Interfiber Competition in Textile Mills Over Time

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Abstract

Cotton and synthetic fiber competition in textile mills between 1961-1990 was examined using a time-varying parameter regression model. Results indicate that the structure of demand for cotton is not stable and cotton's share responses to changes in the prices of cotton and synthetic fiber vary over time. Cotton and synthetic fiber competition in textile mill use is essentially between cotton and noncellulosic fiber. Cellulosic fiber is not a cotton competitor.

Key words: cotton, structural changes, synthetic fiber, time-varying parameter

Cotton and synthetic fiber (cellulosic and noncellulosic) accounted for about 98 percent of total fiber use in textile mills between 1986 and 1990. Interfiber competition in textile manufacturers' use of raw fibers exists primarily between cotton and synthetic fiber. Cotton's share of total fiber at textile mills is directly affected by mill demand for various types of fibers. Changes in textile technology and/or consumer tastes have resulted in a change in the composition of fibers demanded in textile mills (Russell and Sporleder; Shui, Beghin, and Wohlgenant; Sanford; Meyer and Sanford). Cotton's share of total fiber use has experienced a considerable change over the last three decades (Figure 1).

Previous studies on cotton's share of total fiber use assumed that the demand relationship for cotton and synthetic fiber was stable over time (Ward and King; French). However, it would be more appropriate to assume the demand relationships for fibers vary over time due to possible permanent changes in the demand relationship resulting from changes in textile technology and/or consumer tastes. The demand relationship for cotton and synthetic fiber would vary in a nonstationary manner over time if there are structured "drifts" resulting from changes in textile technology and/or consumer tastes (Maddala, pp.390-404).

The issue of parameter variation traditionally has been addressed by disaggregating the time series into one or more subperiods. The use of various F-tests is most often dependent on the criteria for grouping (Ward and Tilley). Also, such a procedure fails to identify the dynamic path of adjustment that must have occurred when various F-tests indicate that parameters have changed (Ward and Tilley). An alternative to temporal disaggregation is to employ the adaptive regression model developed by Cooley and Prescott (1973b). This model allows estimates of the parameters to adapt subject to both permanent and transitory changes. The model assumes that the parameters are the sum of transitory disturbances, which affect the current period, and a permanent component, whose effects persist into the future. The permanent components are allowed to vary systematically over time with no inherent tendency

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Figure 1. Cotton's Share of Total Fiber Use in U.S. Textile Mills, 1961-90
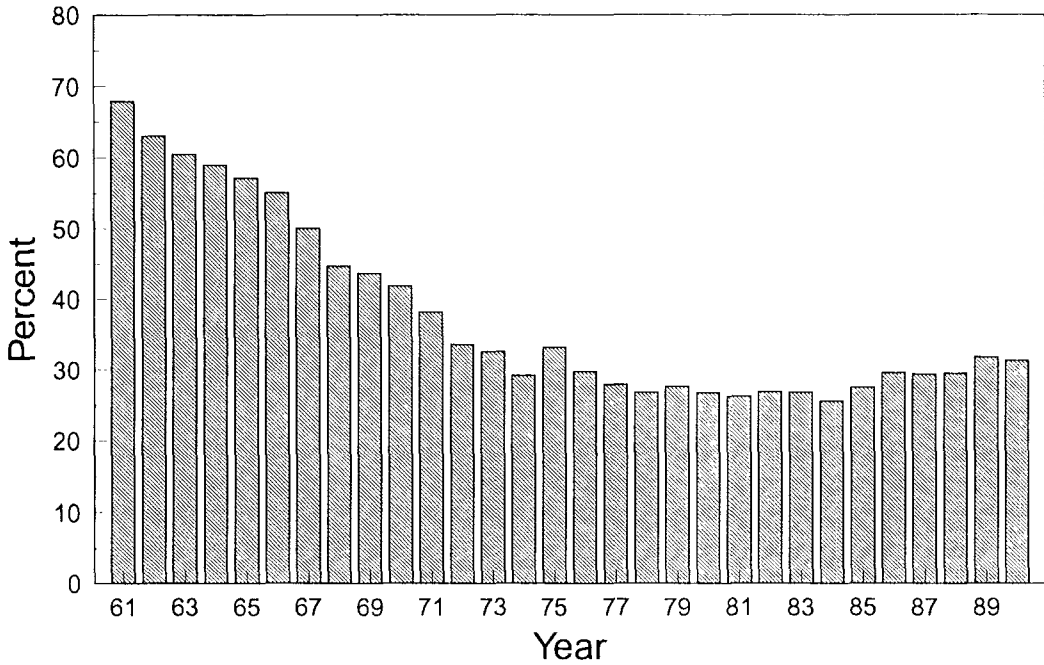
to return to a mean value (Cooley and Prescott, 1973a). This procedure is particularly useful when structural changes are suspected, but the systematic component cannot be hypothesized *a priori*.

The purpose of this paper is to investigate changes in interfiber competition in U.S. textile mills over time. Cotton's share of total fiber use in U.S. textile mills was estimated using a time-varying parameter model. The effects of the price factor and non-price factor on cotton's share were examined. The time path of cotton-share elasticities with respect to cotton- and synthetic-fiber prices was also examined.

A Time-Varying Parameter Model

Besides changes in the textile technology and/or consumer tastes, two additional sources could result in time-varying parameters. First, a trend variable is used as a proxy to capture technological change over time (French). Using such a proxy to represent an unobserved (true) variable can result in parameter variation due to changes in the relationship between the "true" variable and its

proxy over time (Swamy, Conway, and LeBlanc). Second, parameter variations could occur because of the nature of the functional form used to model cotton's share. A linear form is usually assumed as a starting point since the true functional form is unknown. If the true functional form was nonlinear, the coefficients in the estimation equation would vary (Swamy, Conway, and LeBlanc). A time-varying parameter model presented here can incorporate these parameter variations into the estimation process.

The time-varying parameter model was

$$(1) \qquad Y_t = X'_t \, \beta_t \qquad t = 1, 2, ..., T,$$

where X_t is a $(K + 1)$ x 1 matrix of K explanatory variables in time period t; Y_t is the tth observation of the dependent variable; and β_t is a $(K+1)$ x 1 vector of parameters for period t, subject to variation.

The parameters were assumed to be adaptive in nature and subject to both permanent

and transitory changes. The hypothesized parameter variations were

(2a) $\beta_t = \beta_t^p + U_t$

(2b) $\beta_t^p = \beta_{t-1}^p + V_t$,

where β_t^p denotes the permanent component of the parameters. Error U_t measures the transitory component. Equation (2b) provides the dynamic path of the parameters showing the permanent adjustment over time and V_t is the error associated with the permanent component.

The error terms, U_t and V_t, were assumed to be identically and independently distributed with mean vectors 0 and covariances

(3a)   COV $(U_t) = (1-\tau) \sigma^2 \Sigma_u$ and

(3b)   COV $(V_t) = \tau \sigma^2 \Sigma_v$ with $0 \leq \tau \leq 1$,

where Σ_u and Σ_v provide information regarding the relative variability of the parameters and are assumed known up to a scale factor. The parameter, τ, measures the relative importance of the permanent component of the parameter variation. That is, the larger the value of τ, the greater the importance of permanent changes. If $\tau = 0$, the model is transitory, and the parameters are not time-varying. The parameters to be estimated are β, σ^2, and τ.

The process generating the parameters is nonstationary. Therefore, it is impossible to specify the likelihood function. However, in the application of the procedure, researchers are usually interested in a specific realization of the parameter process. The likelihood function conditional on the value of the parameter process time t is well defined. Thus, the unknown parameter can be obtained at a particular realization (e.g., period $T + 1$). In this case

(4) $\beta_{T+1}^p = \beta_t^p + V_T = \beta_t^p + \sum\limits_{s=t+1}^{T+1} V_s$

from which it follows that

(5) $\beta_t = \beta_{T+1}^p + U_t - \sum\limits_{s=t+1}^{T+1} V_s$.

Substituting equation (5) into equation (1), one obtains

(6) $Y_t = X_t' \beta + W_t$,

where $\beta = \beta_{T+1}^p$ and

(7) $W_t = X_t' U_t - X_t' \sum\limits_{s=t+1}^{T+1} V_s$.

W is distributed normally with mean zero and a covariance matrix (Cooley and Prescott, 1973a):

(8)   COV $(W) = \sigma^2 [(1-\tau) R + \tau Q]$
              $\equiv \sigma^2 \Omega(\tau)$,

where R is a $T \times T$ diagonal matrix with

(9) $r_{ii} = (X_i' \Sigma_u X_i)$

and Q is a $T \times T$ matrix such that

(10) $q_{ij} = \min [|t-i|, |t-j|] (X_i' \Sigma_v X_j)$,

for all i, $j \neq t$, otherwise $q_{ij} = 0$.

Specification of Σ_u and Σ_v is required for the estimation since these values are usually not known *a priori*. Without prior information on U or V, Σ_u and Σ_v are assumed, and the elements are estimated from the COV (β) from the ordinary least squares. Once Σ_u and Σ_v are specified, the maximum likelihood procedure can be used to estimate all parameters over values of τ. The estimation of β is to maximize the concentrated likelihood function for a number of points within the range of zero to one for τ. The procedure yields a consistent estimator of τ, which implies that the estimates of β and σ^2 are asymptotically efficient (Cooley and Prescott, 1976).

Model Specification and Data

Cotton's share of total fiber use at textile mills in this study was defined as quantity demanded for cotton divided by quantity demanded for total fiber. Cotton is an input for producing textile products. Following previous studies (e.g., French; Ward and King; Shui, Beghin, and Wohlgenant), cotton's share of total fiber use was derived from profit maximization of textile manufacturers. The profit maximization problem can be formulated as:[1]

(11)

Maximize $\pi^e = PTEX^e \cdot QTEX^s - PCT^e \cdot QCT$

$- PWL^e \cdot QWL - PRAY^e \cdot QRAY$

$- PPOL^e \cdot QPOL - PNF^e \cdot QNF$

subject to

(12) $QTEX^s \leq QTEX^d \cdot QTEX^{im}$ and

(13)

$QTEX^s \leq QTEX \ (QCT, QWL, QRAY, QPOL, T),$

where π^e = expected textile profit; $PTEX^e$ = expected textile price; $QTEX^s$ = quantity of textile supply; PCT^e = expected cotton price; QCT = quantity of cotton; PWL^e = expected wool price; QWL = quantity of wool; $PRAY^e$ = expected rayon price; $QRAY$ = quantity of cellulosic fiber; $PPOL^e$ = expected polyester price; $QPOL$ = quantity of noncellulosic fiber; PNF^e = expected price of non-fiber input; QNF = quantity of non-fiber input; $QTEX^d$ = quantity of textile demanded; $QTEX^{im}$ = quantity of textile imported; and T = technological change (trend). Equations (12) and (13) represent the constraints on marketing equilibrium and production function, respectively.

Assuming that the first- and second-order conditions of the maximization problem are satisfied and net textile imports are proportional to the total demand for textile products, one obtains the derived demand for raw cotton:

(14)

$QCT = QCT(QTEX^d, PCT^e, PWL^e, PRAY^e, PPOL^e, T).$

An important characteristic of the textile market is the invariant relationship between total fiber input and product output (Monke and Taylor). Therefore, the total consumption of fiber input is determined by the level of textile output. Using this relationship and dividing both sides of equation (14) by total fiber input yields

(15)

$SHCT = SHCT(PCT^e, PWL^e, PRAY^e, PPOL^e, T),$

where $SHCT$ is cotton's share of total fiber use.

Assuming naive price expectations (French, Evans), equation (15) becomes

(16)

$SHCT = SHCT(PCT_{t-1}, PWL_{t-1}, PRAY_{t-1}, PPOL_{t-1}, T).$

The time-varying parameter version of equation (16) is specified as

(17) $SHCT_t = \beta_{0t} + \beta_{1t} PCT_{t-1}$

$+ \beta_{2t} PWL_{t-1} + \beta_{3t} PRAY_{t-1}$

$+ \beta_{4t} PPOL_{t-1} + \beta_{5t} T$

(18a) $\beta_{jt} = \beta^p_{jt} + U_{jt}$

(18b) $\beta^p_{jt} = \beta^p_{jt-1} + V_{jt},$

where j = 0, 1, 2, 3, 4, 5; β's are parameters to be estimated; and U and V are the error terms.

Time-series marketing-year data for 30 years (1961-1990) were used in this study. Data on mill consumption of cotton and wool and the prices of cotton, wool, rayon, and polyester at the mill level were obtained from the United States Department of Agriculture. Synthetic fiber consumption data were obtained from the Textile Economics Bureau. The price of cotton was for upland grade 41, 1-1/16" fiber length cotton at U.S. group 201 mill points. The series on the price of rayon was for rayon with 1/5 and 3.0 denier and regular staple, and the price of polyester was for 1.5 denier polyester for cotton blending. All prices were adjusted to real 1967 dollars using the producer price index.

Empirical Results and Discussion

The estimates of the permanent components of β along with the asymptotic standard errors and the estimates of τ are presented in table 1.[2] The signs of the coefficients on cotton prices in all years were negative as expected. The estimated coefficients ranged from -0.19 to -0.39, implying that increasing (decreasing) cotton prices by 10 cents per pound would lead to a decrease (increase) in cotton's share of total fiber by as low as 1.9 percent and as high as 3.9 percent. The signs of the

Table 1. Estimated Permanent Components of the Beta Vector for Cotton's Share of Total Fiber Use, 1962-1990

Year	τ^a	Constant	Cotton price	Rayon price	Polyester price	Trend
1962	0.98	42.974	-0.215	0.047	0.234	-0.601
		(6.15)**b	(0.08)*	(0.20)	(0.06)**	(0.33)
1963	0.98	46.238	-0.247	-0.161	0.252	-0.733
		(5.57)**	(0.08)**	(0.15)	(0.05)**	(0.31)*
1964	0.98	42.031	-0.242	0.278	0.187	-0.782
		(6.41)**	(0.08)**	(0.13)*	(0.04)**	(0.32)*
1965	0.84	46.053	-0.272	0.012	0.231	-0.680
		(5.44)**	(0.07)**	(0.19)	(0.04)**	(0.31)*
1966	0.98	43.458	-0.231	0 097	0.226	-0.664
		(5.05)**	(0.07)**	(0.14)	(0.04)**	(0.33)*
1967	0.98	54.031	-0.347	-0.245	0.258	-0.875
		(4.65)**	(0.05)**	(0.18)	(0.04)**	(0.34)*
1968	0.98	43.805	-0.227	0.069	0.225	-0.797
		(4.63)**	(0.06)**	(0.14)	(0.03)**	(0.31)*
1969	0.64	40.400	-0.260	0.041	0.292	-0.526
		(5.13)**	(0.06)**	(0.16)	(0.04)**	(0.27)*
1970	0.98	39.724	-0.185	0.220	0 289	-0.957
		(7.20)**	(0 06)**	(0.16)	(0.06)**	(0.37)*
1971	0.56	42.387	-0.267	-0.111	0.317	-0.532
		(5.51)**	(0.06)**	(0.17)	(0.05)**	(0.27)*
1972	0.84	43.298	-0.264	-0.180	0.324	-0.553
		(4.61)**	(0.04)**	(0.13)	(0.07)**	(0.30)
1973	0.72	46.239	-0.225	-0.125	0.268	-0.833
		(3.95)**	(0.05)**	(0.15)	(0.78)**	(0.28)**
1974	0.64	48.915	-0.285	-0.024	0.241	-0.904
		(3.42)**	(0.06)**	(0.17)	(0.08)**	(0.25)**
1975	0.88	49.896	-0.212	0.073	0.138	-1.142
		(2.69)**	(0.05)**	(0.18)	(0.08)	(0.19)**
1976	0.76	51.391	-0.187	-0.058	0.104	-1.023
		(3.06)**	(0.05)**	(0 16)	(0.06)	(0 12)**
1977	0.68	48.338	-0.243	0.076	0.099	-0.959
		(3.54)**	(0.05)**	(0.15)	(0.05)	(0.09)**
1978	0.92	42.568	-0.213	0.094	0.096	-0.825
		(3.18)**	(0.04)**	(0.10)	(0.05)	(0.06)**
1979	0 50	36.979	-0.208	0.074	0.203	-0.560
		(3.75)**	(0.06)**	(0.15)	(0.05)**	(0.08)**
1980	0.58	36.960	-0.264	0.023	0.240	-0.462
		(2.77)**	(0.06)**	(0.11)	(0.05)**	(0.07)**
1981	0.80	34.171	-0.204	-0.083	0.240	-0.286
		(2.63)**b	(0.05)**	(0.10)	(0.06)**	(0.07)**
1982	0.56	38.667	-0.273	-0.297	0.281	-0.193
		(3.36)**	(0.06)**	(0.13)*	(0.06)**	(0.08)*
1983	0.80	36.507	-0.289	-0.371	0.284	0.006
		(3.66)**	(0.06)**	(0.14)*	(0.07)**	(0.08)
1984	0.88	30.049	-0.246	-0.459	0.277	0.309
		(3.43)**b	(0.07)**	(0.15)**	(0.08)**	(0.09)**
1985	0.90	32.077	-0.388	-0.500	0.245	0.459
		(4.14)**	(0.08)**	(0.16)**	(0.09)*	(0.11)**
1986	0.98	18.820	-0.375	-0.345	0.290	0.829
		(3.07)**	(0.08)**	(0.18)	(0.11)**	(0.12)**
1987	0.88	18.805	-0.366	0.375	0.227	0.134
		(4.32)**	(0.10)**	(0.28)	(0.10)*	(0.31)
1988	0.98	35.504	-0.254	0.406	0.231	-0.594
		(4.87)**	(0.09)**	(0.17)*	(0.09)*	(0.31)
1989	0.98	38.164	-0.208	0.343	0.195	-0.613
		(5.79)**	(0.09)**	(0.11)**	(0.08)*	(0.29)*
1990	0.98	42.974	-0.193	0.079	0.212	-0.516
		(6.22)**	(0.09)**	(0.18)	(0.08)*	(0.28)

a The τ are the estimates of the fraction of parameter variation due to permanent changes. The closer τ is to one, the more important the permanent changes relative to transitory changes. The maximum likelihood estimation was carried out for $0 \le \tau < 1$ in increments of 0.02 When $\tau = 1$, the variance-covariance matrix Ω is singular and estimates cannot be obtained.

b Asymptotic standard errors in parentheses. Single asterisk indicates significance at the 0.05 level; double asterisk indicates significance at the 0.01 level.

coefficients for rayon price changed over time. However, the estimated coefficients were not statistically significant at the five percent level except for the period 1982-85, implying that cellulosic fiber is neither a substitute nor a complementary fiber for cotton in the fiber market except between 1982-85. The estimated coefficients between 1982-85 indicate a complementary relationship between cotton and cellulosic fiber. A 10-cent increase in rayon price would decrease cotton's share by three to five percent. The signs of the coefficient for polyester prices in all years were positive, indicating that noncellulosic fiber was a substitute for cotton in textile mills. These estimated coefficients imply that changing the polyester price by 10 cents per pound would result in a change in cotton's share of total fiber use of between 1.9 percent and 3.2 percent in the same direction.

The trend variable in the model reflects the effect of factors such as changes in textile technology and/or consumer preferences that have exerted systematic effects over time on cotton's share.[3] The estimated coefficients for the trend variable indicate a negative relationship prior to 1982 and a positive relationship since 1982 except between 1988-90. The negative trend coefficients between 1962 and 1982 could be the result of technological changes in the textile industry, which moved in favor of synthetic fibers during this period (Barlowe and Donald; Russell and Sporleder; Shui, Beghin, and Wohlgenant). Changes in consumer's preference for synthetic fiber products during the 1960s and 1970s due to the active promotion of synthetic fiber products may also have contributed to the decrease in cotton's share (Meyer and Sanford; Sanford). The significantly positive trend effect between 1984 and 1986 may reflect consumers switching back to natural fiber products (Meyer and Sanford; Sanford). The negative coefficients of the trend variable between 1988 and 1990 were not statistically different from zero at the five percent level.

The estimated τ value, the fraction of parameter variations due to permanent change, ranged from 0.5 to 0.98. This result indicates that the model parameters were not constant over time and from 50 to 98 percent of the parameter variation was due to the permanent structural change. A comparison of the τ values for different periods shows that the averaged τ values were 0.93 in the 1960s, 0.71 in the 1970s, and 0.87 in the 1980s. This result implies that the structure of demand for cotton at U.S. textile mills was more stable in the 1970s than in the 1960s and 1980s. While the model is not capable of identifying the specific causes, these differences can be attributed to the additive effect of changes in many factors such as textile technology and/or consumers' tastes.

The responses of cotton's share to changes in prices of cotton, cellulosic fiber, and noncellulosic fiber were also evaluated by elasticities. The cotton-share elasticities with respect to price of cotton and prices of cellulosic and noncellulosic fibers in a given year were calculated and then averaged for five-year time intervals in order to identify trends. These averaged elasticities are presented in figures 2 and 3. Cotton-share elasticities with respect to cotton prices varied from -0.14 to -0.26 (Figure 2). These elasticities became more elastic until 1980 when they started to become less elastic. The nonsignificant coefficients for rayon prices prevented drawing any implication from the calculated price elasticities except for the period 1981-85. The negative cross price elasticity for this period implies that a change in rayon price by 10 percent would result in a 3.5 percent change in cotton's share in the opposite direction. In contrast, polyester price elasticities ranged from 0.40 to 0.85, decreasing from 1962-65 to 1976-80 and increasing between 1976-80 and 1981-85 before decreasing again between 1981-85 and 1986-90 (Figure 3).

In comparison with cotton-share elasticities from previous studies in which a constant demand structure was assumed, Ward and King reported a cotton-share elasticity of -0.08 with respect to cotton prices and an elasticity of 0.07 with respect to cellulosic fiber price. Their cotton-share elasticity with respect to noncellulosic fiber price was not statistically significant. The data used in Ward and King's study was from 1950 to 1969. French, using data between 1950-75 and a cotton and synthetic fiber price ratio in the cotton share equation, reported price elasticities of 0.13 in absolute value for both cotton and synthetic fiber. These previous estimates are lower or close to the lower limit of the estimates in this study. While there is a difference

Figure 2. Derived Cotton-share Elasticities with Respect to Cotton Prices, Summarized by Five-year-averages, 1962-90
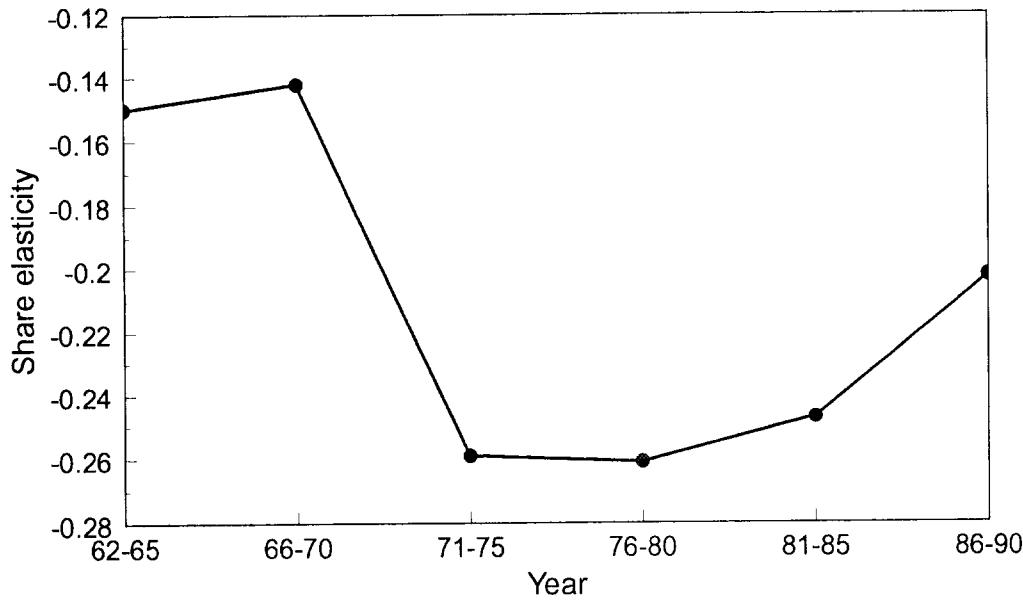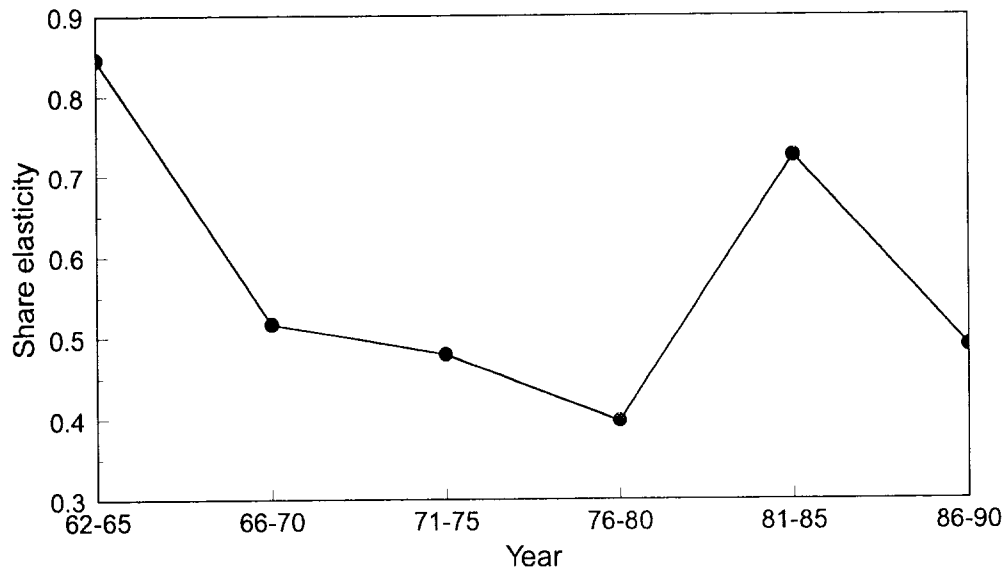

Figure 3. Derived Cotton-share Elasticities with Respect to Polyester Prices, Summarized by Five-year-averages, 1962-90

in data periods used between the previous studies and this study, it appears that the previous studies systematically underestimated cotton's share response to changes in fiber prices. These previous studies ignored possible changes in the demand relationship for cotton and the other fiber resulting from changes in the textile technology and/or consumer tastes. Shui, Beghin, and Wohlgenant also reported a similar estimation bias when they incorporated the change in textile technology into their estimation of mill demand for cotton.

Specific reasons for changes in price responsiveness over time are not identified by the empirical data or by the time-varying parameter model used in this study. The change in the price elasticities is a combination effect of changes in the level of individual fiber price, cotton's share, and the price response. The initial low cotton-price elasticity can mainly be explained by the dominance of cotton's share at that time. A large part of the increase in the cotton-share price elasticity before the late 1970s could be attributed to cotton's share loss resulting from the technological developments in the textile industry. Durable press textiles, for example, revolutionized the industry. Noncellulosic fiber manufacturers quickly capitalized on this development through blends and mixtures. Blends were developed by combining staple fibers of different properties prior to spinning, and mixtures were made from two or more different yarns. This technological progress moved in favor of synthetic fiber in the textile industry resulting in a substitution of noncellulosic fiber for cotton in many textile use categories (Ward and King).

Since the late 1970s, noncellulosic fiber seems to have plateaued in its market share and the price of cotton has fallen to a competitive level relative to noncellulosic fiber price. Furthermore, consumers seemed to have changed their preference to natural fiber products (Meyer and Sanford; Sanford). The combination of these factors could be attributed to the decrease in cotton-share elasticities with respect to cotton price in the late 1970s and 1980s.

The initial high cotton-share elasticity with respect to polyester price was mainly attributed to the initial high polyester price and the low share of noncellulosic fiber in the fiber market. However, the most significant result was the large increase in

cotton-share elasticity with respect to polyester price in the beginning of the 1980s. Changes in consumers' preferences to natural fiber products in the early 1980s could be attributed to this increase in the elasticity (Meyer and Sanford; Sanford).

Conclusions

Analysis of cotton's share of total fiber use in U.S. textile mills between 1961 and 1990 using a time-varying parameter model supports several conclusions. First, the variation in the estimated coefficients for explaining cotton's share implies that the demand structure for cotton at the textile mill level has not been constant over time. Changes in the textile mill technology and/or consumers' preferences for textile products have resulted in a structural change in demand for cotton over time.

The second major conclusion is that the responsiveness of cotton's share of the fiber market to cotton prices and synthetic fiber prices has varied widely over time. The ranges in the five-year-average cotton-share elasticities with respect to fiber prices were -0.14 to -0.26 for cotton and 0.40 to 0.85 for noncellulosic fiber. The wide range in the estimated price elasticities implies that a single estimate does not reflect the textile manufacturers' behavior of demand for cotton and synthetic fiber over time. Using those constant estimates from previous studies to assess the effects on cotton's share of total fiber use from changes in cotton and synthetic fiber prices would be misleading.

The last conclusion is that cotton and cellulosic fiber do not compete with each other at the textile mill. Ward and King reported a substitution relationship between cotton and cellulosic fiber using data between 1950 and 1969. Since then, the composition of the fiber market has changed. The noncellulosic fiber has become a major type of synthetic fiber and has been competing with both cotton and cellulosic fiber in textile mills. The different relationships with cotton between cellulosic fiber and noncellulosic fiber imply that aggregating cellulosic and noncellulosic fibers into one fiber category in the estimation of demand for cotton is inappropriate.

The most important advantage of the time-varying parameter model is that it uses the most recent parameter values for predicating the future. If the parameters have shifted over time, then the values for the last period provide an improved model for forecasting (Rouhiainen). The results estimated from this study provide the most recent estimate for cotton's share response to changes in the price of cotton and other fibers. Using these estimates should improve the projection of future demand for cotton and the accuracy of welfare assessment from changes in government policy on cotton and cotton related sectors.

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Endnotes

1. Three assumptions are implicit in the model derivation. They are: 1) textile can be produced from two inputs, fiber and non-fiber, and there is no substitution effect between them, 2) fiber input consists of cotton, wool, cellulosic, and noncellulosic fibers, and 3) net textile imports is proportional to the total quantity demanded for textile products.

2. The estimated coefficient for the price of wool was not statistically significant at the 10 percent level. Therefore, the price of wool was not included in the final estimation of equation (17).

3. The solution of the profit maximization problem is subject to the relationship that the quantity of textile supplied is equal to the quantity of textile demanded (i.e., equation (12)). Therefore, other non-price factors such as advertising and promotion which influence consumer preference could affect the type of textile products demanded and therefore the demand for a particular type of fiber.