THE EFFECT OF FIBER, YARN, AND FABRIC PRICES ON MILL COTTON FIBER CONSUMPTION

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Abstract

Cotton's share of mill fiber consumption has been increasing since the mid 1980s, due to increased consumer demand for cotton textile products. There has been major restructuring in U.S. textile mills from the 1980s, in terms of the adoption of new spinning and weaving technologies, as well as information systems. However, fluctuating and high cotton fiber prices, coupled with low prices of cotton textile products received by producers, may be leading to a margin squeeze at the intermediate textile mill level. This study uses monthly and quarterly data to analyze factors influencing mill consumption of cotton fiber, for the period 1987-97. Although factors affecting mill fiber consumption, such as relative fiber prices, have been analyzed by several researchers, the time period considered in most of these studies was prior to the mid 1980s, and/or the data used in the analyses were annual data. Consequently, the previous literature does not reflect the changed circumstances of the U.S. textile industry since the 1980s. Moreover, annual data, as used in the previous literature, cannot capture the effects of monthly fiber price variations. In this study, aggregate mill consumption of cotton fiber was modeled as a function of the prices of cotton and manufactured fiber, yarn and fabric prices, and a measure of technology adoption. Two different models were estimated. The first model contained yarn prices as the output prices, and was estimated on a monthly basis for the period October 1987 to October 1997. The second model contained fabric prices as the output prices, and was estimated on a quarterly basis for the period October 1987 to April 1996. The yarn and fabric prices were representative of apparel as well as home textiles end-uses. The results showed that, for the yarn model, mill cotton fiber consumption was positively and significantly related to the price of the yarn used for apparel end-uses, but not to fiber price. The results for the fabric model indicated that mill fiber consumption was positively and significantly related to the price of polyester fiber and to the price of blended print cloth used for apparel end-uses, but mill fiber consumption was not significantly related to cotton fiber price. Technology variables in both models showed a significant, but negative, relationship. These findings imply that mill fiber consumption is more sensitive to output price as compared to input price. Mill sensitivity to output price is apparent for those yarn and fabric types used for apparel end-uses. Yarn and fabric types used for home-textiles end-uses did not show significant coefficients. Thus, it appears that yarns and fabrics applied to apparel are more susceptible to price fluctuations at the output level than those used for home-textile end uses. The negative marginal effect results of the technology variables could mean that the new technology is utilized for the manufacture of complex fabrics used in home textiles, such as jacquards, which leads to higher value-added goods without a necessary increase in the amount of fiber input used. Since output prices (yarn and fabric prices) used for apparel are significant in explaining mill cotton fiber consumption, whereas input prices (fiber prices) are not, a price ceiling at the output level would indicate the potential for a margin squeeze at the intermediate level for textile mills. Output prices used for home textiles are not significant in explaining mill cotton fiber consumption. This implies that mills are responding to factors other than input and output prices in the case of home textiles. Thus, there is less potential for a margin squeeze at the intermediate level. There has been faster growth in production as well as exports of the home textiles segment of the U.S. textile industry in recent years as compared to other segments of the textile industry (Vida & Norton, 1997). As import liberalization continues under the terms of the World Trade Organization (WTO), U.S. textile firms may concentrate more on home furnishings, and start pulling out of the apparel fabrics segment.

Introduction

Cotton is the most important natural fiber input in the U.S. textile industry, and constitutes over 30 percent of all fibers consumed by U.S. mills (Fiber Organon, March 1998). The annual contribution of the cotton textile industry to the U.S. economy is over $25 billion in products and services (Meyer, 1998). Although manufactured fibers accounted for over 66 percent of total mill fiber consumption in 1997, cotton's share has been increasing since the early 1980s. While total U.S. mill fiber consumption grew at an average rate of 4 percent annually since the early 1980s, the annual average growth rate of cotton consumption was 5.3 percent. Manufactured fiber consumption grew at an average rate of only 3.4 percent annually during the same time period (Fiber Organon, March 1998). Consumer demand for apparel, home furnishings and industrial goods drives the demand for raw fiber (Larsen & Meyer, 1996). Per capita consumption of cotton increased from 13.5 lbs. in 1982, to a record high of 32.5 lbs. in 1997 (Cotton and Wool Yearbook, 1998). The increase in per capita consumption is primarily attributed to increasing real incomes and new textile products and finishes (Larson & Meyer, 1996). During the 1980s, the textile industry undertook major restructuring, brought about by increased import competition. Large capital investments were made to increase productivity as a means of countering imports. U.S. mills made large capital investments in new spinning and weaving technologies in the early and mid 1980s (Finnie, 1992). Information technologies were adopted in the late

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1980s, which led to reduced turnaround times between orders placed by buyers and deliveries made by mills (U.S. International Trade Commission, 1995).

In spite of the positive signals from the restructuring of consumption and the industry, the value of cotton textile shipments grew little from 1986 to 1994 (McGraw-Hill, 1998). As a result of bankruptcies and mergers, the number of cotton textile companies declined by over 10 percent between 1982 and 1992 (Census of Manufactures, 1992; Finnie, 1992). This situation has been ascribed to increasing imports of cotton textile products, which exert downward pressure on fabric and apparel prices in the domestic market. Textile mills were also faced with unprecedented variability in the price of cotton fiber over the last decade, and cotton fiber prices reached an all-time high during 1994 (Cotton and Wool Situation and Outlook, various issues). The new trade agreements in the 1990s will lead to greater price competition at the retail level in the future. The Multi-Fiber Agreement (MFA), which restricted imports of clothing and textiles into the U.S., was replaced by the Uruguay Round Agreement on Textiles and Clothing (ATC) in 1995. According to the ATC, there will be a continuing liberalization of apparel and textile imports until the year 2005, at which point all import barriers will be dismantled (Khanna, 1997).

Thus, there has appears to be a 'ceiling' imposed on textile product prices by price competition at the retail level. A combination of price increases at the input level and price ceiling at the output level can result in a margin squeeze at the intermediate textile mill level. As seen in Figures 1 and 2, cotton fiber prices and output (yarn and fabric) prices do not move together, and in order to predict future mill cotton fiber consumption, it is important to know whether consumption is more sensitive to input price or to output price. This study uses monthly and quarterly data to analyze factors influencing mill consumption of cotton fiber, for the period 1987-97. Specifically, the paper examines whether mill consumption of cotton fiber is more sensitive to input price (cotton fiber price), or to output price (yarn and fabric price).

The Structure of The U.S. Cotton Textile Industry

The U.S. cotton textile industry, which transforms fiber into finished fabric, consists of complex linkages between sectors. Raw cotton fiber is used to produce yarn and thread. Yarn is fabricated into woven or knit fabric, which is then dyed, finished, and made into apparel, home textile products or industrial goods. Many textile industry firms are vertically integrated manufacturing units, and undertake several of the stages of manufacturing (Glade, 1996). There are two primary outputs of the textile industry: yarn and fabric. Integrated mills consist of both yarn spinning and fabric manufacturing operations. Non-integrated mills buy yarn from yarn mills. Home textiles (sheets, towels, draperies) require little construction such as cutting and sewing, and are usually the direct product of weaving mills. Apparel manufacturing, which is a labor intensive operation, is usually not integrated with weaving. The total number of mills engaged in yarn spinning, weaving, and finishing of primarily cotton goods decreased from 886 in 1982 to 807 in 1992 (Census of Manufactures, 1992). Most of the decrease in the number of mills was due to bankruptcies and the closing of unprofitable plants, and the rest was due to mergers, which led to multiple plants being consolidated into single units (Finnie, 1992).

The major end-uses of cotton are apparel and home textiles. Apparel accounts for over 65 percent of cotton consumed by mills, and home textiles account for over 25 percent. Industrial products such as felts and filtration sheets contain a small amount of cotton, but are mostly made of manufactured fibers (Larsen & Meyer, 1996). Two major categories of woven fabrics are used in apparel: topweight fabrics and bottomweight fabrics (see Table 1). These two categories of fabrics represent approximately 54 percent of all cotton consumed by mills. Topweight fabrics generally weigh less than 5.0 ounces per square yard, and are used in shirts, blouses, and lightweight dresses. Topweight fabrics also include cotton/polyester blendsExamples of fabric types included in this category are print cloth and shirting. Bottomweight fabrics generally weigh more than 5.0 ounces per square yard, and are used in pants, jeans, sportswear, coats and jackets (Fiber Organon, October 1988). Examples of fabric types included in this category are denim, duck, and drills. Knit goods, which consume about 9-10 percent of all cotton, include a variety of products such as sweaters, socks, hosiery, and lingerie. Home textiles consist of sheets, draperies, upholstery, towels, and other goods.

Mill Fiber Consumption and the Cotton Textile Industry

After World War II, the great demand for manufactured fibers[1] led to a decrease in cotton usage by mills. Petro-chemical based manufactured fibers (i.e., nylon and polyester), which were introduced into the market in the late 1930s, were successful due to several reasons. They had superior performance properties as compared to natural fibers, economies of scale involved in manufacturing enabled producers to lower prices over time, and well-funded research and development efforts led to the creation of new areas of demand (Simpson, 1991). Furthermore, the inherent instability of cotton fiber prices as compared to the predictable, and lower, prices of manufactured fibers, was an important reason for the decrease of cotton fiber usage by mills (Larsen & Meyer, 1996).

In the 1980s, two major factors led to changes in the pattern of mill fiber consumption. Primarily, since the early 1980s, consumer preferences shifted back to natural fiber products, specifically cotton, due to their superior comfort properties (Larson & Meyer, 1996; Simpson, 1991). Also, petroleum-based manufactured fibers lost their price advantage because the oil price increases of the 1970s raised the costs of production (Simpson, 1991).

There was also major restructuring in the U.S. textile industry in the mid and late 1980s. Due to increased competition from imports, textile mills made large capital investments to modernize and increase productivity (Cline, 1990). Shuttleless weaving looms[2], which led to three-fold increases in productivity over the older shuttle looms, were available in the 1970s; however, they were of limited benefit to the cotton textile sector, because the fast machine speeds required the use of yarns which were uniform in density and strength. These features, although an inherent feature of manufactured-fiber yarns, were not available in natural-fiber yarns until the late 1970s, when the new open-end spinning systems[3] were introduced. Thus, most of the new capital investment in the cotton textile industry took place in the early and mid 1980s. Another important form of restructuring that took place in the U.S. textile industry in the late 1980s was the introduction of Quick Response (QR) technologies in the 1980s (Finnie, 1992; U.S. International Trade Commission, 1995). QR has been viewed as a means of countering import competition by emphasizing speed and flexibility in manufacturing. Under QR, retailers are linked to manufacturers through shared point-of-sale information. The computer linkages lead to automatic reordering, known as Just-In-Time responses, which keep retailers' as well as manufacturers' inventories low. Approximately 72 percent of textile and apparel manufacturers had implemented QR techniques by 1994 (U.S. International Trade Commission, 1995).

Prior to the implementation of QR, manufacturers customarily received orders from customers and then planned and procured raw material as far as 6-12 months in advance (Abernathy, Dunlop, Hammond, & Weil, 1995; Stennis, Pinar, & Allen, 1983). After the implementation of QR, the average turnaround time in the fiber to fabric process between orders received and goods delivered can be as little as 8-10 weeks (Dickerson, 1999). As a result, mill managers' concerns about fiber price fluctuations have intensified (Kurt Salmon Associates, 1995).

Previous Research on Fiber Demand

Factors affecting mill fiber consumption, such as relative prices and technology adoption, have been analyzed by several researchers. Lewis (1972) estimated annual dynamic demand equations, for the period 1920-1966, for seven textile fibers. The fibers included three natural fibers (cotton, apparel wool, and carpet wool), and four manmade fibers (cellulosic staple, cellulosic filament, synthetic[4] staple, and synthetic filament). A stock-adjustment model, which assumes that past consumption behavior influences present consumption patterns, was used to describe fiber demand. Demand for each fiber (mill consumption plus imports) was specified as a linear function of lagged demand for the fiber, current own price, lagged prices of other fibers, and per capita income. Results of Ordinary Least Squares (OLS) estimations indicated that for all analyzed fibers, past demand was an important determinant of present demand. Own-price and income elasticities are summarized in Table 2. Demand for cotton and wool fibers was income elastic, but demand for manmade fibers was income elastic, showing the increasing preference for manmade fibers during the time period studied. Demand for natural fibers were found to be own-price inelastic.For three of the four manmade fibers, the own-price coefficients were not significant, indicating that, for these fibers, own price was not statistically significant in determining demand for the study period. For synthetic fibers, significant coefficients and positive cross-price elasticities indicated that synthetic fibers were a substitute for cotton, wool, and rayon.

Sanford (1988) examined factors influencing per capita U.S. fiber consumption, as well as domestic mill demand for cotton, using annual data from 1960 to 1986. Two models were estimated. The dependent variables in the first model was total per capita fiber consumption. Independent variables included real cotton price used as a proxy for all fiber prices, real personal consumption expenditures, and a traditional time trend variable specified as a linearly increasing function of time (i.e., 1960 = 1, ….1986 = 26). Although not explicitly specified by the author, such a trend variable is mostly viewed as a proxy for variables such as technology changes or shifts in consumer tastes. Results of linear regression analysis indicated that total per capita fiber consumption was positively related to real personal consumption expenditures, and was negatively related to the time trend variable as well as the real price of cotton fiber. No rationale was forwarded for the negative effect of the time trend variable. The own price elasticity of fiber demand was found to be low (-0.18), and compares with Lewis' (1972) estimate of –0.17. For the second model, the dependent variable was mill consumption of cotton per capita , specified as a linear function of total fiber consumption per capita, the ratio of cotton fiber price (lagged one year) to polyester fiber price (lagged one year), and a time trend variable. The ratio variable was found to be negatively and significantly related to mill per capita cotton fiber consumption, indicating that an increase in the price of cotton relative to polyester (brought about by cotton price increase or polyester price decrease) led to a decrease in mill cotton consumption. Mill cotton fiber consumption was positively related to total per capita cotton consumption, but was negatively related to the time trend variable. Again, no rationale was forwarded for the negative effect of the time trend variable. The significance of lagged fiber prices indicates that, during the time period analyzed (1960-1987), mills procured or contracted for fiber inputs at least one year in advance. Especially during the 1960s and 1970s, mills held high levels of raw material inventories, which had adverse effects on mill profits (Finnie, 1992).

Jones-Russell and Sporleder (1988[b]) examined factors influencing per capita mill demand for cotton fiber by eight end-use categories for the period 1975-1984, using quarterly data. The end-use categories ranged from fabrics that were 100% cotton (e.g., denim) to fabrics which were 60:40 polyester-cotton blends (e.g., printcloth). The authors computed a derived blend price for cotton fiber based on each end-use category. Mill fiber demand for each category was the dependent variable, and regression results indicated that factors affecting mill demand for cotton fiber differed according to end-use. The fiber demand for end-use categories which utilized a large percent of cotton, such as denim, duck, and corduroy, was negatively and significantly related to the blend price, lagged by two quarters, but positively related to prices of ring-spun yarn lagged one quarter and open-end spun yarn lagged two quarters (see Tables 3 and 4). Fiber demand was positively related to lagged prices of yarn used in competing end uses. The number of open-end rotors installed in U.S. mills, used as a measure of the impact of new technologies, and the number of spindles and rotors active in U.S. mills, used as a measure of capacity utilization, were found to be positively and significantly related to fiber demand. Cotton fiber demand for blended fabric end-use categories was negatively and significantly related to its own blend-price lagged by one quarter and to the price of polyester fiber, indicating the complementary relationship between cotton and polyester for those end-uses. Cotton fiber demand for each of the blended end-use categories was positively and significantly related to the price of ring-spun yarn for that particular end-use, and to the ratio of per capita personal consumption expenditures on clothing to per capita personal disposable income. The significance of fiber prices lagged by one or two quarters rather than one year is indicative of changed mill practices during the time period of the study (1975-1984), as compared to the earlier time periods included in studies by Lewis (1972) and Sanford (1988). Restructuring of the textile industry which began in the 1980s mandated lower raw material inventories. As a result, the practice of purchasing cotton fiber as far as one year in advance was diminishing.

Shui, Beghin, and Wohlgenant (1993) and Zhang, Fletcher, and Ethridge (1994) derived input demand equations for cotton fiber based on a profit maximization/cost minimization approach. Using annual data for the period 1950-1987, Shui, Beghin, and Wohlgenant (1993) estimated a logit model of cost shares derived from a translog cost function, for natural and manmade fibers, specifically accounting for scale effects and technological progress. Technological progress was measured by a traditional time trend, and by the rate of shuttleless looms in total weaving looms. Since cotton comprised of 97 % of natural fibers used, the authors note that estimations of demand for natural fibers could be considered as estimations of demand for cotton fiber. The independent variables included prices for energy, fibers and other material inputs, labor, capital, the two technology variables described above, and two indices of output used in separate models (measured by the index of industrial production for textile mill products, and real shipment values for the U.S. textile industry). Natural fiber price was lagged by a year to account for the lag between orders and deliveries in the textile industry. Scale effects were computed through the output elasticities of inputs, which were each evaluated at the mean of the cost shares. Likelihood ratio tests indicated that the hypothesis of constant returns to scale could not be accepted; scale effects were twice as large for manmade fibers as for cotton fiber. Own-price elasticities of fiber demand were much higher than those found by Lewis (1972) and Sanford (1988), as seen in Table 5. Cross-price elasticities showed that natural and manmade fibers were substitutes (positive elasticities), whereas labor was a complement to natural fiber (negative elasticity) and capital was a complement to manmade fiber. The authors' stated rationale was that the new textile industry technology favored the use of manmade fibers. This is a logical proposition for the time period studied, because the faster weaving speeds of shuttleless looms require yarns with more uniform densities and strengths, such as those from manmade fibers.

Zhang, Fletcher, and Ethridge (1994) analyzed demand for cotton fiber in textile mills, 1961-1990, using annual data in a time-varying parameter model. Such a model captures parameter variation over time, which may exist when demand relationships for fibers vary over time due to changes in technology or tastes. The demand for cotton was specified as a linear function of the lagged fiber prices (for cotton, rayon, polyester, and wool) and of a time trend for technological change. The time trend variable contained no specific measure of technology adoption; it was simply specified as a trend variable. Price elasticities, averaged for five-year intervals, were presented in graphical form. The graphs showed that cotton's own-price elasticity was low, and ranged from -0.26 in the 1970s to -0.14 in the late 1980s. Cross-price elasticities with respect to rayon were not significant, whereas cross-price elasticities with respect to polyester were significant and positive, and ranged from 0.40 to 0.85, indicating a substitution relationship. The estimated parameter coefficients indicated that the model parameters were not constant over time, and that the structure of demand for cotton was more stable in the 1970s than in the 1980s. The time trend showed a significant, negative relationship with mill share of cotton fiber use in the period 1962-82, and a non-significant relationship for the period 1988-1990. In other years, the time trend showed a positive relationship with mill share of cotton fiber use. The authors interpret the trend variable as accounting for changes in technology as well as in consumer tastes. The positive relationship after 1982 may be due to consumer tastes shifting back to cotton, and the negative relationship in the prior years may be due to technology changes which favored the use of manufactured fibers.

Summary of Previous Literature

Table 6 compares the major features of the reviewed studies. Several features in the studies are particular to the time periods that were examined. Lagged fiber prices were used in all the studies to explain mill fiber consumption. Prior to the 1980s, mils typically ordered cotton fiber 6-12 months in advance, and price uncertainty was overcome through the use of the futures market (Stennis, Pinar, & Allen, 1983). The adoption of QR technologies, which began in the mid and late 1980s, discourages such advance ordering, and fabric orders are often placed only a few weeks before delivery is required. This is apparent in Jones-Russell and Sporleder's study, in which 1975-1984 data were used and therefore quarterly time lags instead of annual lags were used. There are some contradictions among studies as to the effects of the technology variables. Shui, Beghin, & Wohlgenant (1993) used the share of shuttleless looms to total looms for the period 1950-1987, which is a measure of fabric weaving technology. The variable was found to be biased against natural (cotton) fiber. With their high weaving speeds, shuttleless looms require uniformly dense and strong yarn, an inherent feature of most manufactured-fiber yarns. These features were not available in the natural-fiber yarns before the mid-1970s, since advances in spinning technology followed those in weaving. In contrast, Jones-Russell and Sporleder (1988) used the number of open-end rotors for the period 1975-1984, which is a measure of yarn spinning technology. This measure was positively related to cotton fiber consumption, because open-end spinning technology for cotton fiber was being adopted during the time period studied.

Although factors affecting mill fiber consumption, such as relative fiber prices, have been analyzed by several researchers (Lewis, 1972; Sanford, 1988; Jones-Russell & Sporleder, 1988[b]; Shiu, Beghin, & Wohlgenant, 1993), the time period considered in most of these studies was prior to the mid 1980s, and/or the data used in the analyses were annual data. Consequently, the previous literature does not reflect the changed circumstances of the U.S. textile industry since the mid 1980s. Moreover, annual or quarterly data, as used in the previous literature, cannot capture the effects of monthly fiber price variations. Table 7 presents summary statistics on cotton fiber price data for the period October 1986-October 1997. Average annual prices do not appear to vary greatly, but the values of the annual standard deviations of prices, and the maximum and minimum prices, show notable variation within years. With the exception of the research by Jones-Russell and Sporleder (1988[b]), none of the previous studies on mill fiber demand included output price as a determinant of mill consumption. Evidence exists of the increased fluctuations in cotton fiber prices, while output prices do not vary commensurately, which may suggest the potential for a margin squeeze at the intermediate level for textile mills. Past research has examined only the effect of input price (cotton fiber price) on mill cotton fiber consumption, but not the effect of output prices. Thus, an analysis which includes both input and output prices on a monthly or quarterly level may provide important insights into factors affecting mill fiber consumption in the 1990s.

Procedure

Data and Variables

Aggregate mill consumption of cotton fiber was modeled as a function of the prices of cotton and manufactured fiber, yarn and fabric prices, and a measure of technology adoption. Mill output consists of both yarn and fabric[5], and two different models were estimated. The first model contained yarn prices as the output prices, and was estimated on a monthly basis for the period October 1987 to October 1997. The second model contained fabric prices as the output prices, and was estimated on a quarterly basis for the period October 1987 to April 1996[10]. Results of correlation analysis .showed that yarn and fabric prices were uncorrelated, indicating that one set of prices could not be used as a proxy for the other. Because fabric prices are only available on a quarterly level, two models were estimated.

For the first model, estimated with monthly data, the dependent variable was mill consumption of cotton fiber in pounds. The independent variables were as follows.

a) Price of cotton fiber in cents per pound, landed Group B mill points[6], Strict Low Middling (SLM)[7] 1-1/16". This particular price series reflects all costs incurred by the mill for the acquisition of the raw cotton fiber and is often used to indicate cotton's competitive position among fibers (Larson & Meyer, 1996). Since increases in cotton fiber price would adversely affect mills, a negative relationship was hypothesized between cotton fiber price and mill cotton fiber consumption.

b) Price of polyester fiber in cents per pound, mill-delivered 1.5-denier[8] polyester staple for cotton blending. This price series is representative of the price of manufactured fibers (Larson & Meyer, 1996). Polyester staple is the dominant manufactured fiber used in the fabrication of cotton blended fabrics. Previous literature indicates that polyester fiber is a substitute for cotton; thus, a positive relationship was hypothesized between the price of polyester fiber and mill cotton fiber consumption.

   The data source for fiber prices was various issues of *Cotton and Wool Situation and Outlook* Report, U.S. Department of Agriculture, Economic Research Service. Yarn prices were chosen so as to represent the major end-uses of cotton. Thus, prices of those yarns were included which are predominantly used in the manufacture of topweight and bottomweight apparel fabrics, and home textile fabrics, as per the derived relationship between yarn and fabric types (see Jones-Russell and Sporleder, 1988a; 1988b).

c) Price of 50 % polyester /50 % carded cotton 30/1 yarn[9], used in topweight apparel fabrics.

d) Price of 100 % carded cotton 18/1 yarn, used in bottomweight apparel fabrics.

e) Price of 100% carded cotton 24/1 yarn, used in home textiles.

Because yarn prices are output prices, and an increase in the prices received for output would encourage increased production by mills, a positive relationship was hypothesized between yarn prices and mill cotton fiber consumption. The data source for yarn prices was various issues of America's Textiles International.

All fiber and yarn prices were deflated by the monthly Producer Price Index (PPI) for intermediate materials excluding foods. This series includes fibers, yarns, and fabrics.

f) Active open-end spindle positions as a percent of all active spindle positions was used to account for the effects of technology adoption on cotton fiber demand. The data source was *Consumption on the Cotton System and Stocks: M22P*, US Bureau of the Census. Compared to the traditional method of ring spinning, open-end spinning provides yarns that are more uniform in density and in strength (Hatch, 1993). Open-end spinning is approximately three times more productive than ring spinning, due to increased production speeds and decreased labor requirements (Glade, 1996; Hatch, 1993). This variable was hypothesized to positively affect mill cotton fiber consumption, because it reflects the adoption of more productive spinning technology on the cotton system. Active spindle positions refer to the number of spindles that are in producing positions at the end of the month, regardless of whether they are actually operating, or have been operated, during the month. One limitation of this variable is that it may not accurately reflect usage of the machinery, it only shows that the technology is in place. Data on actual spindle hours operated for the open-end system were not available for the entire time period analyzed.

For the second model, estimated with quarterly data, the dependent variable was mill consumption of cotton fiber in pounds, and the independent variables were as follows:

a) Prices of cotton fiber and polyester staple fiber, as described in the yarn model. The same hypotheses apply as in the yarn model.

Fabric prices were chosen so as to represent major end-uses of cotton (based on Jones-Russell & Sporleder, 1988a; 1988b) and on data availability. As with yarn prices, a positive relationship was hypothesized between fabric prices and mill cotton fiber consumption.

b) Price of blended print cloth per square yard, 64" in width, weight 6.10 oz/yd (2.62 yds/lb.), representative of topweight[11] fabric.

c) Price of Drills per square yard , 59" in width, weight 8.64 oz/yd (1.85 yds/lb.), representative of bottomweight fabric.

d) Price of Sheeting per square yard, 59" in width, weight 8.64 oz/yd (1.85 yds/lb.), representative of home textiles.

The data source was various issues of the Daily News Record.

All fiber and fabric prices were deflated by the quarterly Producer Price Index (PPI) for intermediate materials excluding foods. This series includes fibers, yarns, and fabrics.

e) Shuttleless loom hours as a percent of all loom hours operated was used to incorporate the effects of technology changes. The data source was *Current Industrial Reports: Broadwoven Fabrics*, MQ22T. U.S. Department of Commerce, Bureau of the Census.

Shuttleless looms increase productivity through high production speeds and lower labor requirements, and adoption of these looms grew strongly in the 1980s (Amacher et al., 1991). Loom hours refer to the number of hours the equipment was actually in use during the month. This variable was hypothesized to positively affect mill cotton fiber consumption, because it reflects the adoption of more productive weaving technology on the cotton system.

Model

It is not possible to determine *a priori* whether mill fiber consumption is a linear function of the independent variables. The relationship could be in the form of a curve, thereby relating squared values of the independent variables to mill fiber consumption. To ascertain the correct functional form, firstly a linear model was estimated with the monthly data, secondly a quadratic model was estimated which included squared values of all the independent variables, and thirdly cross-terms (i.e., interaction effects between all pairs of variables) were added to the model. An F-test was performed to test whether the squared terms contributed significantly to the model, as shown by Gujarati (1995). Results indicated that the squared terms were necessary in the model. An F-test that was used to check if the cross-terms were also required in the model indicated that the cross terms did not contribute to the model. Details of the tests are contained in the Appendix. The process was repeated for the quarterly model, and the results were similar.

Thus, the final equation estimated was the following:

$$\ln C = \alpha_i + \sum_i \beta_i \ln V_i + \sum_i \gamma_i (\ln V_i)^2$$

where
C is mill (i.e., aggregate industry) consumption of cotton fiber in pounds, the V_is are the independent variables, and *ln* indicates logarithmic transformations of the continuous variables.

Results

The Durbin-Watson test statistic indicated that the yarn model with monthly data had correlated errors; thus, an autoregressive generalized least squares estimation[12] was performed. An R^2 value of 0.936 indicated that the model fit the data well. Autocorrelation was not indicated for the fabric model with quarterly data, and it was estimated using ordinary least squares. An R^2 value of 0.943 indicated that this model was fit the data well. Since the individual parameter estimates are not meaningful, F-tests were performed to test for the significance of each pair of variables (the variable and its square)[13] in both models. Tables 8 and 9 contain the F-ratios and the elasticities, the latter estimated at the means of the variables. Table 10 contains the marginal effects of the technology variables. The equation used to compute the elasticities is given in the Appendix.

The results showed that, for the yarn model, mill cotton fiber consumption was positively and significantly related to the price of the carded 30/1 yarn and of the 18/1 yarn. The technology variable, represented by active open-end spindles as a percent of all active spindle positions, showed a significant, but negative, relationship. Cotton fiber price, polyester fiber price, and the price of the carded 24/1 yarn did not show significant coefficients[14]. The results for the fabric model indicated that mill fiber consumption was positively and significantly related to the price of polyester fiber and to the price of blended print cloth. The technology variable, represented by shuttleless loom hours as a percent of all loom hours operated, showed a significant, but negative, relationship. The coefficients for cotton fiber price, price of sheeting, and price of drills, were not statistically significant.

These findings imply that mill fiber consumption is more sensitive to output price as compared to input price. In both models, input price (the price of cotton fiber) did not display statistical significance, although the cotton fiber price elasticities are comparable to those estimated by Lewis (1972) and Sanford (1988). Mill sensitivity to output price is apparent for those yarn and fabric types used for apparel end-uses, such as in the positive elasticities and significant F-ratios of the yarn prices of the 30/1 and 18/1 yarns, and in the fabric price of print cloth. Jones-Russell and Sporleder (1988) also reported a positive relationship between fine-count yarn price and fiber consumption. Yarn and fabric types used for home-textiles end-uses did not show significant coefficients. Thus, it appears that yarns and fabrics applied to apparel are more susceptible to price fluctuations at the output level than those used for home-textile end uses. Home textile fabrics and yarns are less subject to fashion changes, and there is more value-added in the fiber-yarn-fabric process in home textiles than in textiles used for apparel, because of the possible usage of heavier yarn/fabric weights and complex constructions. As a result, home textiles for are more suited to automated production (Vida & Norton, 1997). The high, positive cross-price elasticity estimate of polyester fiber in the quarterly model suggests a high level of substitutability between polyester and cotton fiber. The positive elasticity result supports the results of previous studies, namely, those of Shui et al (1993), and Zhang et al (1994), although those studies reported much smaller values of the elasticity.

The negative marginal effect results of the technology variables are contrary to expectations. A possible reason is that the new technology is utilized for the manufacture of complex fabrics used in home textiles, such as jacquards , which leads to higher value-added goods without a necessary increase in the amount of fiber input used. Import competition is the highest in large volume, low priced, low quality cotton products. U.S. mills have been shifting production to high quality goods, where technology provides efficiency gains that compensate for higher production costs (Dickerson, 1998; Finnie, 1995).

Implications

The U.S. textile industry has undergone substantial changes in the 1980s and the 1990s, which has affected the derived demand for cotton fiber at the mill level. Contrary to the results of previous studies which analyzed earlier time periods, in this study the price of cotton fiber was not significant in explaining mill cotton fiber consumption. Since output prices (yarn and fabric prices) used for apparel are significant in explaining mill cotton fiber consumption, whereas input prices (fiber prices) are not, a price ceiling at the output level would indicate the potential for a margin squeeze at the intermediate level for textile mills. Output prices used for home textiles are not significant in explaining mill cotton fiber consumption. This implies that mills are responding to factors other than input and output prices in the case of home textiles. Thus, these is less potential for a margin squeeze at the intermediate level. There has been faster growth in production as well as exports of the home textiles segment of the U.S. textile industry in recent years as compared to other segments of the textile industry (Vida & Norton, 1997). As import liberalization continues under the terms of the World Trade Organization (WTO), U.S. textile firms may concentrate more on home furnishings, and start pulling out of the apparel fabrics segment.

Endnotes

[1] Manufactured, or manmade, fibers include fibers made from cellulose such as rayon and acetate, synthetic fibers made from petroleum derivatives such as polyester and nylon, and fibers made from inorganic materials such as carbon and glass (Hatch, 1993).

[2] Weaving is the process of interlacing two sets of yarns so that individual yarns cross each other at right angles to produce woven fabric. The warp yarns run lengthwise in the fabric, and the filling yarns run from side to side. In traditional shuttle looms, the filling yarns are shot through the warp yarns by means of a shuttle, which is a boat shaped device. In shuttleless weaving, the continuous supply of yarn in a shuttle is replaced with a discrete length of yarn, which is forced through the shed of warp yarns by a projectile, by a thin rod called a rapier, or by pressurized jets of water or air (Hatch, 1993; Hoechst Celanese, 1989). Compared to shuttle looms, shuttleless looms produce better quality fabric at a lower cost due to lower power requirements, less labor needs, and higher speeds of production (Hatch, 1993).

[3] Spun yarns consist of continuous strands of fiber held together by some binding mechanism, which is usually effected by twisting the fibers together. In the traditional process of ring spinning, cotton fiber must be cleaned and aligned to form a continuous strand. Fibers need to be separated almost to a single fiber state and then reassembled, which also results in efficient cleaning. It results in a rope-like strand of loosely aligned fibers, called the card sliver. If greater smoothness is required, shorter fibers are removed and the fibers are further aligned in a process called combing. Thereafter the sliver is 'drawn' or passed between a series of paired rollers to obtain greater uniformity. This is followed by 'roving', where the sliver is further reduced in size and the fibers are made more parallel. Finally, the roving sliver is converted to yarn by passing it between rollers rotating at different speeds, and twisting it onto a ring spinner. In open-end spinning, the roving and twisting operations are combined into one. A break is introduced in the flow of fibers, and twist is inserted by rotating the yarn end at the break. Since the material to be rotated is of a small mass, very high speeds can be attained (Hatch, 1993; Hoechst Celanese, 1989).

[4] The most widely used synthetic fibers are nylon, polyester, and acrylic. The author does not specify which ones were included in his research.

[5] In 1996, 37 percent of all cotton yarn was for sale by mills, and the rest was for own use or made on order (U.S. Department of Commerce, Current Industrial Reports MP/96, Manufacturing Profiles: 1996).

[6] Landed Group B Mill Price refers to a specific quality of cotton fiber delivered to mills in the western half of North Carolina and South Carolina. The price includes all transportation and storage costs. The price of Landed Group B Strict Low Middling cotton fiber, 1-1/16 inch in length, is usually considered as representative of the price faced by domestic mills (Larson & Meyer, 1998).

[7] Strict Low Middling (SLM) 1-1/16 inch cotton refers to a specific quality of Upland cotton. About 98 percent of all cotton grown in the U.S. is upland cotton (*Gossypium hirsutum L*.) SLM 1-1/16 inch cotton is the standard to which other qualities of cotton are compared (Larson & Meyer, 1998). To be qualified as SLM 1-1/16, the cotton fiber must meet specific color, trash content, and length standards as specified by the U.S. Department of Agriculture.

[8] Denier is the metric system method of measuring fibers, and refers to the weight in grams of 9,000 meters of the fiber. 1.5 denier polyester staple fiber price is considered representative of manufactured fiber price for use on the cotton spinning system. The cotton spinning system is the process used to fabricate cotton and manufactured fibers into spun (staple) yarns, including blends.

[9] Combing is a process which follows carding (see endnote #2). Yarn is numbered based on the number of 840-yard lengths in a pound. The higher the number, the finer the yarn. For example, a pound of 10/1 yarn has 8,400 yards to the pound, and a pound of 20/1 yarn has 16,99 yards to the pound.

[10] Data for the same price series were not available after April 1996. The *DNR* publishes price data for a different fabric width after April 1996, which is not comparable with the prior series.

[11] This fabric type weighs more than 5 ounces per square yard although it is a topweight fabric, because it is has a larger width (64") as compared to most topweight fabrics which have a width of 48"-50". The price series were chosen due to data availability.

[12] One assumption of ordinary least squares linear regression is that the error terms (residuals) are independent, i.e., the value of one residual is independent of the value of any other. In time-series data, this assumption is often violated (Gujarati, 1995), but the problem can be lessened by using an autoregressive model, which specifies that the error at time t is related to the previous errors of earlier time

periods. It is possible to determine how many past period errors are related to the errors of time period t (SAS® System for Regression, 1991). If the errors at time *t* are only related to those of time *t-1*, the model is called a first-order autoregressive model, which was the model used in this study. The parameter estimates are obtained by generalized least squares.

13 In a regression model which contains variables in their linear as well as squared form, the coefficients obtained are not meaningful in themselves. A regression coefficient is a change in the dependent variable induced by a unit change in the independent variable, holding all other independent variables constant. However, it is impossible to measure the change brought about, say by x^2, holding x constant (SAS® System for Regression, 1991).

14 Several models were estimated to check whether cotton fiber prices, lagged by one or more periods, provided a better fit. The use of lagged prices led to much lower R2 values, and the F-ratios showed that the lagged cotton price variable was not significant.

Appendix

The following F-ratio aids in determining whether additional variables add significantly to the explanatory power of a regression:

$$F = \frac{\left(R^2 new - R^2 old\right) / df}{\left(1 - R^2 new\right) / df}$$

where df = degrees of freedom.

$$\text{i.e., } F = \frac{\left(R^2 new - R^2 old\right) / (\text{number of new regressors})}{\left(1 - R^2 new\right) / (\text{n - number of parameters in the new model})}$$

R^2 new is the R^2 obtained from the model with the additional independent variables called regressors. The F-ratio follows the F-distribution with the appropriate numerator and denominator degrees of freedom.

Computation of Elasticities

Given the estimated equation

$$\ln C = \alpha_i + \sum_i \beta_i \ln V_i + \sum_i \gamma_i \left(\ln V_i\right)^2$$

The marginal effect of a variable is the derivative of the function with respect to the variable:

$$\frac{\partial C}{\partial V_i} = \exp(\ln C) * \left(\frac{1}{V_i}\right) * \left\{\beta_i + 2\gamma_i \left(\ln V_i\right)\right\}$$

where β_i and γ_i are the estimated parameters, *lnC* is the mean value of the natural log of consumption, and *lnVi* is the natural log of the value of the variable evaluated at its mean.

The elasticity is :

$$\frac{\partial C}{\partial V_i} * \frac{V_i}{C}$$

where V_i and C are the mean values of the variable and of consumption, respectively.

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Table 1. Mill Consumption of Cotton by Major End-Uses, 1996

Apparel Fabrics		
Fabric Type	Million Pounds	Percent of total cotton consumed
Topweight fabrics	1,167.4	23 %
Bottomweight Fabrics	1,654.6	32 %
Knits	489.2	9 %
Lace, lining, and other	157.3	3 %
TOTAL APPAREL	**3,468.5**	**67 %**
Home Textiles Fabrics		
Product Type	Million Pounds	Percent of total cotton consumed
Sheets and bedding	377.0	7 %
Drapery and Upholstery	436.5	8 %
Towels	397.0	8 %
Blankets, rugs, and Quilts	166.9	3 %
Other	14.8	0.3 %
Total Home Textiles	**1,392.2**	**26%**

Source: Cotton Counts its Customers (1997) and Fiber Organon (February 1988).

Table 2. Lewis, 1972: Estimated Fiber Demand Elasticities Using Annual Data, 1920-1966.

Fiber	Own-Price Elasticity	Income Elasticity
Cotton	-0.17**	0.37**
Apparel Wool	-0.44*	0.27*
Carpet Wool	-0.51*	1.09*
Rayon-Acetate Staple	-0.50*	1.45*
Synthetic Staple	-1.04	7.2
Rayon-Acetate Filament	-0.56	0.96
Synthetic Filament	-0.12	5.09

** significant at the 1% level of significance
* significant at the 5% level of significance

Table 3. Jones-Russell and Sporleder (1988): Parameter Estimates for Variables Influencing Cotton Fiber Demanded by U.S. mills for Input into Denim End-Uses, Quarterly Data for 1975-1984.

Variable	Parameter Estimate
Price of cotton fiber inputs into open-end spun yarn for denim end-use, lagged two quarters	-0.1878***
Number of open-end rotors in U.S. mills	1.2256***
Number of active spindles and rotors in U.S. mills	0.1052*
Price of ring-spun yarn for denim end-use, lagged one quarter	0.4432**
Price of open-end spun yarn for denim end-use, lagged two quarters	2.3055***
Price of ring-spun yarn for towel end-use, lagged one quarter	-0.0951**
Price of open-end spun yarn for towel end-use, lagged two quarters	-2.1130***

***significant at the 1% level of significance
**significant at the 5% level of significance
*significant at the 10% level of significance

Table 4. Jones-Russell and Sporleder (1988): Parameter Estimates for Variables Influencing Cotton Fiber Demanded by U.S. Mills for Input into Apparel End-Uses, Quarterly Data for 1975-1984.

Variable	Parameter Estimate
Price of cotton fiber inputs into ring spun yarn for apparel end-use, lagged one quarter	-0.0920***
Price of polyester staple fiber	-0.1338***
Ratio of per capita personal consumption expenditures on clothing to per capita personal disposable income	0.6446***
Price of ring spun yarn for apparel end-use	0.1632***

***significant at the 1% level of significance

Table 5[a] . Shui et. al (1993): Estimated Demand Elasticities Using Annual Data, 1950-1987.

	Natural Fibers	Manmade Fibers	Materials	Labor	Capital
Natural Fibers	-0.636	0.207	0.347	-0.083	0.165
Manmade Fibers	0.200	-0.558	0.261	0.179	-0.079
Materials	0.143	0.125	-0.652	0.151	0.233
Labor	-0.039	0.036	0.445	-0.540	0.098
Capital	0.062	-0.107	0.681	0.284	-0.919

Source: Shui, Beghin, and Wohlgenant (1993).
[a] Elasticities for the model evaluated at mean cost shares, with output index and shuttless ratio.

Table 6. Comparison of Main Features of Previous Studies

	Lewis (1972)	Sanford (1988)	Jones-Russell & Sporleder (1988)	Shui et al (1993)	Zhang et al (1994)
Time period included	1920-1966	1960-1986	1975-1984	1950-1987	1961-1990
Data time unit	Annual	Annual	Quarterly	Annual	Annual
Cotton own-price elasticity of demand	-0.17[a]	-0.18[a]	-0.245[b]	-0.636[a]	-0.26 to -0.14[a]
Polyester cross-price elasticity of demand for cotton fiber	-	-	-	0.207	0.45 to 0.85
Fiber price lag included	One year	One year	One/ two quarters	One year	One year

[a] elasticity
[b] parameter estimate

Table 7. Summary Statistics of Annual Cotton Fiber Prices[b], 1986-1997

Crop Year[a]	Average Price	Standard Deviation of Prices	Maximum Price	Minimum Price
1986-1987	69.2	10.4	84	53
1987-1988	66.9	4.8	73	58
1988-1989	69.1	6.8	79	60
1989-1990	78.4	5.4	87	70
1990-1991	81.7	7.8	94	68
1991-1992	62.5	3.6	69	57
1992-1993	61.5	3.5	65	55
1993-1994	73.4	9.5	85	55
1994-1995	97.5	14.0	118	73
1995-1996	87.4	4.4	93	79
1996-1997	77.2	1.4	79	75

[a] October-October
[b] Group B Landed Mill Point SLM 1-1/16"
Source: Various issues of Cotton and Wool Situation and Outlook Report.

Table 8. Yarn Model. Estimated Elasticities of Mill Fiber Consumption Using Monthly Data: October 1987-October 1997 ($R^2 = 0.936$)

Variable	F-Ratio	Elasticity
Price of cotton fiber	0.511	-0.166
Price of polyester fiber	0.340	-0.237
Price of carded cotton 24/1 yarn	0.085	0.05
Price of carded 50%polyester/50%cotton 30/1 yarn	5.280**	7.117
Price of carded cotton 18/1 yarn	1.447*	0.687

* significant at the 0.10 level of significance
** significant at the 0.01 level of significance

Table 9. Fabric Model. Estimated Elasticities of Mill Fiber Consumption Using Quarterly Data: October 1987-April 1996 ($R^2 = 0.943$)

Variable	F-Ratio	Elasticity
Price of cotton fiber	0.586	-0.162
Price of polyester fiber	17.111**	11.799
Price of blended print cloth	15.137**	0.163
Price of sheeting	0.828	6.122
Price drill	1.273	-7.24

** significant at the 0.01 level of significance

Table 10. Marginal Effects of Technology Variables.

Variable	F-Ratio	Marginal Effect
Active open-end spindles as a percent of all active spindle positions (Yarn Model)	9.940**	-0.012[a]
Shuttleless loom hours as a percent of all loom hours operated (Fabric Model)	82.500**	-2.33[a]

** significant at the 0.01 level of significance

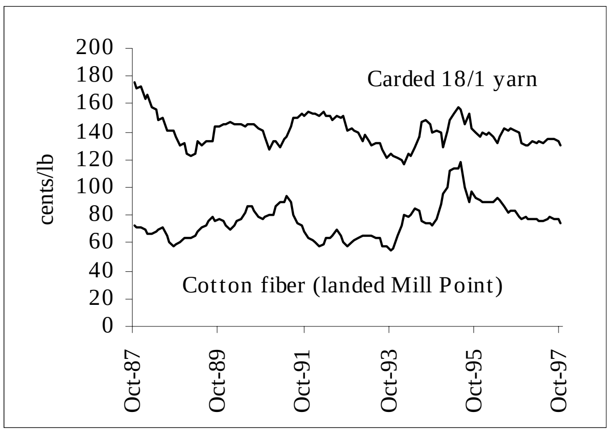

Figure 1. Cotton fiber and yarn prices, 1987-1997.
Source: Cotton and Wool Situation and Outlook Report (various issues) and America's Textiles International (various issues).

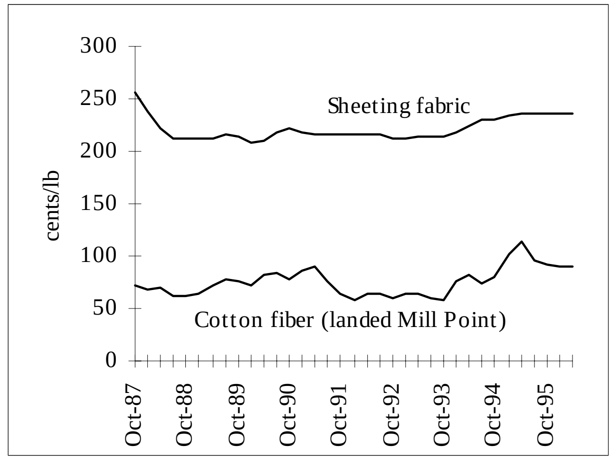

Figure 2. Cotton fiber and fabric prices, 1987-1996.
Source: Cotton and Wool Situation and Outlook Report (various issues) and Daily News Record (various issues).