total fiber demand is illustrated in Figure 5.12 by plotting U.S. cotton mill demand against the fiber price ratio under three total fiber demand levels of 20,000 million pounds, 25,000 million pounds and 30,500 million pounds under a constant cotton promotion expenditure of $60 million and cotton textile deficit of 6000 million pounds.

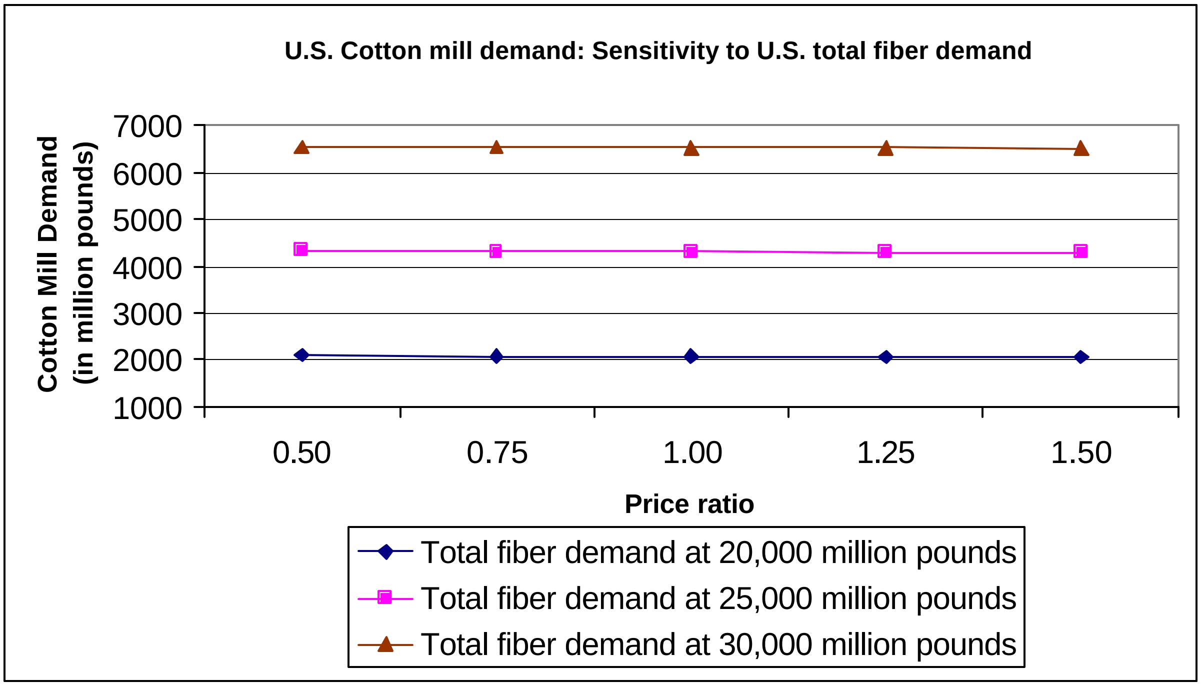


FIGURE 5.12: U.S. COTTON MILL DEMAND: SENSITIVITY TO TOTAL FIBER DEMAND

From figure 5.12 it is evident that as the U.S. total fiber demand increases, U.S. cotton mill demand also increases. For example, at a total fiber demand of 20,000 million pounds, the U.S. cotton mill demand was 2084 million pounds, while at total fiber demand levels of 25,000 million pounds and 30,000 million pounds; U.S. cotton mill demand increased by almost 106% (4309 million pounds) and 213% (6534 million pounds) respectively under a constant cotton promotion expenditure of $65 million and a price ratio of 1.00 (cotton price equals polyester price).

Out-of-sample forecast

The nine-month U.S. cotton mill demand (CMD) for 2002 as reported by USDA was 2823.40 million pounds [2]. The annualized U.S. CMD was determined as in the following equation:

U.S. CMD (for 2002) =[U.S. nine-month CMD / 9)] x 12

By the above formula, the annual (12-month) U.S. CMD for 2002 was 3764.53 million pounds [2]. The model estimate for U.S. CMD in 2002 was 3791.35

million pounds. A 98% confidence interval for this estimate would range from 3715.52 million pounds to 3867.17 million pounds. The estimated U.S. CMD for 2002 was 26.85 million pounds above the actual data. Hence, the above model can predict U.S. CMD within a 98% confidence level.

5.3.5 U.S. per capita cotton mill demand model

Minitab Output of U.S. per capita cotton mill demand

Regression Analysis: CMD versus CTD, RATIO, RCOTPROM, TFD1

```
The regression equation is
CMD = - 3.17 - 0.798 CTD - 0.14 RATIO + 9.35 RCOTPROM + 0.391 TFD1

Predictor        Coef     SE Coef          T        P       VIF
Constant       -3.174       2.780      -1.14    0.291
CTD          -0.79834     0.06293     -12.69    0.000       5.2
RATIO          -0.136       1.411      -0.10    0.926       2.3
RCOTPROM        9.348       7.087       1.32    0.229       4.3
TFD1          0.39069     0.05408       7.22    0.000       9.6

S = 0.4060             R-Sq = 97.1%         R-Sq(adj) = 95.4%
PRESS = 6.53839        R-Sq(pred) = 83.58%

Analysis of Variance

Source             DF          SS          MS         F        P
Regression          4     38.6744      9.6686     58.65    0.000
Residual Error      7      1.1540      0.1649
Total              11     39.8284

No replicates. Cannot do pure error test.

Source       DF      Seq SS
CTD           1     10.5063
RATIO         1      2.9290
RCOTPROM      1     16.6342
TFD1          1      8.6048

Unusual Observations
Obs       CTD       CMD         Fit       SE Fit    Residual    St Resid
  1       7.0    16.620      17.307       0.283      -0.687       -2.36R

R denotes an observation with a large standardized residual

Durbin-Watson statistic = 1.76

No evidence of lack of fit (P > 0.1)
```

5.3.6 U.S. per capita cotton mill demand model analysis

The above model is successful in explaining 97.8% of the variation in per capita U.S. CMD for the period 1990 to 2001. Further, the Durbin-Watson d-statistic of 1.89 shows no evidence of autocorrelation effects (refer Appendix table 8.18). The explanatory variables in the above equation, namely, cotton textile deficit (t-value = -17.54), total fiber demand (t-value = 11.14) and cotton promotion expenditure (t-value = 2.69) are all statistically significant though price ratio (t-value = 0.88) shows low significance as indicated by their t-values. This model however, has Meyer's [6] model as a direct comparison. Meyer's model was successful in explaining only 93.12% of the variation in per capita U.S. CMD [6]. Further, the above model accounts for the strong effect of U.S cotton promotion efforts as reflected in its t-vale of 2.69. In summary, the above model is able to account for the variation in U.S. per capita CMD with greater effect than Meyer's model.

In the process of choosing the model presented in section 5.3.5 other model variations were also considered. The models other than the one chosen represent OLS models created by varying certain explanatory variables. In the case of U.S. per capita CMD the explanatory variables drawn from the hypothesis presented in section 5.3.1 were fiber price ratio, per capita cotton promotion expenditure, per capita U.S. cotton textile deficit and per capita U.S. total fiber demand. Since, the fiber price ratio, per capita U.S. cotton textile deficit are fixed quantities, the variations attempted were restricted to the per capita cotton promotion expenditure variable and the per capita U.S. total fiber demand. With regard to per capita U.S. cotton promotion expenditure, two simulations were performed using real and nominal expenditure. The model using nominal expenditure produced a lower R-squared value as well as a lower Durbin-Watson statistic (see Appendix section 8.35). Meyer [6], in his estimation model for U.S. cotton mill demand, calculated the U.S. total fiber demand, as the sum of the annual mill demand of cotton, wool and man-made fibers plus the net textile trade deficit (in raw fiber equivalent basis) in manufactured products for these fibers. On the, other hand the USDA Cotton and Wool Situation and Outlook Report for 2002, calculates total fiber demand using the same formula as described above, but with an additional fiber category, namely, flax and silk. Hence, two simulations, one using Meyer's definition (designated as TFD 1) and the second using the USDA Cotton and Wool Situation and Outlook Report definition (designated as TFD) were performed. Meyer's definition of TFD was found to produce better results (see Appendix 8.36).

5.3.7 U.S. per capita cotton mill demand model performance evaluation

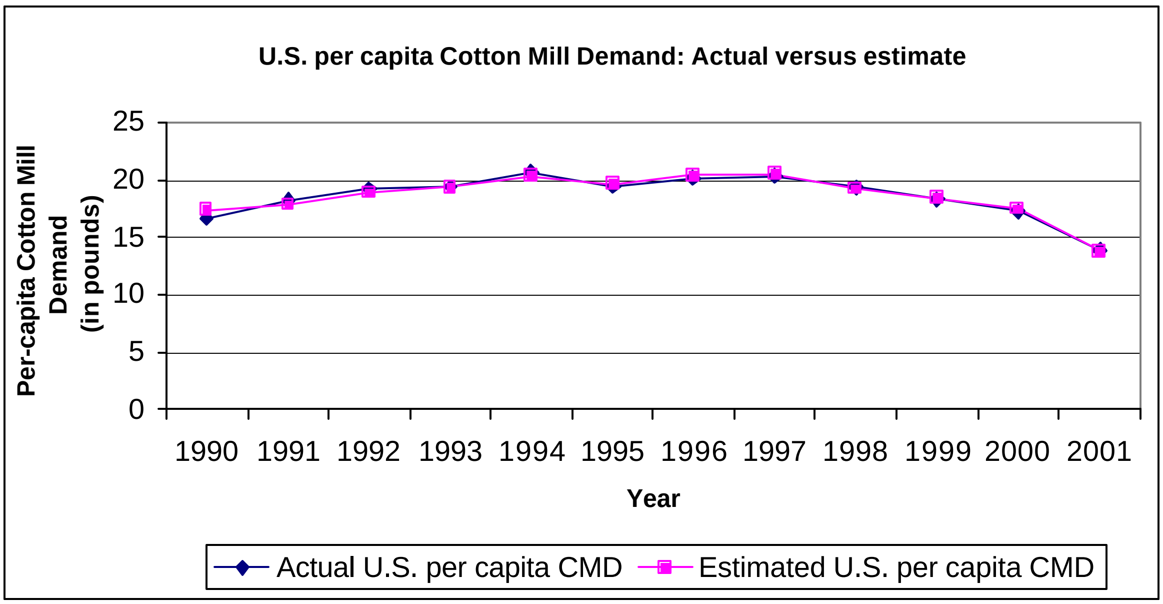


FIGURE 5.13: U.S. PER CAPITA COTTON MILL DEMAND: ACTUAL VERSUS MODEL ESTIMATE

Figure 5.13 illustrates the actual U.S. per capita cotton mill demand versus the model estimate of U.S. per capita cotton mill demand. From this illustration, it is evident that the estimated U.S. per capita CMD values track the actual values throughout the period of 1990 to 2001. This would be indicative of the model's high accuracy of estimation.

Sensitivity Analysis

A sensitivity analysis was performed to observe the effects of changing per capita CTD, cotton promotion expenditure and fiber price ratio on per capita U.S.

CMD. Figure 5.14 illustrates the effect of three per capita cotton promotion expenditure levels of $0.20, $0.25 and $0.30 on U.S. per capita cotton mill demand under a constant per capita cotton textile deficit of 20 pounds and a per capita total fiber demand of 80 pounds. From this illustration it is evident that as per capita cotton promotion expenditure increases U.S. per capita cotton mill demand increases correspondingly. For example U.S. per capita cotton mill demand was nearly 13.8 pounds at a per capita cotton promotion expenditure of $0.20, while at per capita cotton promotion expenditures of $0.25 and $0.30, U.S. per capita CMD were 3.3% (14.34 pounds) and 6.7% (14.81 pounds) higher respectively, under a constant per capita cotton textile deficit of 20 pounds, a per capita total fiber demand of 80 pounds and a price ratio of 1.00 (cotton price equals polyester price).

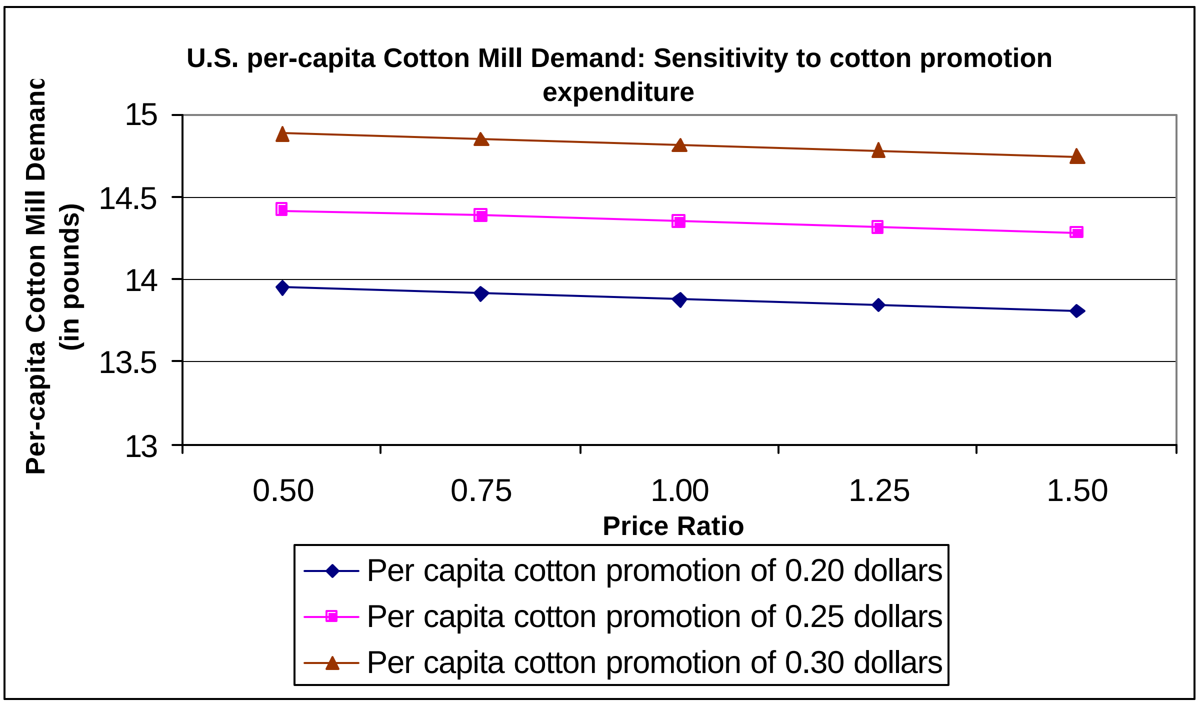


FIGURE 5.14: U.S. PER CAPITA COTTON MILL DEMAND: SENSITIVITY TO COTTON PROMOTION EXPENDITURE

From Figure 5.15 it is evident that as the U.S. per capita cotton textile deficit increases, U.S. per capita cotton mill demand decreases. For example, at a per capita cotton textile deficit of 15 pounds, the U.S. per capita cotton mill demand was 18.33 pounds, while at per capita cotton textile deficits of 20 pounds and 25 pounds; U.S. per capita cotton mill demand decreased by almost 21% (14.34 pounds) and

44% (10.35 pounds) respectively under a constant cotton promotion expenditure of $0.25, a per capita total fiber demand of 80 pounds and a price ratio of 1.00 (cotton price equals polyester price).

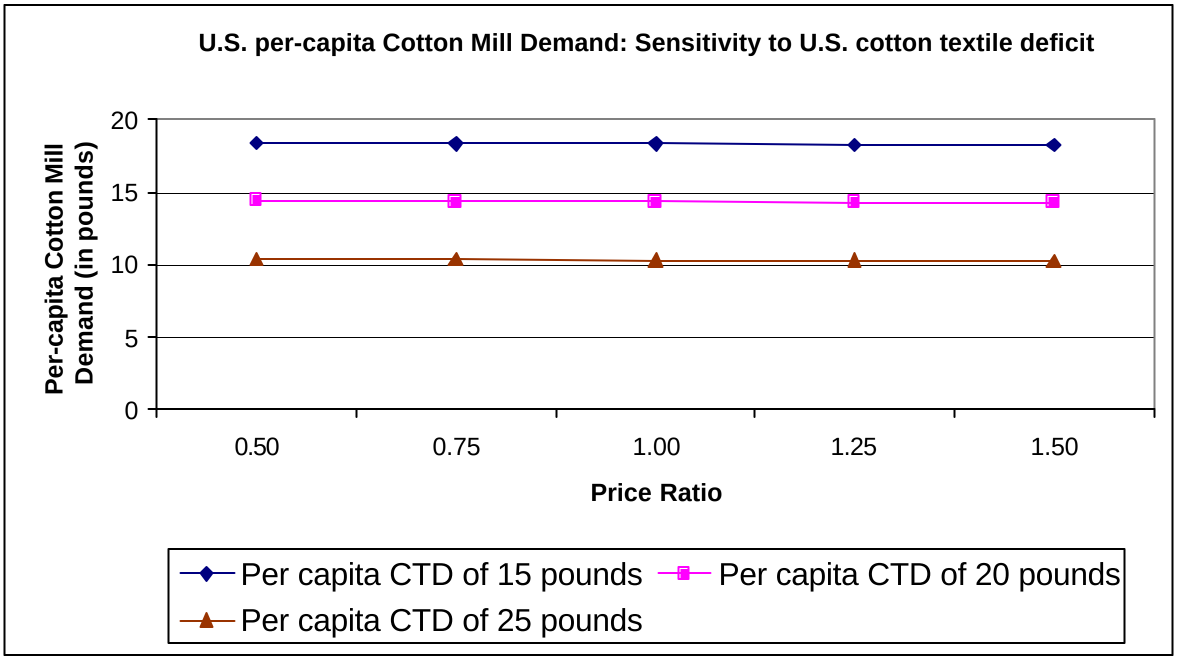


FIGURE 5.15: U.S. PER CAPITA COTTON MILL DEMAND: SENSITIVITY TO COTTON TEXTILE DEFICIT

The effect of varying total fiber demand is illustrated in Figure 5.16 by plotting U.S. per capita cotton mill demand against the fiber price ratio under three per capita total fiber demand levels of 75 pounds, 80 pounds and 85 pounds and a constant cotton promotion expenditure of $0.25 and cotton textile deficit of 20 pounds. From figure 5.16 it is evident that as the U.S. per capita total fiber demand increases, U.S. cotton mill demand also increases. For example, at a per capita total fiber demand of 75 pounds, the U.S. cotton mill demand was 12.39 pounds, while at per capita total fiber demand levels of 80 pounds and 85 pounds; U.S. per capita cotton mill demand increased by almost 16% (14.34 pounds) and 32% (16.30 pounds) respectively under a constant per capita cotton promotion expenditure of $0.25 and a price ratio of 1.00 (cotton price equals polyester price).

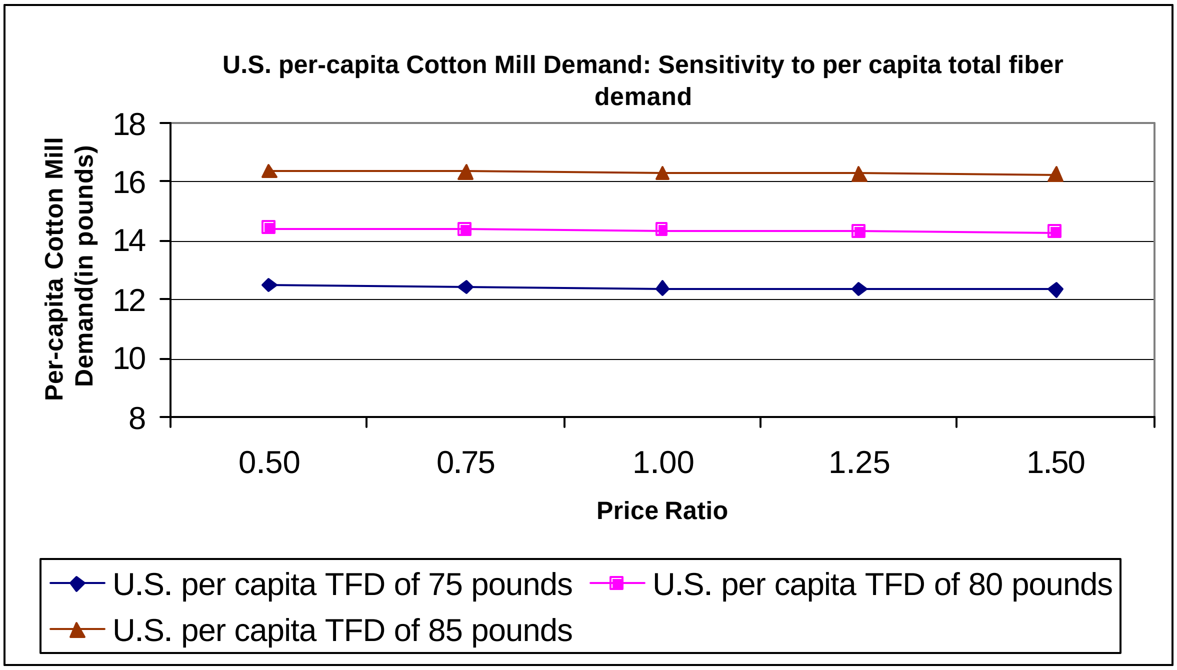


FIGURE 5.16: U.S. PER CAPITA COTTON MILL DEMAND: SENSITIVITY TO TOTAL FIBER DEMAND

Out-of-sample forecast

The nine-month U.S. cotton mill demand (CMD) for 2002 as reported by USDA was 2823.40 million pounds [2]. The annualized U.S. CMD was determined as follows:

U.S. per capita CMD (for 2002) =[U.S. nine-month per capita CMD / 9)] x 12

Using the above formula, the annualized estimate of U.S per capita CMD was 13.21 pounds [2]. The model estimate for U.S. CMD was 14.01 pounds. A 98% confidence interval for this estimate would range from 13.72 pounds to 14.29 pounds. The model estimate for 2002 was 0.8 pounds above the actual data. Hence, the above model can predict U.S. CMD within a 98% confidence level.

5.4 U.S. Polyester fiber demand models

The review of past research revealed that there were no polyester specific fiber demand models developed so far. This could be attributed to the lack of availability of polyester fiber data with respect to end-use demand. Additionally, most research has focuses on studying inter-fiber competition between cotton and man-made fibers as a whole grouping. However, such a comparison would be inadequate for two reasons. First, polyester poses the most direct threat to cotton by substitution. This is because polyester competes with cotton in key end-use segments namely, apparel, home furnishings and semi-manufactured textiles. Further, Zhang [5] et al observe that within the broad man-made fiber grouping cotton statistically shows a substitutive relationship with just the non-cellulosic fibers. This further rules out acetate and rayon fibers from consideration. The remaining two fibers namely, nylon and olefins compete primarily in the industrial fabrics and nonwoven fabric end-uses respectively where cotton and polyester have significantly lesser importance and consequently low demand. With almost 40% share of the synthetic fibers in 2001, polyester continues to be the largest synthetic fiber consumed in the U.S. The following sections will present an analysis of previous models developed for the broader man-made fiber demand estimation and follow up with specific polyester models which have no precedent to be compared with.

5.4.1 Polyester end-use demand model background and variable selection

As stated in the introduction past research has focused exclusively on man-made fiber end-use demand models. Thus there is no polyester specific model available for comparison or review. Barlowe [5] developed an estimation model for U.S man-made fiber end-use demand for the period 1948 to 1964. According to Barlowe's hypothesis U.S. man-made fiber end-use demand is influenced by cotton fiber price, real U.S. disposable personal income and man-made fiber promotion expenditure.

The final U.S. man-made fiber demand estimation model was:

$$C_{tm\text{-}m,\,t} = -13.1774 + 0.2038\, P_{c,\,t-1} + 0.0055\, I_t + 69.5326\, M_{p,\,t}$$

(+5.37) (+2.22) (+ 9.08)

R-squared = 0.99, DW d-statistic = 2.06

where,

$C_{tm\text{-}m,\,t}$ denotes cotton equivalent of man-made fibers consumed in the production of aggregate end-uses in pounds per capita,

$P_{c,\,t-1}$ denotes real price per pound for middling 15/16-inch cotton for group B mill points,

I_t denotes the U.S. real disposable personal income, and

$M_{p,\,t}$ denotes the, real per capita man-made fiber promotion expenditure in dollars.

Though the model performance is satisfactory, its relevance for the period of this study (from 1990 to 2001) is questionable. This is due to the fact that U.S. polyester promotion that was intensive since the 1950's has been either suspended or reduced due to shrinking margins of profit for polyester fibers since 1990 [14,58]. Thus polyester's competitiveness has been primarily due to its engineered property superiority (described in detail in chapter 4) apart from fiber price and U.S. national income. With this background it is hypothesized that U.S. polyester end-use demand (hereafter referred to as total polyester demand) is influenced by polyester fiber price, U.S. national income and technological development of polyester fibers.

The general form of the equation would be:

$$TPD = a + b\,(POLYPRICE) + c\,(Income) + d\,(TECHDEV)$$

where,

TPD denotes U.S. polyester end use demand,

POLYPRICE denotes U.S. mill delivered polyester price,

Income denotes U.S. national income, and

TECHDEV denotes a trend variable representing technological development of polyester fibers (equal to 1 in 1990 and increasing to 12 in 2001).

TPD is defined as the sum of the annual U.S. polyester mill demand (PMD) plus the net polyester textile deficit (calculated as U.S. polyester imports minus U.S. polyester exports in raw fiber equivalent terms). While PMD data for 1990 to 2001 are readily available form Fiber Organon, PTD data are not published in any known sources. FEB provided internal data for man-made fiber percentage shares by individual fiber type. From this data the polyester share was applied to man-made import and export data to isolate the polyester component out of the man-made fiber import and export figures (see Appendix section 8.9). The U.S. mill delivered polyester price published by the National Cotton Council was used to represent the polyester fiber prices (see Appendix section 8.4). In case of the income variable three variations were performed using gross domestic product (GDP), disposable personal income (DPI) and personal consumption expenditure (PCE) in nominal and real dollars. The trend variable for polyester's technological development was a trend variable equal to one in 1990 and increasing by one each successive year to capture continuous engineering development in polyester fibers.

5.4.2 U.S. total polyester demand model

The TPD demand estimation OLS models selected from all the simulations for their best statistical performance only are presented in this section. The remaining models simulated are presented in the appendix section for reference.

5.4.3 Minitab Output of U.S. total polyester demand OLS model

Regression Analysis: Ln(TPD) versus Ln(POLYPRICE), Ln(TECHDEV), Ln (REALGDP)

```
The regression equation is
Ln(TPD) = 7.62 - 0.063 Ln(POLYPRICE) + 0.136 Ln(TECHDEV) + 0.098 Ln(REALGDP)

Predictor        Coef     SE Coef          T        P       VIF
Constant        7.624       3.302       2.31    0.050
Ln(POLYP      -0.0629      0.1349      -0.47    0.653       2.6
Ln(TECHD      0.13592     0.04465       3.04    0.016       5.9
Ln(REALG       0.0977      0.3351       0.29    0.778       8.3

S = 0.04624            R-Sq = 90.4%        R-Sq(adj) = 86.7%
PRESS = 0.037441       R-Sq(pred) = 78.90%

Analysis of Variance

Source            DF          SS          MS         F        P
Regression         3    0.160331    0.053444     24.99    0.000
Residual Error     8    0.017105    0.002138
Total             11    0.177437

No replicates. Cannot do pure error test.

Source       DF      Seq SS
Ln(POLYP      1    0.083189
Ln(TECHD      1    0.076960
Ln(REALG      1    0.000182

Unusual Observations
Obs   Ln(POLYP    Ln(TPD)         Fit      SE Fit    Residual    St Resid
 12       4.04     8.5084      8.5997      0.0252     -0.0913      -2.35R

R denotes an observation with a large standardized residual

Durbin-Watson statistic = 1.45
```

5.4.4 U.S. total polyester demand model analysis

The above equation successfully explains 86.7% of the variation in U.S. total polyester demand for the period 1990 to 2001. Further, the Durbin-Watson *d*-statistic of 1.45 is well above the corresponding *dL* value of 0.658 showing no evidence of autocorrelation effects (refer Appendix section 18). In the above equation, U.S. national income represented by the real gross domestic product (REALGDP), shows a positive coefficient. This confirms the observation in section 4.4.1 that income is directly related to total fiber demand. However, its statistical significance is low as indicated by its *t*-value of 0.29. The technological development in polyester fibers is observed to have the highest statistical significance (*t*-value = 3.04). This observation confirms the hypothesis discussed in section 4.4.4. Polyester fiber price is inversely related to U.S. TPD. This confirms Meyer's [6] observation and the hypothesis of this study. However, the statistical significance of the polyester fiber price is low as indicated by its t-value of –0.47. The low significance of the price and income term may stem from the assumption made in arriving at the TPD, specifically pertaining to the polyester export data discussed in section 5.3.1. The OLS models of TPD on a per capita basis proved unsatisfactory. However, these OLS model simulations are included in Appendix section 8.37 for reference.

In the process of choosing the model presented in section 5.4.3 other model variations were also considered. The models other than the one chosen represent OLS models created by variations of certain explanatory variables. In the case of U.S. total polyester demand as discussed in the hypothesis in section 5.4.1, the three explanatory variables were polyester fiber price, polyester technological development and U.S. income. With regard to polyester fiber price, two variations were performed using nominal U.S. mill delivered polyester price (see section 5.4.3) and real U.S. mill delivered polyester price (see Appendix section 8.38). This OLS model produced a slightly lower r-squared value though the Durbin-Watson statistic was almost the same as the final model. In the case of U.S. income, three simulations were performed using nominal U.S. gross domestic product (GDP), personal consumption expenditure (PCE) and disposable personal income (DPI) and three using real GDP, real PCE and real DPI. While the nominal DPI and nominal PCE simulations produced an unsatisfactory coefficient for the income variable (see Appendix section 8.39 and 8.40), the simulation with nominal GDP produced a lower r-squared value and Durbin-Watson statistic than the final model presented in section 5.4.3 (see Appendix sections 8.41). In the case of real U.S. income, both real DPI and real PCE simulations produced unsatisfactory coefficients for the income variable than the chosen model in section 5.4.3 (see Appendix sections 8.42 and 8.43).

5.4.5 U.S. total polyester demand model performance evaluation

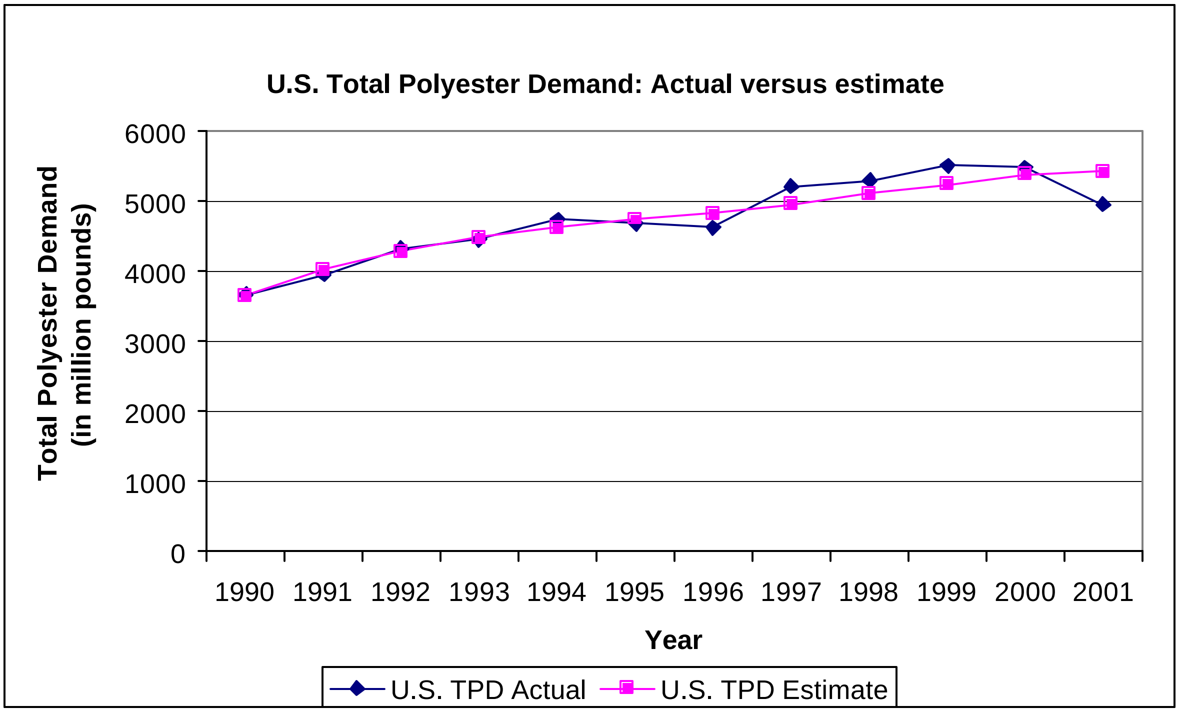


FIGURE 5.17: U.S. TOTAL POLYESTER DEMAND: ACTUAL VERSUS MODEL ESTIMATE

Figure 5.17 illustrates the actual U.S. TPD plotted against estimated U.S. TPD from the equation in section 5.4.3. The estimated values closely track actual TPD from 1990 to 1996. However, the model underestimates the actual values from 1997 to 2000. The average difference in estimated demand and actual demand for this period was nearly 200 million pounds. The reason for this underestimation could be due to increased cotton demand resulting from the rapid decline in cotton fiber prices during the same period from 84.87 cents per pound to 59.85 cents per pound (see Appendix section 8.4). However, the model's 2001 estimate is above the actual value by almost 400 million pounds. This could be due to the 7% increase in cotton prices during 2001 over 2000 levels.

Sensitivity Analysis

A sensitivity analysis was performed to observe the effects of changing income, cotton promotion expenditure and cotton fiber price on U.S. total polyester demand as seen in Figure 5.18.

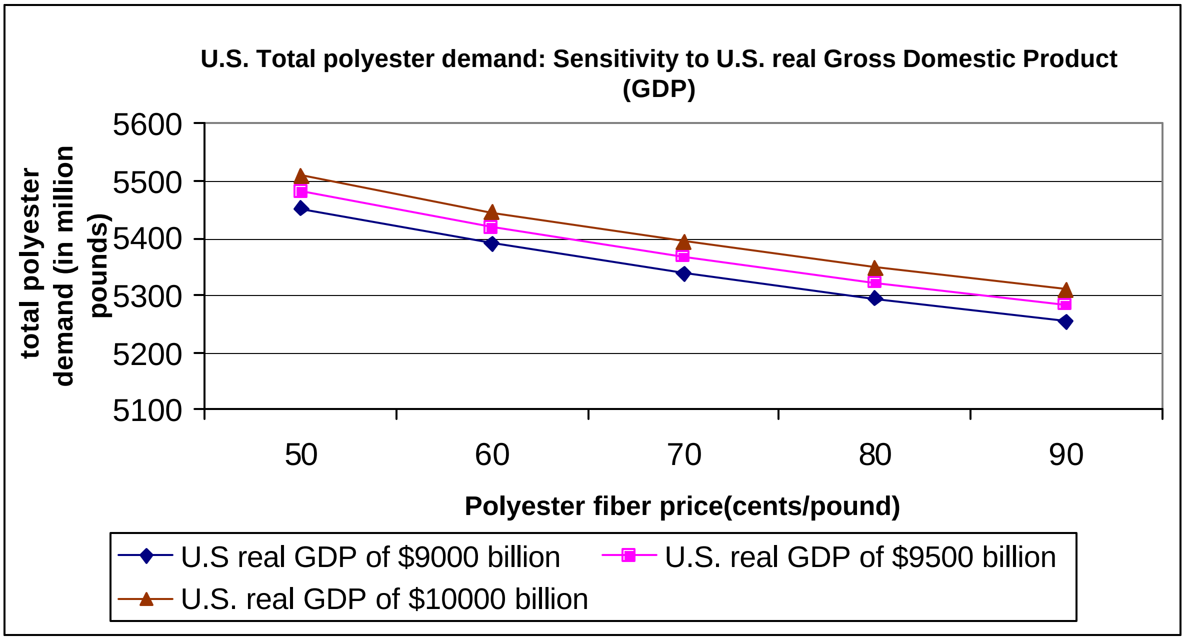


FIGURE 5.18: U.S. TOTAL POLYESTER DEMAND: SENSITIVITY TO U.S. REAL GDP

From figure 5.18 it is evident that as real GDP increases the U.S. TPD also increases though the extent of increase is not very significant. For example, at a real GDP of $9000 billion, U.S. TPD was 5337 million pounds, while at real GDP levels of $9500 billion and $10,000 billion; U.S. TPD increased by a mere 0.53% (5367 million pounds) and 1.03% (5393 million pounds) respectively.

Out-of-sample forecast

The estimated U.S. TPD for 2002 was 5412.62 million pounds. A 95% confidence interval for this estimate would range from 5141 million pounds to 5684 million pounds. However, neither the annual total polyester demand for 2002 nor a nine-month total polyester demand data were available at the time of this study for the purpose of comparison.

5.5 U.S. Polyester mill demand estimation background and variable selection

Similar to polyester end-use demand, there have been no polyester mill demand models developed from past research studies and literature. However, the U.S. mill demand for cotton and polyester are reflective of the overall competitiveness of the U.S. spinning industry and hence the background and variable selection for the PMD model would be the same as that for CMD estimation discussed in section 5.2.4. However, the single point distinguishing the PMD model from the CMD model is the absence of a matching polyester promotion effort in the U.S. to combat Cotton Incorporated's cotton promotion efforts [58,59]. Following from the discussion of polyester's reliance on property superiority stemming from its technological development, as its chief non-price competitive factor (see chapter 4 for polyester technological developments). Based on the previous discussions, it is hypothesized that U.S. polyester mill demand (PMD) is influenced by U.S. polyester textile deficit (PTD), price ratio of lagged cotton fiber price to polyester fiber price, total fiber demand (TFD) and technological development (TECHDEV). The general form of the equation supporting the above hypothesis is:

$$PMD = a - b\,(PTD) + c\,(RATIO) + d\,(TFD) + e\,(TECHDEV) + f\,(COTPROM)$$

where,

PMD denotes U.S. polyester mill demand,

PTD denoted U.S polyester textile deficit,

RATIO denotes U.S. mill delivered cotton fiber price divided by U.S. mill delivered polyester fiber price,

TFD denoted U.S. total fiber demand (sum of annual cotton, wool, man-made and other fibers),

TECHDEV is a trend variable representing technological development in polyester fibers, equal to one in 1990 and increasing by one each year until 2001, and

COTPROM denotes the real U.S cotton promotion expenditure represented by the budget of Cotton Incorporated.

5.5.1 U.S. polyester mill demand models

Based on the hypothesis presented in the previous section OLS models were developed. The models with the most satisfactory results have are presented in this section. The remaining model simulations are presented in the appendix section for reference.

5.5.2 Minitab Output of U.S. polyester mill demand OLS model

Regression Analysis: Ln(PMD) versus Ln(PTD), Ln(RATIO), Ln (TFD) and Ln (REALCOTPROM)

```
The regression equation is
Ln(PMD) = - 6.71 - 0.346 Ln(PTD) + 0.169 Ln(RATIO) + 1.78 Ln(TFD)
           - 0.110 Ln(REALCOTPROM)

Predictor        Coef     SE Coef          T        P       VIF
Constant       -6.714       2.164      -3.10    0.017
Ln(PTD)      -0.34637     0.07052      -4.91    0.002      10.7
Ln(RATIO      0.16912     0.09539       1.77    0.120       2.7
Ln(TFD)        1.7764      0.2858       6.21    0.000      20.6
Ln(REALC     -0.10966     0.08846      -1.24    0.255       7.8

S = 0.02512            R-Sq = 96.5%        R-Sq(adj) = 94.5%
PRESS = 0.017070       R-Sq(pred) = 86.49%

Analysis of Variance

Source            DF          SS         MS        F        P
Regression         4    0.121896   0.030474    48.28    0.000
Residual Error     7    0.004418   0.000631
Total             11    0.126314

No replicates. Cannot do pure error test.

Source       DF      Seq SS
Ln(PTD)       1    0.053319
Ln(RATIO      1    0.005245
Ln(TFD)       1    0.062361
Ln(REALC      1    0.000970


Durbin-Watson statistic = 2.12

No evidence of lack of fit (P > 0.1)
```

5.5.3 U.S. polyester mill demand model analysis

The OLS model for U.S. PMD is successful in explaining 94.5% of the variation in U.S. annual polyester mill demand for the period 1990 to 2001. Further, the Durbin-Watson statistic of 2.12 shows that there is no problem of autocorrelation as it is well above the *dL* of 0.512 (refer Appendix section 8.18). In the above equation, U.S. PMD is hypothesized to emulate the TFD as overall fiber demand is bound to have a positive impact on U.S. PMD [6]. Hence, the positive sign of the TFD coefficient proves this observation. However, as discussed in section 4.2.2 rising U.S. polyester imports has widened the polyester textile trade deficit (PTD). This as expected would have a negative impact on U.S. mill demand. The negative sign of PTD and its significance (*t*-value = -4.91) confirms this observation. The price ratio specification was placed to capture the price competitiveness of cotton relative to polyester. This price ratio term is defined as the ratio of lagged U.S. cotton mill delivered price to lagged U.S. polyester mill delivered price. An increase in the ratio means that cotton fiber is proving more expensive relative to polyester. The positive sign of the co-efficient indicates that if cotton becomes expensive with respect to polyester then inter-fiber substitution would occur and hence U.S. PMD would increase. The cotton promotion specification (COTPROM, *t*-value = -1.24) was included to observe the effect of cotton promotion on U.S. PMD. The negative sign of the coefficient shows that as cotton promotion expenses are inversely related to U.S. PMD. Hence, as cotton promotion expenditure increases, U.S. polyester mill demand would decrease. The OLS models including the technological development (TECHDEV), proved unsatisfactory. This would indicate that the effect of polyester's technological development does not play a significant role in influencing U.S. PMD. Additionally, the TECHDEV specification was set as a trend variable and hence would not be adequately quantifying the exact budget employed in polyester promotion.

In the process of choosing the model presented in section 5.5.2 other model variations were also considered. The models other than the one chosen represent OLS models created by varying certain explanatory variables. In the case of U.S. PMD the explanatory variables drawn from the hypothesis presented in introductory part of section 5.5 were fiber price ratio, cotton promotion expenditure, U.S. polyester textile deficit and U.S. total fiber demand. Since, the fiber price ratio, U.S. polyester textile deficit are fixed quantities, the variations attempted were restricted to the cotton promotion expenditure variable and the U.S. total fiber demand. With regard to U.S. cotton promotion expenditure, two simulations were performed using real and nominal expenditure. The model using nominal cotton promotion expenditure produced almost equal r-squared values as well as Durbin-Watson statistic (see Appendix section 8.44) compared to the chosen model in section 5.5.2. Meyer [6], in his estimation model for U.S. cotton mill demand, calculated the U.S. total fiber demand, as the sum of the annual mill demand of cotton, wool and man-made fibers plus the net textile trade deficit (in raw fiber equivalent basis) in manufactured products for these fibers. On the, other hand the USDA Cotton and Wool Situation and Outlook Report for 2002, calculates total fiber demand using the same formula as described above, but with an additional fiber category, namely, flax and silk. Hence, two simulations, one using Meyer's definition (designated as TFD 1) and the second using the USDA Cotton and Wool Situation and Outlook Report definition (designated as TFD) were performed. The USDA definition of TFD was found to produce better results (see Appendix 8.45).

5.5.4 U.S. polyester mill demand model performance evaluation

Figure 5.19 illustrates the actual U.S. cotton mill demand versus the model estimate of U.S. cotton mill demand. From this illustration, it is evident that the estimated U.S. CMD values track the actual values almost throughout the period of 1990 to 2001 except for certain years. The average difference between estimated and actual values was 175 million pounds. However, the largest differences arose in 2000 and 2001 when the model overestimated the U.S. PMD by more than 200 million pounds. This could be attributed to an overabundance in U.S. cotton supply and the fact that cotton prices were surpassed by polyester in 2001 (see Appendix sections 8.2 and 8.4).

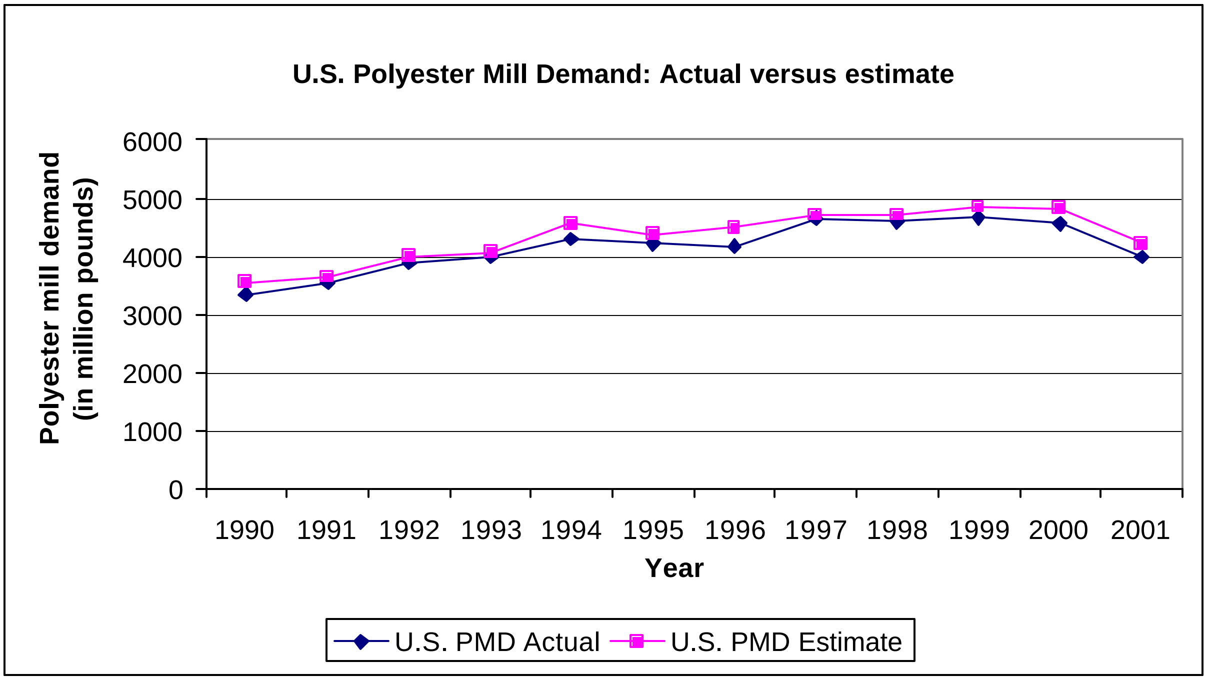


FIGURE 5.19: U.S. POLYESTER MILL DEMAND: ACTUAL VERSUS ESTIMATE

Sensitivity Analysis

A sensitivity analysis was performed to observe the effects of changing PTD, cotton promotion expenditure and fiber price ratio on U.S. PMD. Figure 5.20 illustrates the effect of three cotton promotion expenditure levels of $55 million, $60 million and $65 million on U.S. cotton mill demand under a constant cotton textile deficit of 1000 million pounds and a total fiber demand of 23,000 million pounds. From this illustration it is evident that as cotton promotion expenditure increases U.S. polyester mill demand decreases correspondingly though the extent of decrease was not very significant. For example U.S. polyester mill demand was nearly 4171 million pounds at a cotton promotion expenditure of $55 million, while at cotton promotion expenditures of $60 million and $65 million, U.S. PMD were just 1% (4133 million pounds) and 2% (4095 million pounds) lower respectively, under a constant cotton textile deficit of 1,000 million pounds and a price ratio of 1.00 (cotton price equals polyester price). Hence, the influence of cotton promotion expenditure on U.S. polyester mill demand is present but not very significant.

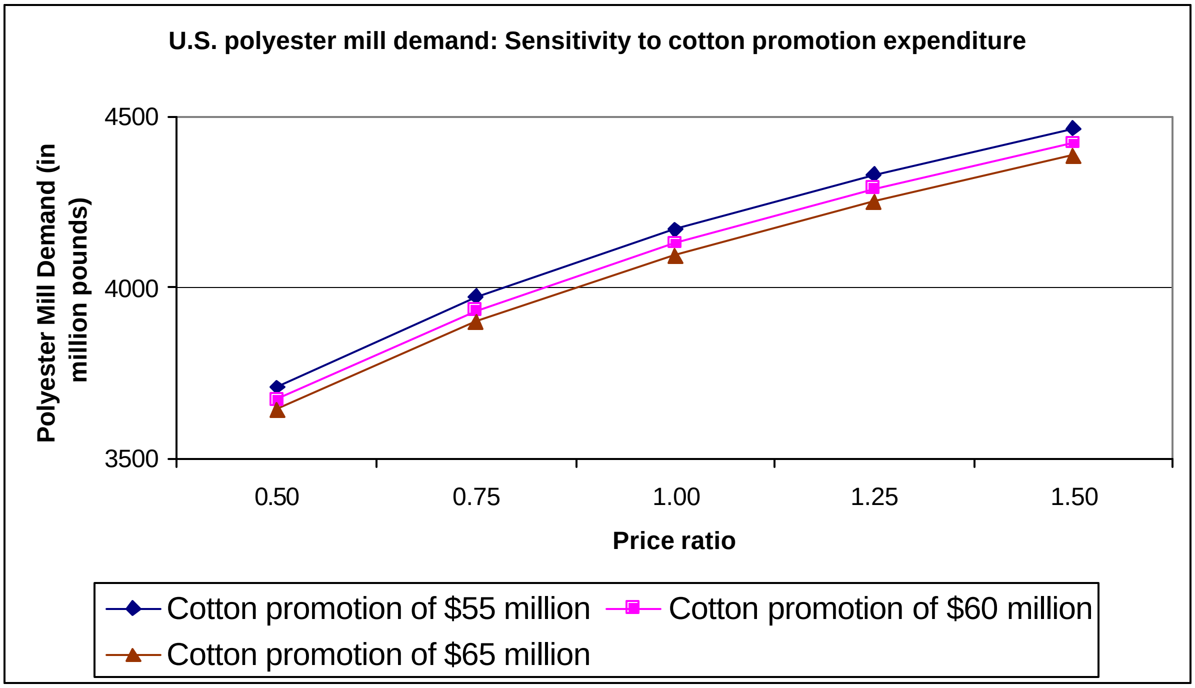


FIGURE 5.20: U.S. POLYESTER MILL DEMAND: SENSITIVITY TO COTTON PROMOTION EXPENDITURE

The effect of varying polyester textile deficit levels on the U.S. polyester mill demand is illustrated in figure 5.21 by plotting U.S. cotton mill demand against the fiber price ratio under three cotton textile deficit levels of 5,500 million pounds, 6,000 million pounds and 6,500 million pounds under a constant cotton promotion expenditure of $60 million. From figure 5.21 it is evident that as U.S. polyester textile deficit increases, U.S. polyester mill demand decreases though not very significantly. For example, at a polyester textile deficit of 900 million pounds, the U.S. polyester mill demand was 4247 million pounds, while at cotton textile deficits of 1,000 million pounds and 1,100 million pounds; U.S. polyester mill demand decreased by just 4% (4095 million pounds) and 7% (3963 million pounds) respectively under a constant cotton promotion expenditure of $65 million and a price ratio of 1.00 (cotton price equals polyester price). Thus, as U.S. polyester textile deficit increases the U.S. polyester mill demand decreases, but with very low significance.

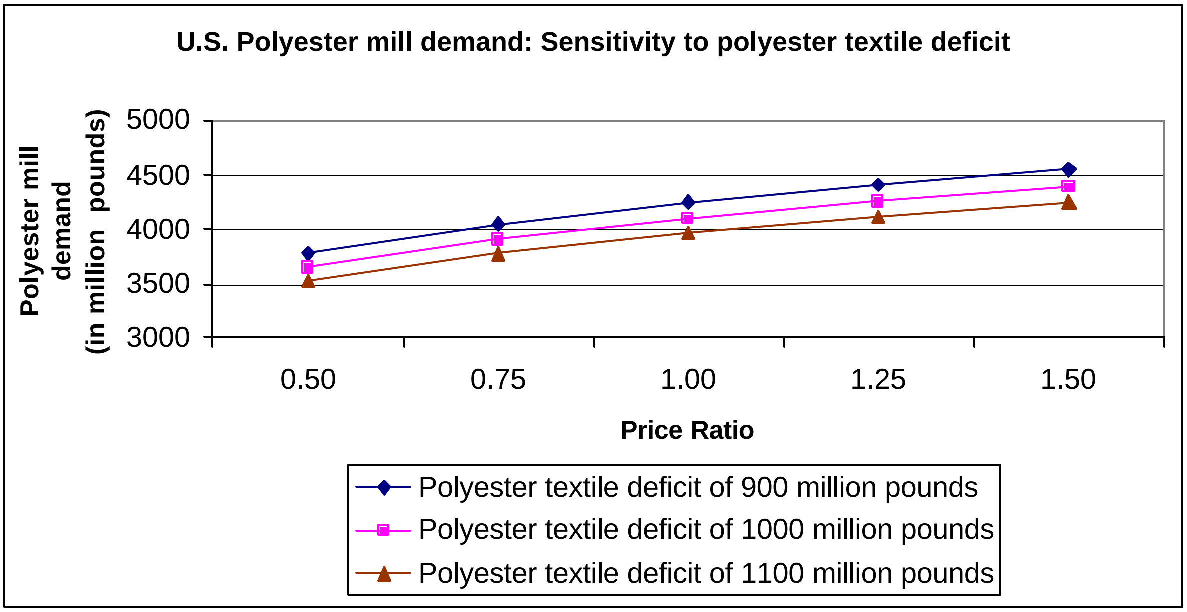


FIGURE 5.21: U.S. POLYESTER MILL DEMAND: SENSITIVITY TO POLYESTER TEXTILE DEFICIT

The effect of varying total fiber demand is illustrated in figure 5.22 by plotting U.S. polyester mill demand against the fiber price ratio under three total fiber demand levels of 20,000 million pounds, 25,000 million pounds and 30,000 million pounds under a constant cotton promotion expenditure of $60 million and polyester textile deficit of 1000 million pounds. From figure 5.22 it is evident that as the U.S. total fiber demand increases, U.S. polyester mill demand also increases. For example, at a total fiber demand of 20,000 million pounds, the U.S. polyester mill demand was 3194 million pounds, while at total fiber demand levels of 25,000 million pounds and 30,000 million pounds; U.S. polyester mill demand increased by almost 49% (4752 million pounds) and 105% (6572 million pounds) respectively under a constant cotton promotion expenditure of $65 million and a price ratio of 1.00 (cotton price equals polyester price).

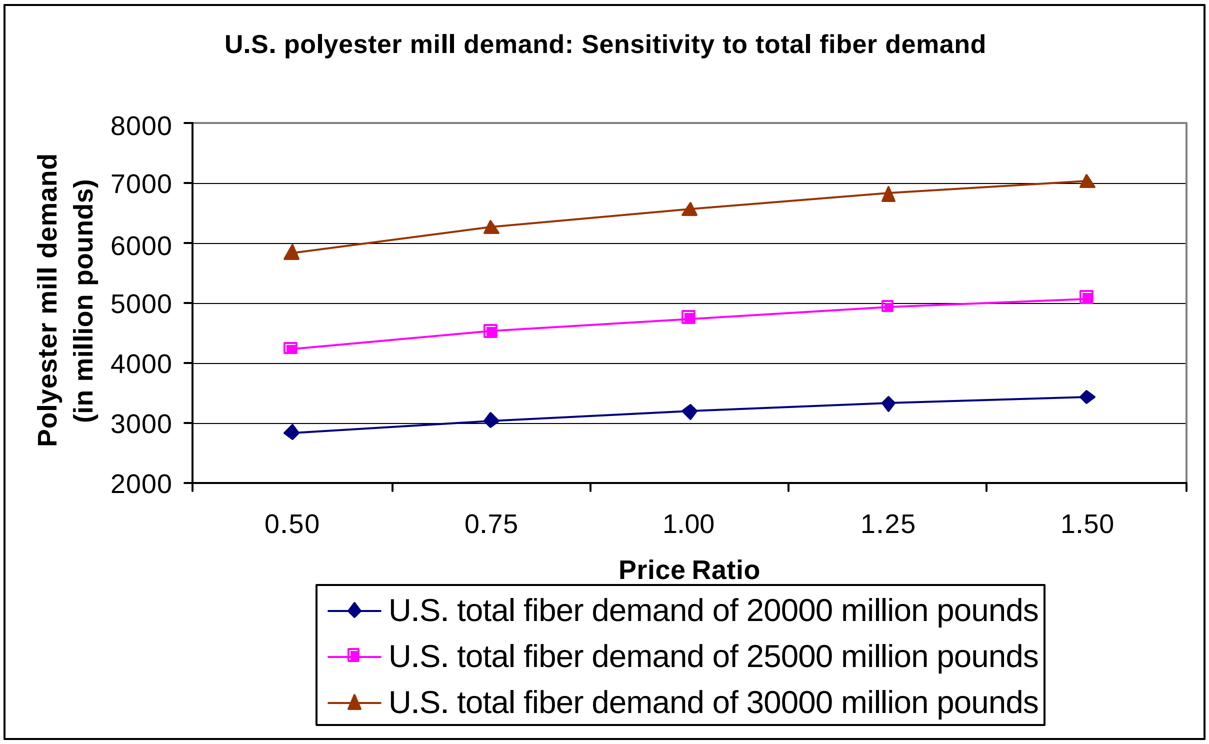


FIGURE 5.22: U.S. POLYESTER MILL DEMAND: SENSITIVITY TO TOTAL FIBER DEMAND

Out-of-sample forecast

The ten-month U.S. polyester mill demand (PMD) for 2002 as reported by FEB was 2492.50 million pounds [4,37,38]. The annualized U.S. PMD was arrived at as follows:

U.S. PMD (for 2002) =[U.S. nine-month PMD / 9)] x 12

By the above formula, the annual (12-month) U.S. PMD for 2002 was 2991 million pounds. However, at the time of this study the U.S. polyester textile deficit and the U.S. total fiber demand for 2002 were not available. Since the actual data for 2002 was unavailable at the time of this study an estimate using the model could also not be made.

5.5.5 Minitab Output of per capita U.S polyester mill demand model

Regression Analysis: PMD versus PTD, RATIO, TFD1, RCOTPROM

```
The regression equation is
PMD = - 7.16 - 1.27 PTD + 1.61 RATIO + 0.354 TFD1 - 2.19 RCOTPROM

Predictor        Coef     SE Coef          T        P       VIF
Constant       -7.163       3.935      -1.82    0.112
PTD           -1.2721      0.3178      -4.00    0.005       8.5
RATIO           1.606       1.842       0.87    0.412       2.7
TFD1          0.35406     0.07359       4.81    0.002      12.4
RCOTPROM       -2.193       8.671      -0.25    0.808       4.5

S = 0.4849             R-Sq = 90.9%         R-Sq(adj) = 85.6%
PRESS = 5.20704        R-Sq(pred) = 71.07%

Analysis of Variance

Source            DF          SS          MS         F        P
Regression         4     16.3539      4.0885     17.39    0.001
Residual Error     7      1.6461      0.2352
Total             11     18.0000

No replicates. Cannot do pure error test.

Source       DF      Seq SS
PTD           1      4.5028
RATIO         1      0.4427
TFD1          1     11.3934
RCOTPROM      1      0.0150

Unusual Observations
Obs        PTD        PMD         Fit       SE Fit    Residual    St Resid
  8       4.82     17.340      16.393        0.181       0.947        2.10R

R denotes an observation with a large standardized residual

Durbin-Watson statistic = 2.34

No evidence of lack of fit (P > 0.1)
```

5.5.6 U.S. per capita polyester mill demand model analysis

The U.S. per capita polyester mill demand results presented above was successful in explaining 85.6% of the variation in annual per capita polyester mill demand for the period 1990 to 2001. Since there was no prior polyester specific U.S. mill demand model the above results could not be checked for relative comparison on performance aspects. The Durbin-Watson d-test bounds for 12 observations with

4 explanatory variables are *dL* = 0.512 and *dU* = 2.177 respectively (refer Appendix section 8.18). The DW d-statistic of 2.34 obtained in the above model indicates that there is no evidence of positive serial autocorrelation. In the above equation, the TFD specification has a positive sign to its coefficient and is statistically significant (*t*-value = 4.67), indicating that as overall U.S. fiber demand increases U.S. PMD would also increase. This confirms Meyer's [6] observation on the effect of TFD on U.S. PMD. However, the increase the polyester textile trade deficit due to rising imports has captured a portion of the total polyester demand. Thus, PTD would be expected to be inversely related to U.S. PMD since this import volume of polyester would be satisfying a certain portion of the overall U.S polyester demand. The negative coefficient of the PTD specification confirms the above hypothesis and also proves statistically significant (*t* = -4.00). As discussed in the case of the model presented in section 5.5.2, price ratio would be expected to have a positive sign to its coefficient indicating price-driven substitution. The model presented in section 5.5.5 confirms this observation and is statistically significant (*t*-value = 0.87). However, the cotton promotion specification has relatively low statistical significance (*t*-value = -0.25), though the negative sign of its coefficient indicates that it shares an inverse relationship with U.S. PMD as discussed in the model presented in section 5.5.2. However, on per capita basis cotton promotion is observed to have a lower significance than on an actual demand basis.

In the process of choosing the model presented in section 5.5.5 other model variations were also considered. The models other than the one chosen represent OLS models created by varying certain explanatory variables. In the case of U.S. per capita PMD the explanatory variables drawn from the hypothesis presented in section 5.3.1 were fiber price ratio, per capita cotton promotion expenditure, per capita U.S. polyester textile deficit and per capita U.S. total fiber demand. Since, the fiber price ratio and per capita U.S. polyester textile deficit are fixed quantities, the variations attempted were restricted to the per capita cotton promotion expenditure variable and the per capita U.S. total fiber demand. With regard to per capita U.S. cotton promotion expenditure, two simulations were performed using real and nominal expenditure. The model using nominal expenditure produced almost equal values of r-squared as well as Durbin-Watson statistic (see Appendix section 8.46). Meyer [6], in his estimation model for U.S. cotton mill demand, calculated the U.S. total fiber demand, as the sum of the annual mill demand of cotton, wool and man-made fibers plus the net textile trade deficit (in raw fiber equivalent basis) in manufactured products for these fibers. On the, other hand the USDA Cotton and Wool Situation and Outlook Report for 2002, calculates total fiber demand using the same formula as described above, but with an additional fiber category, namely, flax and silk. Hence, two simulations, one using Meyer's definition (designated as TFD 1) and the second using the USDA Cotton and Wool Situation and Outlook Report definition (designated as TFD) were performed. Meyer's definition of TFD (see section 5.5.5) was found to produce better results than the USDA approach (see Appendix 8.47).

5.5.7 U.S. per capita polyester mill demand model performance evaluation

Figure 5.23 illustrates the actual U.S. per capita polyester mill demand versus the model estimate of U.S. per capita polyester mill demand.

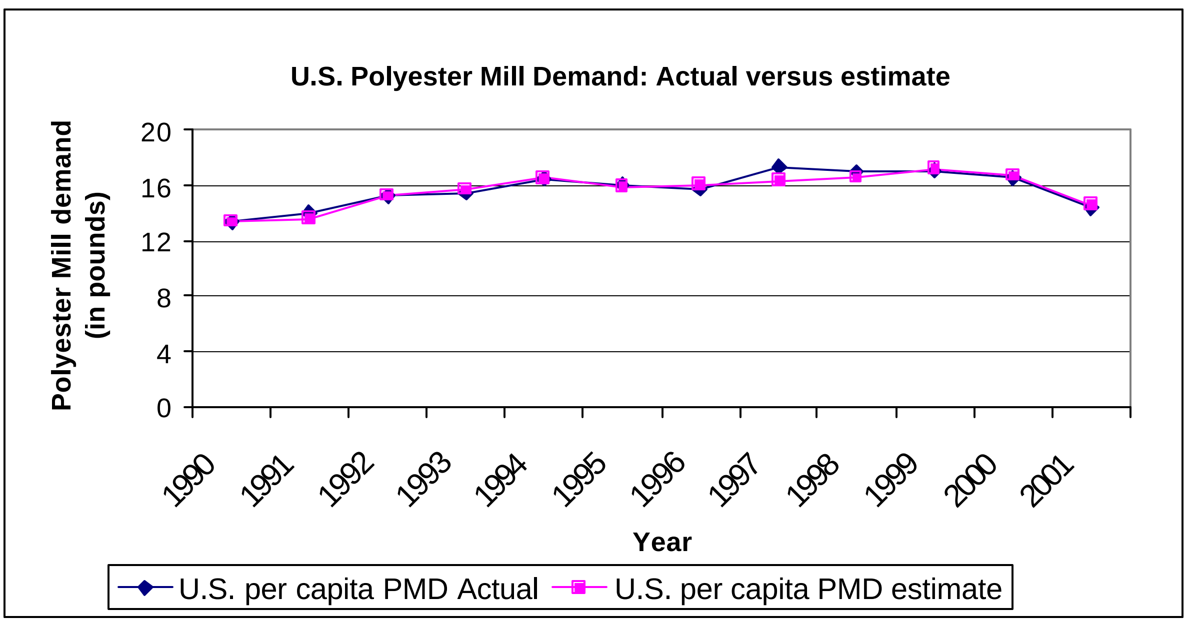


FIGURE 5.23: U.S. POLYESTER MILL DEMAND: ACTUAL VERSUS ESTIMATE

From this illustration, it is evident that the estimated U.S. per capita PMD values track the actual values throughout the period of 1990 to 2001. This would be indicative of the model's high accuracy of estimation.

Sensitivity Analysis

A sensitivity analysis was performed to observe the effects of changing per capita PTD, cotton promotion expenditure and fiber price ratio on per capita U.S. PMD. Figure 5.24 illustrates the effect of three per capita cotton promotion expenditure levels of $0.20, $0.25 and $0.30 on U.S. per capita polyester mill demand under a constant per capita polyester textile deficit of 6 pounds and a per capita total fiber demand of 85 pounds.

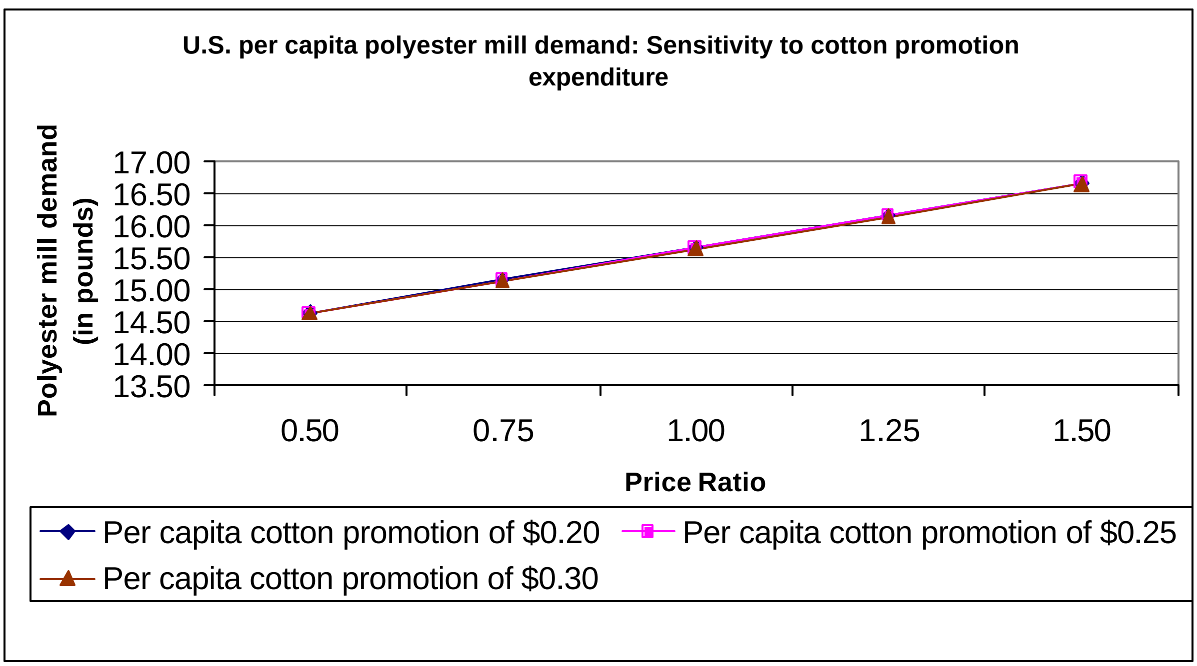


FIGURE 5.24: U.S. PER CAPITA POLYESTER MILL DEMAND: SENSITIVITY TO COTTON PROMOTION EXPENDITURE

From this illustration it is evident that as per capita cotton promotion expenditure increases U.S. per capita polyester mill demand decreases correspondingly though the decrease is very insignificant. For example U.S. per capita polyester mill demand was nearly 15.65 pounds at a per capita cotton promotion expenditure of $0.20, while at per capita cotton promotion expenditures of $0.25 and $0.30, U.S. per capita PMD were just 0.06% (15.64 pounds) and 1.3% (15.63 pounds) lower respectively, under a constant per capita polyester textile deficit of 6 pounds, a per capita total fiber demand of 80 pounds and a price ratio of 1.00 (cotton price equals polyester price).

From figure 5.25 it is evident that as the U.S. per capita polyester textile deficit increases, U.S. per capita polyester mill demand decreases.

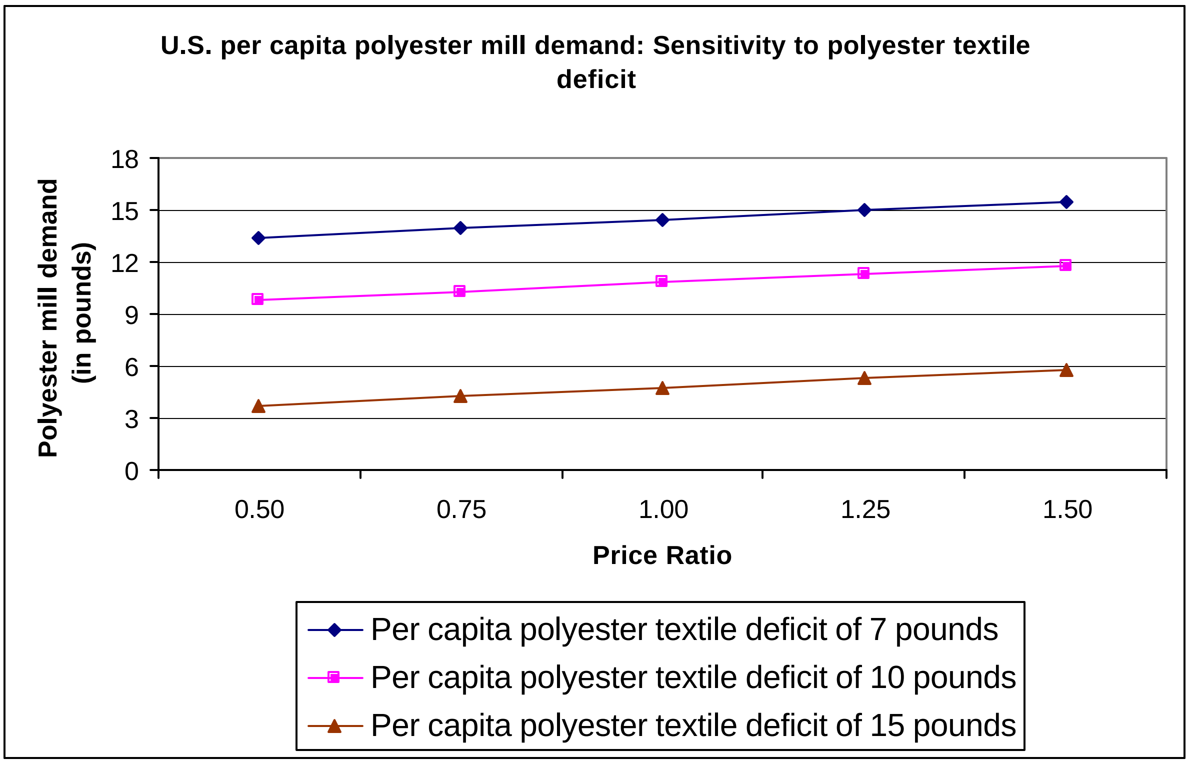


FIGURE 5.25: U.S. PER CAPITA POLYESTER MILL DEMAND: SENSITIVITY TO POLYESTER TEXTILE DEFICIT

For example, at a per capita polyester textile deficit of 7 pounds, the U.S. per capita polyester mill demand was 14.43 pounds, while at per capita polyester textile deficits of 10 pounds and 15 pounds; U.S. per capita polyester mill demand decreased by almost 26% (10.80 pounds) and 68% (4.75 pounds) respectively under a constant cotton promotion expenditure of $0.20, a per capita total fiber demand of 85 pounds and a price ratio of 1.00 (cotton price equals polyester price).

The effect of varying total fiber demand is illustrated in figure 5.26 by plotting U.S. per capita polyester mill demand against the fiber price ratio under three per capita total fiber demand levels of 80 pounds, 85 pounds and 90 pounds and a constant cotton promotion expenditure of $0.20 and cotton textile deficit of 6 pounds.

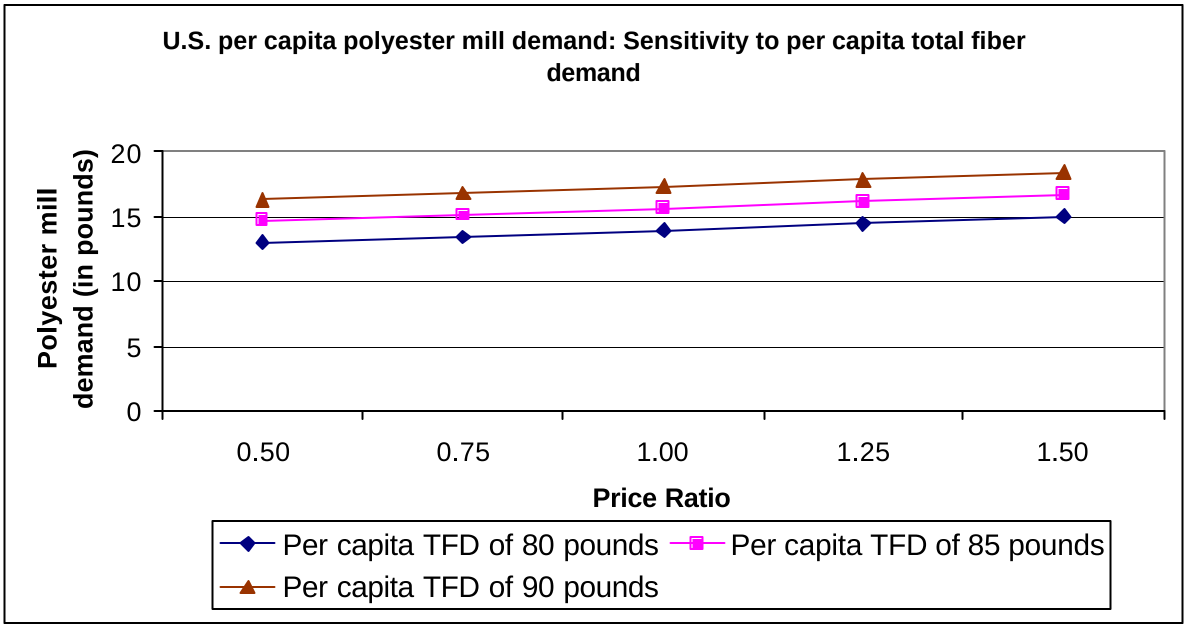


FIGURE 5.26: U.S. PER CAPITA POLYESTER MILL DEMAND: SENSITIVITY TO TOTAL FIBER DEMAND

From figure 5.26 it is evident that as the U.S. per capita total fiber demand increases, U.S. polyester mill demand also increases, though the increase is marginal. For example, at a per capita total fiber demand of 80 pounds, the U.S. per capita polyester mill demand was 13.94 pounds, while at per capita total fiber demand levels of 80 pounds and 85 pounds; U.S. per capita polyester mill demand increased by almost 13% (15.64 pounds) and 25% (17.34 pounds) respectively under a constant per capita cotton promotion expenditure of $0.25 and a price ratio of 1.00 (cotton price equals polyester price).

Out-of-sample forecast

The ten-month U.S. per capita polyester mill demand (PMD) for 2002 as reported by FEB was 8.67 pounds [4,37,38]. The annualized U.S. per capita PMD was arrived at as follows:

U.S. per capita PMD (for 2002) =[U.S. nine-month per capita PMD / 9)] x 12

By the above formula, the annual (12-month) U.S. per capita PMD for 2002 was 10.40 pounds. However, at the time of this study the per capita U.S. polyester textile deficit and the per capita U.S. total fiber demand for 2002 were not available. Since the actual data for 2002 was unavailable at the time of this study an estimate using the model could also not be made.

6.

Conclusions and Recommendations for future work

6.1 Conclusions

The OLS regression models yielded an understanding of the quantitative impact of the factors influencing U.S. total cotton demand, U.S. cotton mill demand, U.S. total polyester demand, and U.S. polyester mill demand on a total demand volume as well as per capita basis. Based on the statistical outputs of the regression models for the four demand equations mentioned above, the following conclusions were reached.

The influence of cotton promotion activities on U.S. total cotton demand was found to be strong as reflected by their *t*-values in both the per capita model as well as the actual total demand models (i.e., actual demand refers to the total U.S. volume demand in million pounds whereas per capita demand would be the actual demand divided by the U.S. population). This confirms the hypothesis that U.S. cotton demand at the end use or retail level during the study period of 1990 to 2001 was strongly influenced by cotton promotion efforts as reflected by its *t*-values. Additionally, the cotton promotion variable showed the highest relative statistical significance among the chosen variables, namely, income, fiber prices and cotton promotion expenditure. On the other hand, in case of U.S. cotton mill demand, the cotton textile deficit proved to be the of the highest relative statistical significance followed by U.S total fiber demand and real cotton promotion expenditure in both the per capita model as well as the actual demand model. Both these models were effective in explaining about 98% and 95% of the variation in annual U.S. cotton mill demand. This proves that the effect of cotton promotion at the mill level was not as effective or strong in boosting cotton mill consumption as it was at the retail or end use level though it was still statistically significant. However, the U.S cotton textile deficit with its highest relative statistical significance is reflective of the strength of foreign competition in textile trade as well as accounts for the large U.S. mill closings and layoffs. In the U.S. total polyester demand model, technological development of polyester fibers was found to have the highest relative statistical significance followed by polyester fiber price and U.S. real gross domestic product. The OLS simulations incorporating the U.S. cotton promotion variable yielded unsatisfactory results. Thus the effect of U.S. cotton promotion on U.S. total polyester demand was not adequately demonstrated by the statistical results obtained. The results confirms the hypothesis that technological development has constantly provided additional demand for polyester fibers as well as a competitive advantage over cotton while being influenced by income and fiber prices like U.S. total cotton demand. On the other hand, in the case of U.S. polyester mill demand, the U.S. total fiber demand showed the highest relative statistical significance followed by the U.S. polyester textile deficit, price ratio, and cotton promotion. As in the case of the U.S. cotton mill demand models discussed, polyester mill demand also was severely affected by the strength of imports s well as U.S. mill closures and layoffs. The quantitative proof of this lies in the highest relative statistical significance of the U.S. polyester textile deficit. As in the case of U.S. cotton mill demand, the U.S. polyester mill demand was also influenced by the U.S. total fiber demand and the price ratio. Further, the weak influence of U.S. cotton promotion efforts on U.S. polyester mill demand is reflected in its relatively low statistical significance. This further reinforces the observation made in the discussion of U.S. cotton mill demand, that the influence of cotton promotion at the mill level is much weaker compared to the retail or end use level.

6.2 Recommendations for future work

The following three points listed below are my recommendations for future expansion on the models developed in this study.

1. Expand the estimation model to include the inter-fiber competition of all synthetic fibers polyester, nylon and olefins. Presently the data for breaking out the man-made by individual fiber type is unavailable.

2. Perform the same analysis over a greater period of time, say from 1975 for greater reliability of results. Further, from 1960 to 1980 polyester promotion was a crucial factor influencing cotton demand negatively and also the reason for the formation of cotton incorporated to promote cotton actively. In a dramatic reversal, since 1980 per capita retail cotton demand has gone up while polyester demand has not registered an equivalent rate of demand increases. Thus a wider time period of study would be inclusive of both these changes and hence be of added value and accuracy.

3. The inter-fiber competition for cotton polyester is end-use specific. For instance while cotton typically derives its large demand from apparel and clothing, polyester has a much wider application and demand spectrum including industrial fabrics, belting, tire cord and ropes. Hence an end-use based study would prove valuable. Presently, while cotton demand data by end use is available through USDA, a similar break out by individual fiber type for man-made is unavailable. The availability of such a data would throw open the possibility for modeling the inter-fiber competition of nylon, olefins as well as polyester.

7.

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8. Appendix

8.1

U.S. raw cotton fiber production area: 1990 to 2001

CROP YEAR	PLANTED AREA (in million acres)	HARVESTED AREA (in million acres)	YIELD (in pounds per acre)	ABANDONMENT (%)
1990	12.348	11.732	634	5.0
1991	14.052	12.960	652	7.8
1992	13.240	11.123	700	16.0
1993	13.438	12.783	606	4.9
1994	13.720	13.322	708	2.9
1995	16.931	16.007	537	5.5
1996	14.653	12.888	705	12.0
1997	13.898	13.406	673	3.5
1998	13.393	10.684	625	20.2
1999	14.874	13.425	607	9.7
2000	15.517	13.053	632	15.9
2001	15.800	12.140	705	12.7

Source: Cotton and Wool Situation and Outlook Yearbook, Market and Trade Economics Division, Economics Research Service, U.S. Department of Agriculture, November 2002, CWS-2002

8.2

U.S. Raw cotton fiber supply (in million pounds): 1990 to 2001

CROP YEAR	BEGINNING STOCKS	PRODUCTION	IMPORTS	TOTAL
1990	1440.00	7442.40	1.92	8884.32
1991	1125.12	8454.72	6.24	9586.08
1992	1777.92	7784.64	0.48	9563.04
1993	2237.76	7744.32	2.88	9984.96
1994	1694.40	9437.76	9.60	11141.76
1995	1272.00	8592.00	195.84	10059.84
1996	1252.32	9092.16	193.44	10537.92
1997	1906.08	9020.64	6.24	10932.96
1998	1865.76	6680.64	212.64	8759.04
1999	1890.72	8144.64	46.56	10081.92
2000	1882.56	8250.24	7.20	10140.00
2001	2880.96	9744.00	4.80	12629.76

Source: Cotton and Wool Situation and Outlook Yearbook, Market and Trade Economics Division, Economics Research Service, U.S. Department of Agriculture, November 2002, CWS-2002

8.3

U.S. Raw cotton fiber consumption (in million pounds): 1990 to 2001

CROP YEAR	COTTON MILL DEMAND	EXPORTS	TOTAL	UNACCOUNTED	ENDING STOCKS
1990	4155.36	3740.64	7896.00	136.80	1125.12
1991	4614.24	3190.08	7804.32	-3.84	1777.92
1992	4920.00	2496.48	7416.98	91.20	2237.76
1993	5000.64	3293.76	8294.40	3.84	1694.40
1994	5375.04	4512.96	9888.00	18.24	1272.00
1995	5110.56	3684.00	8794.56	-12.96	1252.32
1996	5340.48	3295.20	8635.68	3.84	1906.08
1997	5447.52	3600.00	9047.52	-19.68	1865.76
1998	4992.48	2085.12	7077.60	209.28	1890.72
1999	4915.20	3240.00	8155.20	-44.16	1882.56
2000	4263.36	3246.24	7509.60	250.56	2880.96
2001	3696.00	5280.00	8976.00	-6.24	4176.00

Source: Cotton and Wool Situation and Outlook Yearbook, Market and Trade Economics Division, Economics Research Service, U.S. Department of Agriculture, November 2002, CWS-2002

8.4

U.S. Cotton and polyester fiber prices (in cents per pound): 1990 to 2001

CALENDAR YEAR	U.S. COTTON MILL DELIVERED[1]	COTLOOK A INDEX	NYCE FUTURES	U.S. POLYESTER MILL DELIVERED[2]
1989	71.99	75.91	68.08	85.67
1990	79.29	82.71	70.17	82.58
1991	79.07	76.75	66.69	73.50
1992	61.92	57.94	59.28	73.50
1993	62.41	58.09	59.82	72.50
1994	78.69	79.97	72.26	74.92
1995	100.76	98.11	80.32	88.83
1996	84.87	80.41	76.57	79.58
1997	76.29	79.23	74.13	68.58
1998	74.21	65.27	70.91	60.67
1999	59.85	53.09	56.10	51.67
2000	64.08	59.11	62.30	57.08
2001	46.93	47.99	45.36	60.42

Source: National Cotton Council (NCC) of America, Memphis, TN: http://risk.cotton.org/prices/

1. 4-market average landed mill price reported by USDA Market News Branch
2. Polyester prices are for 1.5 denier quality estimated by NCC

8.5

U.S. cotton fiber end-use consumption (in million pounds): 1990 to 2001

CALENDAR YEAR	COTTON MILL DEMAND (CMD)	IMPORTS[1]	EXPORTS[1]	TOTAL COTTON DEMAND[2] (TCD)
1990	4115.30	2411.04	638.82	5887.51
1991	4347.50	2586.59	676.31	6257.78
1992	4761.60	3179.98	794.97	7146.60
1993	4937.70	3576.83	914.73	7599.81
1994	5230.60	3826.46	1080.82	7976.24
1995	5183.50	4089.45	1330.81	7942.14
1996	5226.80	4222.85	1524.68	7924.97
1997	5441.40	5084.07	1792.38	8733.09
1998	5234.30	6026.21	1957.10	9303.41
1999	4962.30	6711.43	2073.51	9600.23
2000	4747.00	7541.38	2442.98	9845.40
2001	3848.40	7545.25	2123.78	9269.87

Source: Source: Cotton and Wool Situation and Outlook Yearbook, Market and Trade Economics Division, Economics Research Service, U.S. Department of Agriculture, November 2002, CWS-2002

1. Raw fiber equivalent of U.S. cotton imports and exports
2. End-use consumption equals mill consumption plus imports minus exports for a given year

8.6

U.S. polyester fiber end-use consumption (in million pounds): 1990 to 2001

CALENDAR YEAR	POLYESTER MILL DEMAND (PMD)	IMPORTS[1]	EXPORTS[1]	TOTAL POLYESTER DEMAND[2] (TPD)
1990	3335.01	617.34	278.14	3674.21
1991	3555.92	748.50	347.76	3956.66
1992	3882.97	828.94	385.50	4326.42
1993	3979.56	864.13	386.60	4457.08
1994	4297.54	909.00	472.47	4734.07
1995	4219.24	972.01	504.25	4686.99
1996	4162.89	995.40	527.70	4630.60
1997	4647.18	1290.76	716.11	5221.83
1998	4593.05	1443.94	735.13	5301.87
1999	4663.19	1546.32	704.82	5504.69
2000	4555.16	1726.82	796.66	5485.32
2001	3979.42	1760.77	783.95	4956.24

Source: Fiber Organon, March 2002

1. Raw fiber equivalent of U.S. polyester imports and exports
2. End-use consumption equals mill consumption plus imports minus exports for a given year

8.7

U.S. polyester fiber mill consumption (in million pounds): 1990 to 2001

CALENDAR YEAR	FILAMENT[1]	STAPLE[2]	WASTE	POLYESTER MILL DEMAND[3] (PMD)
1990	1088.13	2138.50	108.38	3335.01
1991	1153.96	2307.68	94.28	3555.92
1992	1288.58	2496.16	98.23	3882.97
1993	1309.08	2564.43	106.05	3979.56
1994	1507.45	2720.95	69.14	4297.54
1995	1547.31	2610.66	61.27	4219.24
1996	1584.74	2508.50	69.65	4162.89
1997	1778.62	2806.20	62.36	4647.18
1998	1706.86	2768.23	117.96	4593.05
1999	1771.24	2768.01	123.94	4663.19
2000	1695.66	2684.22	175.28	4555.16
2001	1449.04	2390.32	140.06	3979.42

Source: Fiber Organon, March 2002

1. Inclusive of yarn + monofilament
2. Inclusive of staple + tow + fiberfill
3. Mill Consumption equals sum of annual filament, staple and waste domestic consumption

8.8

U.S. man-made fiber end-use consumption (in million pounds): 1990-2001

CALENDAR YEAR	MILL DEMAND	IMPORTS[1]	EXPORTS[1]	TOTAL MAN-MADE FIBER DEMAND[2]
1990	8837.00	1820.00	820.00	9837.00
1991	8861.20	1907.00	886.00	9882.20
1992	9498.90	2060.00	958.00	10600.90
1993	9928.50	2186.00	978.00	11136.50
1994	10515.60	2269.00	1179.40	11605.30
1995	10307.10	2452.70	1272.40	11487.40
1996	10508.7	2580.10	1367.80	11721.00
1997	11071.00	3135.20	1739.40	12466.80
1998	11076.80	3528.70	1796.50	12809.00
1999	11287.80	3719.80	1695.50	13312.00
2000	11198.90	4254.30	1962.70	13490.50
2001	10070.30	4299.80	1914.40	12455.70

Source: Fiber Organon, March 2002

1. Raw fiber equivalent of U.S. polyester imports and exports
2. End-use consumption equals mill consumption plus imports minus exports for a given year

8.9

Decomposition of polyester fiber components from overall man-made apparent fiber consumption data (in million pounds): 1990-2001

YEAR	MAN-MADE IMPORTS[1]	MAN-MADE EXPORTS[1]	POLYESTER SHARE[2]	POLYESTER IMPORTS[1]	POLYESTER EXPORTS[1]
1990	1820.00	820.00	33.92%	617.34	278.14
1991	1907.00	886.00	39.25%	748.50	347.76
1992	2060.00	958.00	40.24%	828.94	385.50
1993	2186.00	978.00	39.53%	864.13	386.60
1994	2269.00	1179.40	40.06%	909.00	472.47
1995	2452.70	1272.40	39.63%	972.01	504.25
1996	2580.10	1367.80	38.58%	995.40	527.70
1997	3135.20	1739.40	41.17%	1290.76	716.11
1998	3528.70	1796.50	40.92%	1443.94	735.13
1999	3719.80	1695.50	41.57%	1546.32	704.82
2000	4254.30	1962.70	40.59%	1726.82	796.66
2001	4299.80	1914.40	40.95%	1760.77	783.95

Source: Polyester Shares: Internal FEB data, Man-made Imports and Exports: Fiber Organon March 2002:

1. Imports and Exports are in raw fiber equivalent

2. Polyester Share data are for domestic consumption applied to imports and exports

8.10
U.S. Man-made fibers end-use consumption share by fiber type: 1990 to 2001

YEAR	RAYON	ACETATE/ ACRYLIC	POLYESTER	NYLON	OLEFIN	OTHER
1990	6.63%	2.45%	33.92%	35.88%	20.97%	0.14%
1991	5.95%	4.17%	39.25%	28.62%	21.38%	0.62%
1992	5.51%	4.07%	40.24%	28.31%	21.24%	0.62%
1993	5.65%	3.84%	39.53%	28.29%	22.02%	0.66%
1994	4.83%	3.60%	40.06%	28.30%	22.56%	0.65%
1995	4.88%	3.19%	39.63%	28.27%	23.17%	0.86%
1996	4.34%	3.12%	38.58%	28.46%	24.27%	1.22%
1997	3.81%	3.12%	41.17%	26.98%	24.16%	0.76%
1998	3.29%	2.97%	40.92%	26.06%	25.83%	0.93%
1999	2.87%	2.50%	41.57%	25.65%	26.17%	1.24%
2000	2.66%	2.56%	40.59%	25.46%	26.95%	1.78%
2001	2.47%	2.51%	40.95%	25.40%	26.56%	2.11%

Source: FEB Internal Data
Note: All fiber shares expressed as a total for staple and yarn

8.11

U.S. Population Tables (in millions): 1990 to 2001

CALENDAR YEAR	TOTAL U.S POPULATION
1990	249.97
1991	252.66
1992	255.41
1993	258.11
1994	260.63
1995	263.08
1996	265.50
1997	268.04
1998	270.50
1999	272.94
2000	275.37
2001	276.87

Source:
U.S. Census Bureau: http://www.census.gov/statab/freq/00s0002.xls

8.12

U.S. per capita cotton mill use and end-use demand (in pounds): 1990 to 2001

YEAR	COTTON MILL DEMAND (CMD)	COTTON TEXTILE DEFICIT [1](CTD)	TOTAL COTTON DEMAND[2] (TCD)
1990	16.46	7.09	23.55
1991	17.21	7.56	24.77
1992	18.64	9.34	27.98
1993	19.13	10.31	29.44
1994	20.07	10.53	30.60
1995	19.70	10.49	30.19
1996	19.69	10.16	29.85
1997	20.30	12.28	32.58
1998	19.35	15.04	34.39
1999	18.18	16.99	35.17
2000	17.24	18.51	35.75
2001	13.90	19.58	33.48

Source: Cotton and Wool Situation and Outlook Yearbook, Market and Trade Economics Division, Economics Research Service, U.S. Department of Agriculture, November 2002, CWS-2002

1. U.S. Per capita Cotton textile deficit (CTD) equals U.S. Cotton Imports minus U.S. Cotton Exports in raw fiber equivalent terms (as U.S. is a net cotton importer)
2. U.S. Per capita total cotton demand equals per capita U.S. cotton mill demand plus per capita U.S. cotton textile deficit (CTD)

8.13

U.S. per capita polyester mill and end-use demand (in pounds): 1990 to 2001

YEAR	POLYESTER MILL DEMAND (PMD)	POLYESTER TEXTILE DEFICIT [1](PTD)	TOTAL POLYESTER DEMAND[2] (TPD)
1990	13.34	2.47	14.70
1991	14.07	2.96	15.66
1992	15.20	3.25	16.94
1993	15.42	3.35	17.27
1994	16.49	3.49	18.17
1995	16.04	3.69	17.81
1996	15.68	3.75	17.44
1997	17.34	4.82	19.48
1998	16.98	5.34	19.60
1999	17.08	5.67	20.17
2000	16.54	6.27	19.92
2001	14.37	6.36	17.83

Source: Fiber Organon, March 2002

1. U.S Polyester Textile Deficit (PTD) equals U.S. Polyester Imports minus U.S. Polyester Exports in raw fiber equivalent terms (as U.S. is a net polyester importer)
2. U.S. Per capita Total Polyester Demand (TPD) equals per capita U.S. polyester mill demand (PMD) plus per capita U.S. polyester textile deficit (PTD)

8.14

U.S. Real Income (in billions of chained 1996 dollars): 1990-2001

YEAR	Gross Domestic Product (GDP)	Disposable Personal Income (DPI)	Personal Consumption Expenditure (PCE)
1990	6707.90	5014.20	4474.50
1991	6676.40	5033.00	4466.60
1992	6880.00	5189.30	4594.50
1993	7062.60	5261.30	4748.90
1994	7347.70	5397.20	4928.10
1995	7543.80	5539.10	5075.60
1996	7813.20	5677.70	5237.50
1997	8159.50	5854.50	5423.90
1998	8508.90	6168.60	5683.70
1999	8859.00	6328.40	5964.50
2000	9191.40	6630.30	6223.90
2001	9214.50	6748.00	6377.20
2002	9436.10	7049.20	6573.00

Source:
United States Bureau of Economic Analysis: http://www.bea.doc.gov/bea/dn/nipaweb/index.asp

8.15

U.S. per capita real Income table (in chained 1996 dollars): 1990-2001

YEAR	Gross Domestic Product (GDP)	Disposable Personal Income (DPI)	Personal Consumption Expenditure (PCE)
1990	26,834	20,058	17,899
1991	26,363	19,873	17,637
1992	26,809	20,220	17,903
1993	27,163	20,235	18,264
1994	27,918	20,507	18,724
1995	28,325	20,798	19,058
1996	28,997	21,072	19,438
1997	29,992	21,470	19,891
1998	30,482	22,359	20,601
1999	31,746	22,678	21,373
2000	32,579	23,501	22,061
2001	32,352	23,692	22,390

Source:
U.S. Bureau of economic analysis: http://www.bea.doc.gov/bea/dn/nipaweb/TableViewFixed.asp#Mid

8.16

U.S Cotton promotion expenditure (in million dollars): 1990 to 2001

YEAR	Marketing	Research	Administration	Cotton Promotion Expenditure (COTPROM)
1990	17.89	6.70	1.95	26.55
1991	18.61	7.90	2.04	28.55
1992	28.20	12.87	2.02	43.10
1993	29.38	13.58	2.11	45.07
1994	30.66	14.52	2.21	47.39
1995	35.92	16.86	2.30	55.09
1996	42.03	16.66	2.36	61.05
1997	41.70	17.09	2.47	61.28
1998	43.67	16.70	2.61	63.00
1999	40.92	16.25	2.826	60.00
2000	40.50	16.68	2.804	60.00
2001	42.87	17.28	2.84	63.00

Sources: Jacobson. T. C. and Smith. G. D., 'Cotton's Renaissance: A Study in Market innovation', Cambridge University Press, 2001 and "Annual Report 2001: Cotton Incorporated", www.cottoninc.com/2001AnnualReport/homepage.cfm

8.17

Real U.S. cotton promotion expenditure (in million dollars): 1990 to 2001

YEAR	Nominal Cotton Promotion Expenditure (COTPROM)	GDP deflator[1]	Real Cotton Promotion Expenditure (RCOTPROM)[3]
1990	26.55	0.8634	30.75
1991	28.55	0.8953	31.89
1992	43.10	0.9160	47.06
1993	45.07	0.9392	48.00
1994	47.39	0.9608	49.33
1995	55.09	0.9811	56.16
1996	61.05	1.0000	61.06
1997	61.28	1.0170	60.26
1998	63.00	1.0300	61.17
1999	60.00	1.0434	57.50
2000	60.00	1.0590 [2]	56.66
2001	63.00	1.0802 [2]	58.32

Source:

1. GDP deflator: Budget of the United States Government: Fiscal Year 2001 (base year 1996): **http://w3.access.gpo.gov/usbudget/fy2001/sheets/hist10z1.xls**
2. Estimated GDP deflators for 2000 and 2001
3. U.S Real cotton promotion expenditure equals the product of U.S nominal cotton promotion expenditure and the GDP deflator

8.18

Durbin-Watson d-statistic table: 5% significance points of dL and dU

N	K =1		K =2		K =3		K =4		K =5	
	dL	dU	dL	dU	dL	dU	dL	dU	dL	dU
10	0.879	1.320	0.697	1.641	0.525	2.016	0.376	2.414	0.243	2.822
11	0.927	1.324	0.758	1.604	0.595	1.928	0.444	2.283	0.316	2.645
12	0.971	1.331	0.812	1.579	0.658	1.864	0.512	2.177	0.379	2.506
13	1.010	1.340	0.861	1.562	0.715	1.816	0.574	2.094	0.445	2.390
14	1.045	1.350	0.905	1.551	0.767	1.779	0.632	2.030	0.505	2.296
15	1.077	1.361	0.946	1.543	0.814	1.750	0.685	1.977	0.562	2.220
16	1.106	1.371	0.982	1.539	0.857	1.728	0.734	1.935	0.615	2.157
17	1.133	1.381	1.015	1.536	0.897	1.710	0.779	1.900	0.664	2.104
18	1.158	1.391	1.046	1.535	0.933	1.696	0.820	1.872	0.710	2.060
19	1.180	1.401	1.074	1.536	0.967	1.685	0.859	1.848	0.752	2.023
20	1.201	1.411	1.100	1.537	0.998	1.676	0.894	1.828	0.792	1.991
21	1.221	1.420	1.125	1.538	1.026	1.669	0.927	1.8112	0.829	1.964

Source: Savin, N.E. and White. K.J., ‘The Durbin-Watson Test for serial correlation with extreme sample sizes or many regressions’, Volume 45, No.8, Econometrika, November 1977

Note:

‘N’ represents the number of observations

‘K’ represents the number of explanatory variables

‘dL’ and ‘dU’ represent the lower and upper bounds of the d-statistic respectively

8.19

U.S. total cotton demand OLS model using real U.S. mill delivered cotton price

Regression Analysis: Ln(TCD) versus Ln(REALCOTPRICE), Ln(REALDPI), ...

```
The regression equation is
Ln(TCD) = 2.54 - 0.171 Ln(REALCOTPRICE) + 0.666 Ln(REALDPI)
           + 0.363 Ln(REALCOTPROM)

Predictor         Coef     SE Coef          T        P       VIF
Constant         2.542       1.744       1.46    0.183
Ln(REALC      -0.17083     0.08176      -2.09    0.070       1.7
Ln(REALD        0.6662      0.1966       3.39    0.010       3.5
Ln(REALC       0.36342     0.07193       5.05    0.001       2.5

S = 0.03641            R-Sq = 96.4%         R-Sq(adj) = 95.1%
PRESS = 0.026605       R-Sq(pred) = 91.08%

Analysis of Variance

Source            DF          SS          MS        F        P
Regression         3    0.287614    0.095871    72.32    0.000
Residual Error     8    0.010606    0.001326
Total             11    0.298220

No replicates. Cannot do pure error test.

Source       DF      Seq SS
Ln(REALC      1    0.097185
Ln(REALD      1    0.156584
Ln(REALC      1    0.033845

Unusual Observations
Obs   Ln(REALC    Ln(TCD)         Fit      SE Fit    Residual    St Resid
 12       4.08     9.1345      9.1962      0.0227     -0.0617      -2.17R

R denotes an observation with a large standardized residual

Durbin-Watson statistic = 1.52
Possible lack of fit at outer X-values       (P-Value = 0.000)
Overall lack of fit test is significant at P = 0.000
```

Note:

1. This simulation for U.S. TCD showed a possible lack of fit as well as a lower Durbin-Watson statistic than the chosen model in section 5.2.4.
2. The real U.S. mill delivered price was arrived at, by dividing the lagged U.S. nominal mill delivered price (see appendix section 7.4) by the gross domestic product (GDP) deflator for the same year (see appendix section 7.17).

8.20

U.S. total cotton demand OLS model using nominal U.S. cotton promotion expenditure

Regression Analysis: Ln(TCD) versus Ln(COTPRICE), Ln(REALDPI), ...

```
The regression equation is
Ln(TCD) = 3.32 - 0.169 Ln(COTPRICE) + 0.584 Ln(REALDPI) + 0.345 Ln(COTPROM)

Predictor        Coef     SE Coef          T        P       VIF
Constant        3.317       1.706       1.94    0.088
Ln(COTPR     -0.16924     0.08100      -2.09    0.070       1.3
Ln(REALD       0.5844      0.2003       2.92    0.019       3.7
Ln(COTPR      0.34538     0.06724       5.14    0.001       3.5

S = 0.03610             R-Sq = 96.5%         R-Sq(adj) = 95.2%
PRESS = 0.025853        R-Sq(pred) = 91.33%

Analysis of Variance

Source            DF          SS          MS        F        P
Regression         3    0.287795    0.095932    73.61    0.000
Residual Error     8    0.010425    0.001303
Total             11    0.298220

No replicates. Cannot do pure error test.

Source       DF      Seq SS
Ln(COTPR      1    0.013025
Ln(REALD      1    0.240388
Ln(COTPR      1    0.034382

Unusual Observations
Obs   Ln(COTPR    Ln(TCD)        Fit      SE Fit    Residual    St Resid
 12       4.16     9.1345     9.1967      0.0224     -0.0621       -2.19R

R denotes an observation with a large standardized residual

Durbin-Watson statistic = 1.46
Possible lack of fit at outer X-values       (P-Value = 0.000)
Overall lack of fit test is significant at P = 0.000
```

Note:

1. This simulation for U.S. TCD produced an overall lack of fit that was statistically significant as well as a lower Durbin-Watson statistic than the chosen model in section 5.2.4.
2. The real U.S. cotton promotion expenditure was arrived at, by dividing the U.S. nominal cotton promotion expenditure by the gross domestic product (GDP) deflator for the same year (see appendix section 7.17).

8.21

U.S. total cotton demand OLS model using nominal U.S. disposable personal income

Regression Analysis: Ln(TCD) versus Ln(COTPRICE), Ln(DPI), Ln(REALCOTPR

```
The regression equation is
Ln(TCD) = 4.19 - 0.166 Ln(COTPRICE) + 0.490 Ln(DPI) + 0.328 Ln(REALCOTPROM)

Predictor        Coef     SE Coef        T       P       VIF
Constant       4.1859      0.9461     4.42   0.002
Ln(COTPR     -0.16593     0.08221    -2.02   0.078       1.3
Ln(DPI)        0.4903      0.1158     4.24   0.003       3.5
Ln(REALC      0.32838     0.08555     3.84   0.005       3.4

S = 0.03664           R-Sq = 96.4%        R-Sq(adj) = 95.0%
PRESS = 0.026833      R-Sq(pred) = 91.00%

Analysis of Variance

Source           DF          SS          MS        F       P
Regression        3    0.287478    0.095826    71.36   0.000
Residual Error    8    0.010742    0.001343
Total            11    0.298220

No replicates. Cannot do pure error test.

Source       DF      Seq SS
Ln(COTPR      1    0.013025
Ln(DPI)       1    0.254669
Ln(REALC      1    0.019784

Unusual Observations
Obs   Ln(COTPR    Ln(TCD)         Fit      SE Fit    Residual    St Resid
 12       4.16     9.1345      9.1985      0.0233     -0.0640      -2.26R

R denotes an observation with a large standardized residual

Durbin-Watson statistic = 1.39
Possible lack of fit at outer X-values       (P-Value = 0.032)
Overall lack of fit test is significant at P = 0.032
```

Note:

1. The above simulation showed as good an r-squared value as the chosen model in section 5.2.4 although the overall lack of fit test was significant (with a p-value of 0.032) as well as a lower DW-statistic of 1.39 compared to the chosen model in section 5.2.4.

8.22

U.S. total cotton demand OLS model using nominal U.S. personal consumption expenditure

Regression Analysis: Ln(TCD) versus Ln(COTPRICE), Ln(PCE), Ln(REALCOTPR

The regression equation is
Ln(TCD) = 4.70 - 0.168 Ln(COTPRICE) + 0.436 Ln(PCE) + 0.329 Ln(REALCOTPROM)

Predictor	Coef	SE Coef	T	P	VIF
Constant	4.6965	0.8425	5.57	0.001	
Ln(COTPR	-0.16775	0.08259	-2.03	0.077	1.3
Ln(PCE)	0.4362	0.1040	4.20	0.003	3.5
Ln(REALC	0.32901	0.08615	3.82	0.005	3.4

S = 0.03688 R-Sq = 96.4% R-Sq(adj) = 95.0%
PRESS = 0.027594 R-Sq(pred) = 90.75%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	3	0.287339	0.095780	70.42	0.000
Residual Error	8	0.010881	0.001360		
Total	11	0.298220			

No replicates. Cannot do pure error test.

Source	DF	Seq SS
Ln(COTPR	1	0.013025
Ln(PCE)	1	0.254477
Ln(REALC	1	0.019838

Unusual Observations

Obs	Ln(COTPR	Ln(TCD)	Fit	SE Fit	Residual	St Resid
12	4.16	9.1345	9.1974	0.0233	-0.0629	-2.20R

R denotes an observation with a large standardized residual

Durbin-Watson statistic = 1.34

No evidence of lack of fit (P > 0.1)

Note:

1. The above simulation showed as good an r-squared value as the chosen model in section 5.2.4 though the Durbin-Watson statistic at 1.29 was lower compared to the chosen model that had a DW-statistic of 1.60.

8.23

U.S. total cotton demand OLS model using nominal U.S. gross domestic product

Regression Analysis: Ln(TCD) versus Ln(COTPRICE), Ln(GDP), Ln(REALCOTPR

```
The regression equation is
Ln(TCD) = 4.25 - 0.174 Ln(COTPRICE) + 0.474 Ln(GDP) + 0.317 Ln(REALCOTPROM)

Predictor        Coef    SE Coef        T       P      VIF
Constant       4.2531     0.8406     5.06   0.001
Ln(COTPR     -0.17368    0.07497    -2.32   0.049      1.2
Ln(GDP)        0.4745     0.1007     4.71   0.002      3.5
Ln(REALC      0.31684    0.07964     3.98   0.004      3.5

S = 0.03395            R-Sq = 96.9%        R-Sq(adj) = 95.7%
PRESS = 0.023053       R-Sq(pred) = 92.27%

Analysis of Variance

Source            DF         SS         MS       F       P
Regression         3   0.288997   0.096332   83.56   0.000
Residual Error     8   0.009223   0.001153
Total             11   0.298220

No replicates. Cannot do pure error test.

Source       DF     Seq SS
Ln(COTPR      1   0.013025
Ln(GDP)       1   0.257726
Ln(REALC      1   0.018246

Unusual Observations
Obs   Ln(COTPR   Ln(TCD)        Fit     SE Fit    Residual    St Resid
 12       4.16   9.13452    9.19281    0.02042    -0.05828      -2.15R

R denotes an observation with a large standardized residual

Durbin-Watson statistic = 1.36

No evidence of lack of fit (P > 0.1)
```

Note:

1. The above simulation showed as good an r-squared value as the chosen model in section 5.2.4 though; the Durbin-Watson statistic at 1.30 was lower compared to the chosen model that had a DW-statistic of 1.60.

8.24

U.S. total cotton demand OLS model using real U.S. personal consumption expenditure

Regression Analysis: Ln(TCD) versus Ln(COTPRICE), Ln(REALPCE), ...

```
The regression equation is
Ln(TCD) = 4.70 - 0.168 Ln(COTPRICE) + 0.436 Ln(REALPCE) + 0.329 Ln(REALCOTPROM)

Predictor        Coef     SE Coef         T       P       VIF
Constant       4.6965      0.8425      5.57   0.001
Ln(COTPR     -0.16775     0.08259     -2.03   0.077       1.3
Ln(REALP       0.4362      0.1040      4.20   0.003       3.5
Ln(REALC      0.32901     0.08615      3.82   0.005       3.4

S = 0.03688            R-Sq = 96.4%         R-Sq(adj) = 95.0%
PRESS = 0.027594       R-Sq(pred) = 90.75%

Analysis of Variance

Source            DF          SS          MS        F        P
Regression         3    0.287339    0.095780    70.42    0.000
Residual Error     8    0.010881    0.001360
Total             11    0.298220

No replicates. Cannot do pure error test.

Source       DF      Seq SS
Ln(COTPR      1    0.013025
Ln(REALP      1    0.254477
Ln(REALC      1    0.019838

Unusual Observations
Obs   Ln(COTPR    Ln(TCD)         Fit      SE Fit    Residual    St Resid
 12       4.16     9.1345      9.1974      0.0233     -0.0629      -2.20R

R denotes an observation with a large standardized residual

Durbin-Watson statistic = 1.34

No evidence of lack of fit (P > 0.1)
```

Note:

1. The above simulation showed as good an r-squared value as the chosen model in section 5.2.4 though; the Durbin-Watson statistic at 1.34 was lower compared to the chosen model in section 5.2.4 that had a DW-statistic of 1.60.

8.25

U.S. total cotton demand OLS model using real U.S. gross domestic product

Regression Analysis: Ln(TCD) versus Ln(COTPRICE), Ln(REALGDP), ...

```
The regression equation is
Ln(TCD) = 2.09 - 0.177 Ln(COTPRICE) + 0.700 Ln(REALGDP) + 0.355 Ln(REALCOTPROM)

Predictor        Coef     SE Coef         T        P       VIF
Constant        2.088       1.233      1.69    0.129
Ln(COTPR     -0.17699     0.07256     -2.44    0.041       1.2
Ln(REALG       0.7003      0.1433      4.89    0.001       3.0
Ln(REALC      0.35456     0.07065      5.02    0.001       2.9

S = 0.03305            R-Sq = 97.1%         R-Sq(adj) = 96.0%
PRESS = 0.023374       R-Sq(pred) = 92.16%

Analysis of Variance

Source            DF          SS          MS         F        P
Regression         3    0.289482    0.096494     88.34    0.000
Residual Error     8    0.008739    0.001092
Total             11    0.298220

No replicates. Cannot do pure error test.

Source       DF      Seq SS
Ln(COTPR      1    0.013025
Ln(REALG      1    0.248946
Ln(REALC      1    0.027510


Durbin-Watson statistic = 1.54

Lack of fit test
Possible curvature in variable Ln(COTPR (P-Value = 0.078)
Overall lack of fit test is significant at P = 0.078
```

Note:

1 The above simulation showed a higher r-squared value than the chosen model in section 5.2.4 though; there was a statistically significant overall lack of fit while the Durbin-Watson statistic at 1.54 was lower compared to the chosen model in section 5.2.4 that had a DW-statistic of 1.60.

8.26

U.S. per capita total cotton demand OLS model using real U.S. mill delivered cotton price

Regression Analysis: Ln(TCD) versus Ln(REALCOTPRICE), Ln(REALGDP), ...

```
The regression equation is
Ln(TCD) = - 2.20 - 0.162 Ln(REALCOTPRICE) + 0.671 Ln(REALGDP)
           + 0.348 Ln(RCOTPROM)

Predictor        Coef     SE Coef          T        P       VIF
Constant       -2.201       2.219      -0.99    0.350
Ln(REALC     -0.16250     0.06505      -2.50    0.037       1.5
Ln(REALG       0.6709      0.1931       3.47    0.008       2.6
Ln(RCOTP      0.34849     0.06033       5.78    0.000       1.9

S = 0.03049            R-Sq = 96.1%        R-Sq(adj) = 94.7%
PRESS = 0.019331       R-Sq(pred) = 89.95%

Analysis of Variance

Source            DF          SS          MS         F        P
Regression         3    0.184870    0.061623     66.27    0.000
Residual Error     8    0.007439    0.000930
Total             11    0.192308

No replicates. Cannot do pure error test.

Source       DF      Seq SS
Ln(REALC      1    0.063089
Ln(REALG      1    0.090750
Ln(RCOTP      1    0.031030

Durbin-Watson statistic = 1.55

No evidence of lack of fit (P > 0.1)
```

Note:

1. The above simulation showed as good an r-squared value as the chosen model in section 5.2.7 but a lower Durbin-Watson statistic of 1.55 compared to the chosen model in section 5.2.4 that had a DW-statistic of 1.63.
2. The real U.S. mill delivered price was arrived at, by dividing the lagged U.S. nominal mill delivered price (see appendix section 7.4) by the gross domestic product (GDP) deflator for the same year (see appendix section 7.17).

8.27

U.S. per capita total cotton demand OLS model using real per capita U.S. disposable personal income

Regression Analysis: Ln(TCD) versus Ln(COTPRICE), Ln(REALDPI), ...

```
The regression equation is
Ln(TCD) = - 3.73 - 0.155 Ln(COTPRICE) + 0.851 Ln(REALDPI) + 0.405 Ln(RCOTPROM)

Predictor        Coef     SE Coef         T        P       VIF
Constant       -3.731       2.590     -1.44    0.188
Ln(COTPR     -0.15521     0.07711     -2.01    0.079       1.3
Ln(REALD       0.8511      0.2357      3.61    0.007       2.0
Ln(RCOTP      0.40484     0.06747      6.00    0.000       1.9

S = 0.03478            R-Sq = 95.0%         R-Sq(adj) = 93.1%
PRESS = 0.024075       R-Sq(pred) = 87.48%

Analysis of Variance

Source            DF          SS          MS        F        P
Regression         3    0.182631    0.060877    50.33    0.000
Residual Error     8    0.009677    0.001210
Total             11    0.192308

No replicates. Cannot do pure error test.

Source       DF      Seq SS
Ln(COTPR      1    0.009295
Ln(REALD      1    0.129786
Ln(RCOTP      1    0.043550



Durbin-Watson statistic = 1.72
Possible lack of fit at outer X-values       (P-Value = 0.033)
Overall lack of fit test is significant at P = 0.033
```

Note:

1 The above simulation showed a lower r-squared value of 93.1% than the chosen model in section 5.2.7 (r-squared value 94.8%) though the Durbin-Watson statistic of 1.72 was higher to that of the chosen model, which had a DW-statistic of 1.63 and the overall lack of fit test was significant as seen in the results above.

8.28

U.S. per capita total cotton demand OLS model using real per capita U.S. personal consumption expenditure

Regression Analysis: Ln(TCD) versus Ln(COTPRICE), Ln(REALPCE), ...

```
The regression equation is
Ln(TCD) = - 1.83 - 0.158 Ln(COTPRICE) + 0.664 Ln(REALPCE) + 0.387 Ln(RCOTPROM)

Predictor         Coef     SE Coef          T        P       VIF
Constant        -1.831       2.055      -0.89    0.399
Ln(COTPR      -0.15760     0.07645      -2.06    0.073       1.2
Ln(REALP        0.6644      0.1827       3.64    0.007       2.2
Ln(RCOTP       0.38708     0.07048       5.49    0.001       2.0

S = 0.03463            R-Sq = 95.0%         R-Sq(adj) = 93.1%
PRESS = 0.025022       R-Sq(pred) = 86.99%

Analysis of Variance

Source            DF          SS          MS         F        P
Regression         3    0.182715    0.060905     50.79    0.000
Residual Error     8    0.009593    0.001199
Total             11    0.192308

No replicates. Cannot do pure error test.

Source       DF      Seq SS
Ln(COTPR      1    0.009295
Ln(REALP      1    0.137248
Ln(RCOTP      1    0.036171


Durbin-Watson statistic = 1.54

No evidence of lack of fit (P > 0.1)
```

Note:

1. The above simulation showed a lower r-squared value of 93.1% than the chosen model in section 5.2.7 (r-squared value 94.8%) and the Durbin-Watson statistic of 1.54 was lower than that of the chosen model, which had a DW-statistic of 1.63.

8.29

U.S. per capita total cotton demand OLS model using nominal per capita U.S. personal consumption expenditure

Regression Analysis: Ln(TCD) versus Ln(COTPRICE), Ln(PCE), Ln(RCOTPROM)

```
The regression equation is
Ln(TCD) = 0.71 - 0.159 Ln(COTPRICE) + 0.400 Ln(PCE) + 0.335 Ln(RCOTPROM)

Predictor        Coef     SE Coef          T        P       VIF
Constant        0.710       1.380       0.51    0.621
Ln(COTPR     -0.15856     0.07678      -2.07    0.073       1.2
Ln(PCE)        0.3998      0.1109       3.61    0.007       2.8
Ln(RCOTP      0.33522     0.08181       4.10    0.003       2.7

S = 0.03481            R-Sq = 95.0%         R-Sq(adj) = 93.1%
PRESS = 0.024637       R-Sq(pred) = 87.19%

Analysis of Variance

Source            DF          SS          MS         F        P
Regression         3    0.182616    0.060872     50.24    0.000
Residual Error     8    0.009693    0.001212
Total             11    0.192308

No replicates. Cannot do pure error test.

Source       DF      Seq SS
Ln(COTPR      1    0.009295
Ln(PCE)       1    0.152977
Ln(RCOTP      1    0.020343

Unusual Observations
Obs   Ln(COTPR    Ln(TCD)         Fit      SE Fit    Residual    St Resid
 12       4.16     3.5109      3.5680      0.0224     -0.0570       -2.14R

R denotes an observation with a large standardized residual

Durbin-Watson statistic = 1.40

No evidence of lack of fit (P > 0.1)
```

Note:

1. The above simulation showed a lower r-squared value of 93.1% than the chosen model in section 5.2.7 (r-squared value 94.8%) and the Durbin-Watson statistic of 1.40 was lower than that of the chosen model, which had a DW-statistic of 1.63.

8.30

U.S. per capita total cotton demand OLS model using nominal per capita U.S. disposable personal income

Regression Analysis: Ln(TCD) versus Ln(COTPRICE), Ln(DPI), Ln(RCOTPROM)

```
The regression equation is
Ln(TCD) = 0.04 - 0.157 Ln(COTPRICE) + 0.463 Ln(DPI) + 0.336 Ln(RCOTPROM)

Predictor        Coef     SE Coef          T        P       VIF
Constant        0.037       1.559       0.02    0.982
Ln(COTPR     -0.15677     0.07688      -2.04    0.076       1.2
Ln(DPI)        0.4632      0.1282       3.61    0.007       2.8
Ln(RCOTP      0.33566     0.08156       4.12    0.003       2.7

S = 0.03476            R-Sq = 95.0%         R-Sq(adj) = 93.1%
PRESS = 0.024203       R-Sq(pred) = 87.41%

Analysis of Variance

Source            DF          SS          MS         F        P
Regression         3    0.182641    0.060880     50.38    0.000
Residual Error     8    0.009667    0.001208
Total             11    0.192308

No replicates. Cannot do pure error test.

Source       DF      Seq SS
Ln(COTPR      1    0.009295
Ln(DPI)       1    0.152881
Ln(RCOTP      1    0.020465

Unusual Observations
Obs   Ln(COTPR    Ln(TCD)         Fit      SE Fit    Residual    St Resid
 12       4.16     3.5109      3.5689      0.0225     -0.0580      -2.19R

R denotes an observation with a large standardized residual

Durbin-Watson statistic = 1.45
Possible lack of fit at outer X-values       (P-Value = 0.040)
Overall lack of fit test is significant at P = 0.040
```

Note:

1. The above simulation showed a lower r-squared value of 93.1% than the chosen model in section 5.2.7 (r-squared value 94.8%). Further, the overall lack of fit test was statistically significant and the Durbin-Watson statistic of 1.45 was lower than that of the chosen model, which had a DW-statistic of 1.63.

8.31

U.S. per capita total cotton demand OLS model using nominal per capita U.S. gross domestic product

Regression Analysis: Ln(TCD) versus Ln(COTPRICE), Ln(GDP), Ln(RCOTPROM)

```
The regression equation is
Ln(TCD) = 0.08 - 0.164 Ln(COTPRICE) + 0.446 Ln(GDP) + 0.323 Ln(RCOTPROM)

Predictor        Coef     SE Coef          T        P       VIF
Constant        0.081       1.365       0.06    0.954
Ln(COTPR     -0.16365     0.06955      -2.35    0.046       1.2
Ln(GDP)        0.4456      0.1086       4.10    0.003       2.8
Ln(RCOTP      0.32298     0.07552       4.28    0.003       2.7

S = 0.03202             R-Sq = 95.7%         R-Sq(adj) = 94.1%
PRESS = 0.020298        R-Sq(pred) = 89.45%

Analysis of Variance

Source            DF          SS          MS         F        P
Regression         3    0.184109    0.061370     59.87    0.000
Residual Error     8    0.008200    0.001025
Total             11    0.192308

No replicates. Cannot do pure error test.

Source       DF      Seq SS
Ln(COTPR      1    0.009295
Ln(GDP)       1    0.156064
Ln(RCOTP      1    0.018749

Unusual Observations
Obs   Ln(COTPR    Ln(TCD)         Fit      SE Fit    Residual    St Resid
 12       4.16    3.51095     3.56425     0.01942    -0.05330       -2.09R

R denotes an observation with a large standardized residual

Durbin-Watson statistic = 1.42
Possible lack of fit at outer X-values       (P-Value = 0.078)
Overall lack of fit test is significant at P = 0.078
```

Note:

1. The above simulation showed a lower r-squared value of 94.1% than the chosen model in section 5.2.7 (r-squared value 94.8%). Further, the overall lack of fit test was statistically significant and the Durbin-Watson statistic of 1.42 was lower than that of the chosen model, which had a DW-statistic of 1.63.

8.32

U.S. per capita total cotton demand OLS model using nominal U.S. cotton promotion expenditure

Regression Analysis: Ln(TCD) versus Ln(COTPRICE), Ln(REALGDP), ...

```
The regression equation is
Ln(TCD) = - 1.13 - 0.178 Ln(COTPRICE) + 0.569 Ln(REALGDP) + 0.322 Ln(COTPROM)

Predictor        Coef     SE Coef        T       P      VIF
Constant       -1.128       2.785    -0.40   0.696
Ln(COTPR     -0.17767     0.07965    -2.23   0.056      1.2
Ln(REALG       0.5689      0.2459     2.31   0.049      3.0
Ln(COTPR      0.32238     0.06844     4.71   0.002      2.9

S = 0.03627            R-Sq = 94.5%        R-Sq(adj) = 92.5%
PRESS = 0.027542       R-Sq(pred) = 85.68%

Analysis of Variance

Source            DF         SS         MS        F       P
Regression         3   0.181785   0.060595    46.06   0.000
Residual Error     8   0.010524   0.001315
Total             11   0.192308

No replicates. Cannot do pure error test.

Source       DF     Seq SS
Ln(COTPR      1   0.009295
Ln(REALG      1   0.143298
Ln(COTPR      1   0.029191


Durbin-Watson statistic = 1.46

Lack of fit test
Possible curvature in variable Ln(COTPR (P-Value = 0.043)
Overall lack of fit test is significant at P = 0.043
```

Note:

1. The above simulation showed a lower r-squared value of 92.5% than the chosen model in section 5.2.7 (r-squared value 94.8%). Further, the overall lack of fit test was statistically significant and the Durbin-Watson statistic of 1.46 was lower than that of the chosen model, which had a DW-statistic of 1.63.

8.33

U.S. cotton mill demand OLS model using nominal U.S. cotton promotion expenditure

Regression Analysis: CMD versus CTD, RATIO, TFD, COTPROM

```
The regression equation is
CMD = - 1914 - 0.925 CTD - 33 RATIO + 0.452 TFD + 7.74 COTPROM

Predictor        Coef     SE Coef          T        P       VIF
Constant      -1913.5       489.3      -3.91    0.006
CTD          -0.92533     0.04697     -19.70    0.000       7.6
RATIO           -32.9       251.3      -0.13    0.900       2.5
TFD           0.45218     0.03404      13.28    0.000      15.9
COTPROM         7.736       4.282       1.81    0.114       7.2

S = 69.17              R-Sq = 98.8%        R-Sq(adj) = 98.1%
PRESS = 97248.2        R-Sq(pred) = 96.43%

Analysis of Variance

Source            DF          SS          MS         F        P
Regression         4     2693993      673498    140.76    0.000
Residual Error     7       33493        4785
Total             11     2727486

No replicates. Cannot do pure error test.

Source       DF      Seq SS
CTD           1       24988
RATIO         1      246233
TFD           1     2407155
COTPROM       1       15617

Unusual Observations
Obs        CTD        CMD         Fit      SE Fit    Residual    St Resid
  7       2698     5226.8      5325.4        48.6       -98.6      -2.01R

R denotes an observation with a large standardized residual

Durbin-Watson statistic = 2.27

No evidence of lack of fit (P > 0.1)
```

Note:

1. The above simulation showed a lower r-squared value of 98.1% than the chosen model in section 5.3.2 (r-squared value 98.3%) and the Durbin-Watson statistic of 2.27 was lower than that of the chosen model, which had a DW-statistic of 2.32.

8.34

U.S. cotton mill demand OLS model using U.S. total fiber demand considering cotton, wool, man-made fiber and flax and silk

Regression Analysis: CMD versus CTD, RATIO, COTPROM, TFD1

```
The regression equation is
CMD = - 742 - 0.902 CTD + 155 RATIO + 7.28 COTPROM + 0.398 TFD1

Predictor        Coef     SE Coef          T        P       VIF
Constant       -742.5       493.9      -1.50    0.176
CTD          -0.90187     0.05490     -16.43    0.000       7.3
RATIO           154.7       303.9       0.51    0.626       2.5
COTPROM         7.275       5.189       1.40    0.204       7.4
TFD1          0.39758     0.03618      10.99    0.000      15.1

S = 82.89               R-Sq = 98.2%        R-Sq(adj) = 97.2%
PRESS = 161021          R-Sq(pred) = 94.10%

Analysis of Variance

Source           DF          SS          MS         F        P
Regression        4     2679386      669846     97.48    0.000
Residual Error    7       48100        6871
Total            11     2727486
No replicates. Cannot do pure error test.

Source       DF      Seq SS
CTD           1       24988
RATIO         1      246233
COTPROM       1     1578337
TFD1          1      829828

Durbin-Watson statistic = 1.91

No evidence of lack of fit (P > 0.1)
```

Note:

1. The above simulation proved unsatisfactory as the fiber price ratio variable (RATIO) showed a positive coefficient. The price ratio is defined as the U.S. cotton mill delivered price lagged one year divided by the U.S. polyester mill delivered price lagged by one year. A positive coefficient for the ratio variable means that as U.S. cotton prices rise U.S. cotton mill demand would also rise. However, economic theory suggests that as prices increase demand would decrease.

8.35

U.S. per capita cotton mill demand OLS model using nominal U.S. cotton promotion expenditure

Regression Analysis: CMD versus CTD, RATIO, COTPROM, TFD1

```
The regression equation is
CMD = - 3.98 - 0.825 CTD - 0.06 RATIO + 5.07 COTPROM + 0.415 TFD1

Predictor        Coef     SE Coef         T        P       VIF
Constant       -3.983       3.067     -1.30    0.235
CTD          -0.82501     0.06192    -13.32    0.000       4.3
RATIO          -0.057       1.578     -0.04    0.972       2.5
COTPROM         5.073       6.685      0.76    0.473       5.2
TFD1          0.41544     0.05386      7.71    0.000       8.2

S = 0.4361             R-Sq = 96.7%         R-Sq(adj) = 94.7%
PRESS = 12.3696        R-Sq(pred) = 68.94%

Analysis of Variance

Source            DF          SS          MS         F        P
Regression         4     38.4970      9.6243     50.60    0.000
Residual Error     7      1.3313      0.1902
Total             11     39.8284

No replicates. Cannot do pure error test.

Source       DF      Seq SS
CTD           1     10.5063
RATIO         1      2.9290
COTPROM       1     13.7450
TFD1          1     11.3166

Unusual Observations
Obs        CTD        CMD         Fit       SE Fit    Residual    St Resid
  1        7.0     16.620      17.402        0.288      -0.782      -2.39R

R denotes an observation with a large standardized residual

Durbin-Watson statistic = 1.64

No evidence of lack of fit (P > 0.1)
```

Note:

1. The above simulation showed a lower r-squared value of 94.7% than the chosen model in section 5.3.5 (r-squared value 95.4%) and the Durbin-Watson statistic of 1.64 was lower than that of the chosen model, which had a DW-statistic of 1.76.

8.36

U.S. cotton mill demand OLS model using U.S. total fiber demand considering cotton, wool, man-made fiber and flax and silk as constituent fibers

Regression Analysis: CMD versus CTD, RATIO, RCOTPROM, TFD

```
The regression equation is
CMD = - 4.68 - 0.793 CTD + 0.48 RATIO + 10.8 RCOTPROM + 0.386 TFD

Predictor        Coef     SE Coef          T        P       VIF
Constant       -4.679       2.858      -1.64    0.146
CTD          -0.79296     0.06003     -13.21    0.000       5.0
RATIO           0.478       1.367       0.35    0.737       2.3
RCOTPROM       10.774       6.684       1.61    0.151       4.1
TFD           0.38610     0.05136       7.52    0.000       8.7

S = 0.3920             R-Sq = 97.3%        R-Sq(adj) = 95.8%
PRESS = 6.74996        R-Sq(pred) = 83.05%

Analysis of Variance

Source            DF          SS          MS         F        P
Regression         4     38.7529      9.6882     63.06    0.000
Residual Error     7      1.0754      0.1536
Total             11     39.8284
No replicates. Cannot do pure error test.

Source       DF      Seq SS
CTD           1     10.5063
RATIO         1      2.9290
RCOTPROM      1     16.6342
TFD           1      8.6833

Unusual Observations
Obs        CTD        CMD         Fit      SE Fit    Residual    St Resid
  1        7.0     16.620      17.241       0.274      -0.621       -2.21R

R denotes an observation with a large standardized residual
Durbin-Watson statistic = 2.02
No evidence of lack of fit (P > 0.1)
```

Note:

1 The above simulation proved unsatisfactory as the fiber price ratio variable (RATIO) showed a positive coefficient. The price ratio is defined as the U.S. cotton mill delivered price lagged one year divided by the U.S. polyester mill delivered price lagged by one year. A positive coefficient for the ratio variable means that as U.S. cotton prices rise U.S. cotton mill demand would also rise. However, economic theory suggests that as prices increase demand would decrease.

8.37

U.S. per capita total polyester demand OLS model using per capita U.S. total fiber demand

Regression Analysis: TPD versus POLYPRICE, TECHDEV, GDP

```
The regression equation is
TPD = 22.9 - 0.0166 POLYPRICE + 0.496 TECHDEV -0.000241 GDP

Predictor        Coef     SE Coef         T        P       VIF
Constant        22.92       19.73      1.16    0.279
POLYPRIC     -0.01660     0.04640     -0.36    0.730       2.5
TECHDEV        0.4962      0.4310      1.15    0.283      21.5
GDP        -0.0002410   0.0007177     -0.34    0.746      23.8

S = 1.111              R-Sq = 68.6%        R-Sq(adj) = 56.8%
PRESS = 33.3106        R-Sq(pred) = 0.00%

Analysis of Variance

Source            DF          SS          MS         F        P
Regression         3      21.608       7.203      5.83    0.021
Residual Error     8       9.883       1.235
Total             11      31.490

No replicates. Cannot do pure error test.

Source       DF      Seq SS
POLYPRIC      1      13.225
TECHDEV       1       8.243
GDP           1       0.139

Unusual Observations
Obs   POLYPRIC        TPD         Fit      SE Fit    Residual    St Resid
 12       57.1     17.830      20.129       0.637      -2.299      -2.52R

R denotes an observation with a large standardized residual

Durbin-Watson statistic = 1.16
Lack of fit test
Possible curvature in variable POLYPRIC (P-Value = 0.062)
Possible interactions with variable POLYPRIC (P-Value = 0.073)
Possible curvature in variable GDP (P-Value = 0.009)
Possible interactions with variable GDP (P-Value = 0.048)
Overall lack of fit test is significant at P = 0.009
```

Note:

1. In the above simulation for per capita U.S. total polyester demand, the overall lack of fit test was statistically significant and hence proved unsatisfactory. Additionally, the U.S. income term represented by per capita U.S. GDP showed a negative coefficient. However, economic theory suggests that the national income would show an increase as demand increases. Based on these two factors this model was found to be unsatisfactory.

8.38

U.S. total polyester demand OLS model using real U.S. mill delivered polyester price

Regression Analysis: Ln(TPD) versus Ln(REALPOLYPRICE), Ln(REALGDP), ...

```
The regression equation is
Ln(TPD) = 7.56 - 0.052 Ln(REALPOLYPRICE) + 0.100 Ln(REALGDP)
           + 0.133 Ln(TECHDEV)

Predictor        Coef     SE Coef          T        P       VIF
Constant        7.565       3.597       2.10    0.069
Ln(REALP      -0.0516      0.1385      -0.37    0.719       4.8
Ln(REALG       0.0997      0.3613       0.28    0.790       9.5
Ln(TECHD      0.13255     0.04421       3.00    0.017       5.7

S = 0.04646            R-Sq = 90.3%         R-Sq(adj) = 86.6%
PRESS = 0.038342       R-Sq(pred) = 78.39%

Analysis of Variance

Source            DF          SS          MS         F        P
Regression         3    0.160166    0.053389     24.73    0.000
Residual Error     8    0.017271    0.002159
Total             11    0.177437

No replicates. Cannot do pure error test.

Source       DF      Seq SS
Ln(REALP      1    0.115928
Ln(REALG      1    0.024834
Ln(TECHD      1    0.019403

Unusual Observations
Obs   Ln(REALP    Ln(TPD)         Fit      SE Fit    Residual    St Resid
 12       3.97     8.5084      8.5997      0.0256     -0.0913      -2.36R

R denotes an observation with a large standardized residual

Durbin-Watson statistic = 1.47
```

Note:

1. The above simulation showed a slightly lower r-squared value of 86.6% than the chosen model in section 5.4.3 (r-squared value 86.7%) and the Durbin-Watson statistic of 1.47 was almost equal to that of the chosen model, which had a DW-statistic of 1.46.

8.39

U.S. total polyester demand OLS model using nominal U.S. disposable personal income

Regression Analysis: Ln(TPD) versus Ln(POLYPRICE), Ln(DPI), Ln(TECHDEV)

```
The regression equation is
Ln(TPD) = 9.57 - 0.117 Ln(POLYPRICE) - 0.102 Ln(DPI) + 0.165 Ln(TECHDEV)

Predictor        Coef     SE Coef          T        P       VIF
Constant        9.566       2.761       3.46    0.009
Ln(POLYP      -0.1171      0.1422      -0.82    0.434       2.9
Ln(DPI)       -0.1023      0.2805      -0.36    0.725      13.1
Ln(TECHD      0.16493     0.05535       2.98    0.018       9.1

S = 0.04610            R-Sq = 90.4%         R-Sq(adj) = 86.8%
PRESS = 0.052088       R-Sq(pred) = 70.64%

Analysis of Variance

Source            DF          SS          MS         F        P
Regression         3    0.160432    0.053477     25.16    0.000
Residual Error     8    0.017005    0.002126
Total             11    0.177437

No replicates. Cannot do pure error test.

Source       DF      Seq SS
Ln(POLYP      1    0.083189
Ln(DPI)       1    0.058369
Ln(TECHD      1    0.018874

Unusual Observations
Obs   Ln(POLYP    Ln(TPD)         Fit      SE Fit    Residual    St Resid
 12       4.04     8.5084      8.5907      0.0292     -0.0823       -2.30R

R denotes an observation with a large standardized residual

Durbin-Watson statistic = 1.38
```

Note:

1. In the above simulation for U.S. total polyester demand, the U.S. income term represented by per capita nominal U.S. DPI showed a negative coefficient. However, economic theory suggests that the national income would show an increase as demand increases. Based on these two factors this model was found to be unsatisfactory.

8.40

U.S. total polyester demand OLS model using nominal U.S. personal consumption expenditure

Regression Analysis: Ln(TPD) versus Ln(POLYPRICE), Ln(PCE), Ln(TECHDEV)

```
The regression equation is
Ln(TPD) = 9.33 - 0.111 Ln(POLYPRICE) - 0.078 Ln(PCE) + 0.162 Ln(TECHDEV)

Predictor        Coef     SE Coef         T        P       VIF
Constant        9.327       2.406      3.88    0.005
Ln(POLYP      -0.1110      0.1384     -0.80    0.446       2.7
Ln(PCE)       -0.0780      0.2441     -0.32    0.758      12.4
Ln(TECHD      0.16250     0.05486      2.96    0.018       8.9

S = 0.04619            R-Sq = 90.4%        R-Sq(adj) = 86.8%
PRESS = 0.055355       R-Sq(pred) = 68.80%

Analysis of Variance

Source            DF          SS          MS         F        P
Regression         3    0.160367    0.053456     25.05    0.000
Residual Error     8    0.017070    0.002134
Total             11    0.177437

No replicates. Cannot do pure error test.

Source       DF      Seq SS
Ln(POLYP      1    0.083189
Ln(PCE)       1    0.058459
Ln(TECHD      1    0.018719

Unusual Observations
Obs   Ln(POLYP    Ln(TPD)         Fit      SE Fit    Residual    St Resid
 12       4.04     8.5084      8.5917      0.0289     -0.0833       -2.31R

R denotes an observation with a large standardized residual

Durbin-Watson statistic = 1.39
```

Note:

1. In the above simulation for U.S. total polyester demand, the U.S. income term represented by per capita nominal U.S. PCE showed a negative coefficient. However, economic theory suggests that the national income would show an increase as demand increases. Based on these two factors this model was found to be unsatisfactory.

8.41

U.S. total polyester demand OLS model using nominal U.S. gross domestic product

Regression Analysis: Ln(TPD) versus Ln(POLYPRICE), Ln(GDP), Ln(TECHDEV)

```
The regression equation is
Ln(TPD) = 8.48 - 0.082 Ln(POLYPRICE) + 0.010 Ln(GDP) + 0.145 Ln(TECHDEV)

Predictor        Coef     SE Coef         T        P       VIF
Constant        8.475       2.541      3.34    0.010
Ln(POLYP      -0.0820      0.1343     -0.61    0.559       2.5
Ln(GDP)        0.0102      0.2525      0.04    0.969      11.9
Ln(TECHD      0.14481     0.05520      2.62    0.030       8.9

S = 0.04648            R-Sq = 90.3%         R-Sq(adj) = 86.6%
PRESS = 0.043237       R-Sq(pred) = 75.63%

Analysis of Variance

Source            DF          SS          MS         F        P
Regression         3    0.160153    0.053384     24.71    0.000
Residual Error     8    0.017284    0.002160
Total             11    0.177437

No replicates. Cannot do pure error test.

Source       DF      Seq SS
Ln(POLYP      1    0.083189
Ln(GDP)       1    0.062092
Ln(TECHD      1    0.014872

Unusual Observations
Obs   Ln(POLYP    Ln(TPD)        Fit      SE Fit    Residual    St Resid
 12       4.04     8.5084     8.5975      0.0269     -0.0891       -2.35R

R denotes an observation with a large standardized residual

Durbin-Watson statistic = 1.43
```

Note:

1. The above simulation showed a slightly lower r-squared value of 86.6% than the chosen model in section 5.4.3 (r-squared value 86.7%) and the Durbin-Watson statistic of 1.43 was almost lower than that of the chosen model, which had a DW-statistic of 1.46. Hence, this model was found to be unsatisfactory.

8.42

U.S. total polyester demand OLS model using real U.S. personal consumption expenditure

Regression Analysis: Ln(TPD) versus Ln(POLYPRICE), Ln(REALPCE), ...

```
The regression equation is
Ln(TPD) = 9.17 - 0.101 Ln(POLYPRICE) - 0.062 Ln(REALPCE) + 0.154 Ln(TECHDEV)

Predictor        Coef     SE Coef         T        P       VIF
Constant        9.169       3.137      2.92    0.019
Ln(POLYP      -0.1015      0.1416     -0.72    0.494       2.8
Ln(REALP      -0.0624      0.3256     -0.19    0.853       8.6
Ln(TECHD      0.15383     0.04410      3.49    0.008       5.7

S = 0.04638            R-Sq = 90.3%        R-Sq(adj) = 86.7%
PRESS = 0.051688       R-Sq(pred) = 70.87%

Analysis of Variance

Source            DF          SS         MS         F        P
Regression         3    0.160228   0.053409     24.83    0.000
Residual Error     8    0.017208   0.002151
Total             11    0.177437

No replicates. Cannot do pure error test.

Source       DF      Seq SS
Ln(POLYP      1    0.083189
Ln(REALP      1    0.050861
Ln(TECHD      1    0.026179

Unusual Observations
Obs   Ln(POLYP    Ln(TPD)         Fit      SE Fit    Residual    St Resid
 12       4.04     8.5084      8.5941      0.0280     -0.0857       -2.32R

R denotes an observation with a large standardized residual

Durbin-Watson statistic = 1.40
```

Note:

1. In the above simulation for U.S. total polyester demand, the U.S. income term represented by per capita real U.S. PCE showed a negative coefficient. However, economic theory suggests that the national income would show an increase as demand increases. Based on these two factors this model was found to be unsatisfactory.

8.43

U.S. total polyester demand OLS model using real U.S. disposable personal income

Regression Analysis: Ln(TPD) versus Ln(POLYPRICE), Ln(REALDPI), ...

```
The regression equation is
Ln(TPD) = 9.43 - 0.107 Ln(POLYPRICE) - 0.090 Ln(REALDPI) + 0.155 Ln(TECHDEV)

Predictor        Coef     SE Coef        T       P      VIF
Constant        9.431       3.798     2.48   0.038
Ln(POLYP      -0.1069      0.1479    -0.72   0.490      3.1
Ln(REALD      -0.0896      0.3942    -0.23   0.826      8.7
Ln(TECHD      0.15474     0.04263     3.63   0.007      5.3

S = 0.04634            R-Sq = 90.3%        R-Sq(adj) = 86.7%
PRESS = 0.047933       R-Sq(pred) = 72.99%

Analysis of Variance

Source            DF         SS         MS        F       P
Regression         3   0.160260   0.053420    24.88   0.000
Residual Error     8   0.017176   0.002147
Total             11   0.177437

No replicates. Cannot do pure error test.

Source       DF      Seq SS
Ln(POLYP      1    0.083189
Ln(REALD      1    0.048786
Ln(TECHD      1    0.028285

Unusual Observations
Obs   Ln(POLYP    Ln(TPD)        Fit      SE Fit    Residual    St Resid
 12       4.04     8.5084     8.5935      0.0283     -0.0851       -2.32R

R denotes an observation with a large standardized residual

Durbin-Watson statistic = 1.39
```

Note:

1. In the above simulation for U.S. total polyester demand, the U.S. income term represented by per capita real U.S. DPI showed a negative coefficient. However, economic theory suggests that the national income would show an increase as demand increases. Based on these two factors this model was found to be unsatisfactory.

8.44

U.S. polyester mill demand OLS model using nominal U.S. cotton promotion expenditure

Regression Analysis: Ln(PMD) versus Ln(PTD), Ln(RATIO), ...

The regression equation is
Ln(PMD) = - 7.19 - 0.342 Ln(PTD) + 0.176 Ln(RATIO) + 1.82 Ln(TFD)
- 0.109 Ln(COTPROM)

Predictor	Coef	SE Coef	T	P	VIF
Constant	-7.190	2.224	-3.23	0.014	
Ln(PTD)	-0.34222	0.06357	-5.38	0.001	9.2
Ln(RATIO	0.17601	0.09277	1.90	0.100	2.7
Ln(TFD)	1.8212	0.2826	6.44	0.000	21.3
Ln(COTPR	-0.10929	0.07640	-1.43	0.196	9.9

S = 0.02441 R-Sq = 96.7% R-Sq(adj) = 94.8%
PRESS = 0.016054 R-Sq(pred) = 87.29%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	4	0.122145	0.030536	51.27	0.000
Residual Error	7	0.004169	0.000596		
Total	11	0.126314			

No replicates. Cannot do pure error test.

Source	DF	Seq SS
Ln(PTD)	1	0.053319
Ln(RATIO	1	0.005245
Ln(TFD)	1	0.062361
Ln(COTPR	1	0.001219

Durbin-Watson statistic = 2.22

No evidence of lack of fit (P > 0.1)

Note:

1. The above simulation produced almost equal values of r-squared of 94.8% than the chosen model in section 5.5.2 (r-squared value 94.5%) while the Durbin-Watson statistic of 2.22 was higher than the chosen model, which had a DW-statistic of 2.12.

8.45

U.S. polyester mill demand model using U.S. total fiber demand considering cotton, wool, man-made fiber and flax and silk as constituent fibers

Regression Analysis: Ln(PMD) versus Ln(PTD), Ln(RATIO), ...

```
The regression equation is
Ln(PMD) = - 6.65 - 0.340 Ln(PTD) + 0.141 Ln(RATIO) + 1.77 Ln(TFD1)
           - 0.118 Ln(COTPROM)

Predictor        Coef     SE Coef          T        P       VIF
Constant       -6.648       2.236      -2.97    0.021
Ln(PTD)      -0.33965     0.06593      -5.15    0.001       9.2
Ln(RATIO      0.14122     0.09463       1.49    0.179       2.6
Ln(TFD1)       1.7738      0.2875       6.17    0.000      22.5
Ln(COTPR     -0.11780     0.08086      -1.46    0.189      10.3

S = 0.02533            R-Sq = 96.4%        R-Sq(adj) = 94.4%
PRESS = 0.017634       R-Sq(pred) = 86.04%

Analysis of Variance

Source            DF          SS          MS         F        P
Regression         4    0.121824    0.030456     47.48    0.000
Residual Error     7    0.004490    0.000641
Total             11    0.126314

No replicates. Cannot do pure error test.

Source       DF      Seq SS
Ln(PTD)       1    0.053319
Ln(RATIO      1    0.005245
Ln(TFD1)      1    0.061898
Ln(COTPR      1    0.001361


Durbin-Watson statistic = 2.39

No evidence of lack of fit (P > 0.1)
```

Note:

1. The above simulation showed almost equal r-squared value of 94.4% that was lower than the chosen model in section 5.5.2 (r-squared value 94.5%) though the Durbin-Watson statistic of 2.39 was higher than the chosen model, which had a DW-statistic of 2.12.

8.46

U.S. per capita polyester mill demand OLS model using nominal U.S. cotton promotion expenditure

Regression Analysis: PMD versus PTD, RATIO, TFD1, COTPROM

```
The regression equation is
PMD = - 6.93 - 1.25 PTD + 1.56 RATIO + 0.348 TFD1 - 1.27 COTPROM

Predictor        Coef     SE Coef          T        P       VIF
Constant       -6.930       3.881      -1.79    0.117
PTD           -1.2450      0.2867      -4.34    0.003       6.9
RATIO           1.562       1.884       0.83    0.434       2.8
TFD1          0.34771     0.06641       5.24    0.001      10.1
COTPROM        -1.266       7.501      -0.17    0.871       5.3

S = 0.4862              R-Sq = 90.8%         R-Sq(adj) = 85.6%
PRESS = 5.79283         R-Sq(pred) = 67.82%

Analysis of Variance

Source            DF          SS          MS         F        P
Regression         4     16.3456      4.0864     17.29    0.001
Residual Error     7      1.6544      0.2363
Total             11     18.0000

No replicates. Cannot do pure error test.

Source       DF      Seq SS
PTD           1      4.5028
RATIO         1      0.4427
TFD1          1     11.3934
COTPROM       1      0.0067

Unusual Observations
Obs        PTD        PMD         Fit       SE Fit    Residual    St Resid
  8       4.82     17.340      16.391        0.206       0.949       2.16R

R denotes an observation with a large standardized residual

Durbin-Watson statistic = 2.36

No evidence of lack of fit (P > 0.1)
```

Note:

1. The above simulation produced an r-squared value of 85.6 % that was equal to that for the chosen model in section 5.5.5 (r-squared value 85.6%) while the Durbin-Watson statistic of 2.36 was higher than the chosen model, which had a DW-statistic of 2.34.

8.47

U.S. polyester mill demand model using U.S. total fiber demand considering cotton, wool, man-made fiber and flax and silk as constituent fibers

Regression Analysis: PMD versus PTD, RATIO, TFD, RCOTPROM

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The regression equation is
PMD = - 7.98 - 1.21 PTD + 2.03 RATIO + 0.340 TFD - 0.21 RCOTPROM

Predictor        Coef     SE Coef         T        P       VIF
Constant       -7.975       4.218     -1.89    0.101
PTD           -1.2135      0.3165     -3.83    0.006       8.1
RATIO           2.031       1.910      1.06    0.323       2.8
TFD           0.34050     0.07298      4.67    0.002      11.0
RCOTPROM       -0.209       8.599     -0.02    0.981       4.2

S = 0.4964            R-Sq = 90.4%         R-Sq(adj) = 84.9%
PRESS = 5.36928       R-Sq(pred) = 70.17%

Analysis of Variance

Source            DF          SS          MS         F        P
Regression         4     16.2750      4.0687     16.51    0.001
Residual Error     7      1.7250      0.2464
Total             11     18.0000

No replicates. Cannot do pure error test.

Source       DF      Seq SS
PTD           1      4.5028
RATIO         1      0.4427
TFD           1     11.3294
RCOTPROM      1      0.0001

Unusual Observations
Obs       PTD       PMD         Fit      SE Fit    Residual    St Resid
  8      4.82    17.340      16.357       0.186       0.983       2.14R

R denotes an observation with a large standardized residual

Durbin-Watson statistic = 2.04

No evidence of lack of fit (P > 0.1)
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Note:

1. The above simulation produced r-squared value of 84.9% that was lower than that for the chosen model in section 5.5.5 (r-squared value 85.6%) while the Durbin-Watson statistic of 2.04 was also lower than that of the chosen model, which had a DW-statistic of 2.34.