EVALUATION OF CONSUMER DEMAND FOR SELECTED END-USE MARKETS FOR COTTON

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Abstract

This research study analyzes changes in the demand for cotton fiber at the end-use level from 1973 to 1997. The first objective is to determine the factors that influence demand for cotton at the end-use level. The second objective is to compare models based on economic theory with models developed using directed graphs. Basic statistical measures as well as forecasting accuracy will be considered when determining the model that most accurately portrays consumer demand.

Introduction

The U.S. cotton industry is facing a rapidly diminishing share of the domestic and foreign textile markets. Imports have been and continue to be a burden on the U.S. apparel, textile, and cotton industries. These industries will have to become more efficient to compete in world markets. Policies such as import quotas, tariffs, and restrictions on trade may be enacted by policymakers to manage international trade forces. However, the apparel industry should be able to increase exports to other industrialized countries that are experiencing similar trends by knowing the economic factors driving U.S. apparel markets. A more productive and competitive textile industry can be developed by having knowledge of where consumer demand is being directed. Currently, cotton produced, manufactured, and consumed in the U.S. accounts for only 40% of the total cotton products used in the domestic market. That share was much larger a decade ago.

Previous research has focused mainly on aggregate cotton fiber consumption at the mill level, while very little evaluation has been directed at the specific end-use level. Though research conducted on specific end-uses of cotton has been relevant, it has considered only fairly short time periods or is no longer current.

Methodology

Four structural models were developed to explain the demand for selected end-uses of cotton. Because the "true" model will always be unknown, construction of four models is more valuable than only one. The first model, known as the full model, includes variables that are consistent with economic theory and prior research in this field. The second model contains a number of the same variables as the first model, but will be limited to those that indicate causality. The causality will be determined by the application of directed graphs, thus this model is referred to as the directed graph model. The third and fourth models are equivalent to the prior two models, with the exception of functional form. The first two models are in linear form, while the last two models are in double logarithmic form.

The cotton end-use consumption data used as dependent variables was compiled from various issues of *Cotton Counts Its Customers*, a publication produced by the National Cotton Council. The publication contains annual estimates of the quantities of cotton and competing materials consumed in specified textile products manufactured in the United States. *Cotton Counts Its Customers* has identified ninety-two major product classifications as end-uses for cotton. Three broad sections, apparel, home furnishings, and industrial uses also classify the data. Apparel is further classified according to Men's, Youths', and Boys' (MYB) apparel, Women's, Misses', and Juniors' (WMJ) apparel, and Girls', Children's, and Infants' (GCI) apparel. Data for each end-use classification of cotton are reported in tabular form by the total amount of materials consumed for the end-use, the percentage of cotton used in the total market for the end-use, and the amount of cotton consumed for the end-use. The amounts are reported in thousands of 480-pound net weight bale equivalents of cotton. The amount of cotton consumed for the end-use is the data used as the dependent variables for the models.

Four of the ninety-two end-use product classifications were selected for this presentation. One product was chosen from each of the three broad apparel categories, as well as one product from the home furnishings category. They include men's shirts, women's jeans, children's hosiery, and home sheets and pillowcases. These end-uses represent a significant portion of the cotton market, as they compose twenty-five percent of cotton used in all products in 1997. Also, all markets selected exhibit an upward trend over the time period 1973 - 1997.

Independent variables chosen for the full models include disposable personal income, population variables based on age and gender, the consumer price index for apparel and upkeep, and cotton and polyester fiber prices. The variables are hypothesized to have the following effects on domestic cotton consumption:

The coefficients associated with Disposable Personal Income (DPI) are expected to be positive. For a normal durable good, one expects consumption of that good to increase as income increases.

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As stated previously, the apparel end-use category is further classified into Men's, Youths', and Boys' (MYB) apparel, Women's, Misses', and Juniors' (WMJ) apparel, and Girls', Children's, and Infants' (GCI) apparel. The segments of the population that wear apparel in these three groups are as follows:

Men's, Youths', and Boys'
    males, five and older
Women's, Misses', and Juniors'
    females, fourteen and older
Girls', Children's, and Infants'
    males under five years and females fourteen and under

A variable was created for each age/gender group. As the number of consumers in each group changes, one would expect the consumption of goods to change in the same direction.

The consumer price index, or CPI, for apparel and upkeep is an indicator of the relative expensiveness of apparel items and their upkeep. The years 1982-84 serve as a base year of 100, with the other years in the series representing a relative increase or decrease in the price of apparel. As this index rises, apparel and upkeep as a whole becomes more expensive, and thus less apparel should be demanded. This variable is an indicator of prices at the end-use level, while the fiber prices are indicative of prices at the mill level. Because this particular index only considers the prices of apparel and upkeep, CPI was not included in the Sheets and Pillowcases models.

The price of cotton used in this model is the raw-fiber equivalent for landed Group B mill points, Strict Low Middling (SLM) 1 - 1/16", in terms of cents per pound. Zhang, Fletcher, and Ethridge (1994) used the equivalents of raw cotton fiber prices in estimating the demand for cotton fiber at the mill use level, and Dudley (1974) used the equivalents of raw cotton fiber prices in estimating the demand for cotton at the end-use level. These prices are lagged one year, to represent the time between the sale of the raw cotton and the consumption of the final product. The lagging of prices by one period also was done by Shui, Beghin, and Wohlgenant (1993). A negative cotton price coefficient is expected, indicating the inverse relationship between the quantity of the good consumed and its price.

Raw-fiber equivalent polyester prices are used as an indicator of competition between cotton and synthetic fibers. These prices also are lagged one year, as was done by Shui, Beghin, and Wohlgenant (1993). Several studies (Shui, Beghin, and Wohlgenant (1993), Dudley (1974), Zhang, Fletcher, and Ethridge (1994), and Smith and Dardis (1972)) have suggested that cotton and polyester fibers have a substitutive relationship. If substitutes, the polyester price coefficient is expected to be positive. However, with the prevalence of fiber blending it may be reasonable to expect that cotton and polyester have a complementary relationship. If so, the coefficient of a complementary good is expected to be negative. This is consistent with the findings of Jones-Russell and Sporleder (1988).

All variables, both dependent and independent, were tested for stationarity using the Dickey-Fuller test. A data series is considered stationary if the data returns to its historical mean. If any of the variables were non-stationary, differencing would be required to induce stationarity. All variables were determined to be integrated of order one, which indicates they are not stationary. However, because they were integrated of the same order, first differencing was not necessary.

Directed Graphs

Directed graphs assist in specifying causal flow between variables which theory suggests should be related. This methodology begins with a complete undirected graph, with edges connecting all variables. Using the variance/covariance matrix, edges can be removed using zero and first order conditioning to form the final undirected graph. The conditioning variable(s) on removed edges between two variables is called the sepset of the variables whose edge has been removed. Edges are directed by considering triples X-Y-Z, such that X and Y are adjacent as are Y and Z, but X and Z are not adjacent. Direct edges between triples: X-Y-Z as
X ➜ Y ⬅ Z if Y is not in the sepset of X and Z. If X ➜ Y, Y and Z are adjacent, X and Z are not adjacent, and there is no arrowhead at Y, then orient Y-Z as Y ➜ Z. If there is a directed path from X to Y, and an edge between X and Y, then direct (X-Y) as X ➜ Y (Scheines, Spirtes, and Glymour, 1994).

Directed graphs were completed for both linear and logarithmic data. The results of directed graphs indicated whether there was causal flow between two variables. The independent variables that cause the dependent variable, as shown by the directed graph, were included in the second and fourth models. These models are as follows:

Q Men's Shirts = $\beta_0 + \beta_1$ DPI + β_2 MYB Population
Q Women's Jeans = $\beta_0 + \beta_1$ WMJ Population
Q Girl's Hosiery = $\beta_0 + \beta_1$ DPI + β_2 CPI + β_3 GCI Population
Q Sheets & Pillowcases = $\beta_0 + \beta_1$ GCI Population
Ln Q Men's Shirts = Ln $\beta_0 + \beta_1$ Ln Polyester Price$_{t-1}$ + β_2 Ln MYB Population
Ln Q Women's Jeans = Ln $\beta_0 + \beta_1$ Ln WMJ Population
Ln Q Girl's Hosiery = Ln $\beta_0 + \beta_1$ Ln DPI + β_2 Ln GCI Population
Ln Q Sheets & Pillowcases = Ln $\beta_0 + \beta_1$ Ln GCI Population

Due to the method of calculating directed graphs, all variables in these models are highly significant. These models were tested using similar statistical analysis as the full models, and then the forecasts of the models were calculated and compared.

Statistical Analysis

The method of Ordinary Least Squares (OLS) was used to determine the effects of changes of the independent variables on the consumption of the selected end-uses. Assumptions for the model are that the independent variables are not correlated and there is no measurement error of the independent variables. Analysis of the models was performed by examining the parameter estimates and their statistical significance and algebraic sign, as well as by using R^2 results.

For forecasting purposes, the models were built using only the first twenty observations. Forecasts for the next five years were generated using the parameter estimates from the model and then compared with the actual data from the last five years of the data set. This procedure is known as out-of-sample forecasting. The accuracy of the models and forecasts were examined by using the Theil's U statistic, the Root Mean Square Error (RMSE), and Mean Absolute Percentage Error (MAPE). The Theil's U statistic used was calculated with the following equation:

$$U = [\sum(Y_t - Yhat_t)^2]^{1/2} / [\sum(Y_t - Y_{t-1})^2]^{1/2}$$

This equation analyzes the model forecast error relative to what the forecast error would be if a random walk (where tomorrow's quantity is a function of today's quantity) were used. If the Theil's U statistic is less than one, the model has a smaller forecast error than the random walk, and thus the model should be used in forecasting. Otherwise, it would be preferable to simply use a random walk to predict the quantity demanded.

The MAPE and RMSE measure forecasting error; therefore, a small value denotes good forecasts. Using MAPE allows one to compare the forecasting abilities of the models for the different end-uses, while RMSE allows one to compare the forecasting ability of the four models created for one end-use. Following Bessler and Brandt (1992), the 'best', i.e. lowest RMSE, full model was tested against the 'best' directed graph model for each end-use studied to determine if the two forecasts were significantly different from one another. The differences in bias as well as variance between the two chosen models was also seen through this test.

The information obtained from these models will assist in understanding the demand for end-uses of cotton, rather than for the total demand for raw cotton as many previous researchers have reported. Determination of the factors that influence demand will allow textile and apparel manufacturers to manage operations in response to expected trends in these end-use markets.

Results

The linear and logarithmic full models had an R^2 value ranging from 0.93 to 0.89 and from 0.95 to 0.85 respectively. The R^2 for the linear and logarithmic directed graph models was a little lower, ranging from 0.92 to 0.31 and from 0.90 to 0.25 respectively. The low R^2 values of 0.31 and 0.25 in the directed graph models was for the Home Furnishings Sheets & Pillowcases end-use, proving that home furnishings present more difficulty in modeling than apparel.

Results from all four models have a negative coefficient for lagged polyester prices, which indicates that cotton and polyester fiber have a complementary relationship at the end-use levels selected (see Tables 1-4). This is probably due to the prevalence of blending natural and synthetic fibers when producing apparel and other items. The polyester price variable was significant in the linear full model for sheets and pillowcases, and for men's shirts, women's jeans, and sheets and pillowcases in the logarithmic full model. Again, due to the nature in which directed graphs are calculated, all variables in those models are significantly related to the quantity of cotton consumed in the selected end-use. Other variables that were significantly related in several of the end-uses were Consumer Price Index for Apparel and Upkeep and the three population variables. See Tables 1 through 4 for regression results.

The out-of-sample forecasts were evaluated by the Theil's U statistic, the Root Mean Square Error (RMSE), and the Mean Absolute Percentage Error (MAPE). As seen in Tables 5-8, the Theil's U statistic proved that the model was more accurate than a random walk for two end-uses, women's jeans and girl's hosiery, in the linear full model and for women's jeans in the logarithmic full model. In all other cases, the current quantity demanded is a better indicator of next year's quantity demanded than the model is. By comparing only the Theil's U statistic, one can conclude that the linear full model performs better than the other models.

The full models were compared against the directed graph models in terms of bias (average error) and variance. Table 9 presents the results, which indicate that the directed graph model had lower average error for men's shirts (by 80.52); however, it was not significant from zero at significant levels. In all other end-uses, the full model had lower average error. These differences were significant in the women's jeans and sheets and pillowcases end-uses. When considering variance, the directed graph model performed significantly better than the full model for sheets and pillowcases. For women's jeans, the opposite was true. The full model performed significantly better than the directed graph model. In the remaining two end-uses, men's shirts and girl's hosiery, the full model had less variance yet it was not statistically significant.

The models developed in this study indicate that demand for the selected end-uses are best described as a function of lagged polyester fiber prices, the consumer price index for apparel and upkeep, and age/gender population segments. Factors that did not prove to be significant in explaining demand for these end-uses include disposable personal income and lagged cotton fiber prices. Overall, it appears that the full models outperformed the directed graph models.

Implications

The demand analyzed in this study is a derived demand that flows from the consumer of apparel to the fiber producer. Value is added to apparel or home furnishings products at various stages along the supply chain, which include retailers, apparel manufacturers, textile mills (both spinners and weavers), merchants, breeders, and finally producers. Quick Response (QR) and Just-In-Time (JIT) technologies have been developed and implemented in the apparel and textile industries to become more competitive with imports by decreasing the lead time between segments of this supply chain (Plassmann and Jones, 1999). The goals of these systems are to be respondent to the needs of customers, as well as to lower lead times and have a leaner inventory that is more cost efficient. An assumption of the QR and JIT systems is that demand cannot be accurately predicted; therefore, a system must be in place to guard against the risk of stock-outs or surplus inventories. A model with low bias and low variance that estimates meaningful demand for particular end-uses can alleviate the pressure on the QR and JIT systems.

Retailers, apparel manufacturers, and perhaps textile mills can adjust their ordering and production in the short-run if they are familiar with the product markets that are expected to grow, stagnate or decline. Knowledge of consumer demand for end-uses can lower the apparel manufacturer's risk, and thus decrease the variability in which they now produce. These effects may trickle down the supply chain to the merchants. As an example, if the demand is expected to grow for textile products that require a longer staple length or lower trash content of cotton fiber, merchants can be more selective in the quality of cotton that they buy in order to meet these manufacturing needs. In a vertically integrated system between producers and textile manufacturers, which there is a growing interest in, cotton producers may also have an incentive to adjust their production practices to meet demand.

In the long run, apparel manufacturers and textile mills should have demand estimates for their products when making the decision to update technology. The type of spinning machine to use is in part dependent on the end-use of the yarn. Generally, open-end rotor spinning is best for short-staple fibers, ring spinning is more suitable for longer staple fibers, and air-jet spinning requires uniform staple lengths. Questions such as whether to expand a particular type of spinning machine may be answered by having knowledge of the product markets that are estimated to grow.

In conclusion, the textile and apparel industries are becoming increasingly competitive. Participants that are aware of demand factors and can adapt management strategies to changing market forces have a greater chance of survival, and furthermore, success.

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Table 1. Parameter estimates and t-statistics for linear full model, 1973-1992.

	Shirts	Jeans	Hosiery	Sheets
	3811.8*	-1067*	-138.47	2038*
Constant	(1.896)	(-3.172)	(-0.973)	(3.554)
	0.269	0.0964	0.0234	0.1365*
DPI	(1.112)	(1.539)	(0.817)	(4.155)
	33.39*	-7.77	0.6545	
CPI	(1.737)	(-1.713)	(0.347)	
Cotton	-3.88	0.207	-0.573	-0.759
Price	(-1.09)	(0.228)	(-1.43)	(-1.241)
	-4.984	-1.706	-0.669	-2.104*
Poly Price	(-1.21)	(-1.521)	(-1.321)	(-2.884)
MYB	-0.086*			0.031
Pop	(-2.82)			(1.538)
WMJ		0.0203*		-0.042*
Pop		(4.504)		(-2.74)
GCI			0.005	-0.03*
Pop			(1.436)	(-2.55)
R^2	0.92	0.89	0.93	0.91

Table 2. Parameter estimates and t-statistics for logarithmic full model, 1973-1992.

	Shirts	Jeans	Hosiery	Sheets
Constant	-0.42	-102.3*	-34.06*	60.32*
	(-0.007)	(-2.26)	(-2.37)	(1.98)
DPI	-1.19	-0.28	2.077*	1.005*
	(-1.64)	(-0.25)	(2.085)	(2.87)
CPI	6.176*	-0.367	-2.18	
	(3.56)	(-0.185)	(-0.707)	
Cotton	-0.453	-0.057	-0.708*	-0.074
Price	(-1.58)	(-0.175)	(-1.73)	(-0.544)
Poly Price	-0.774*	-0.744*	-0.631	-0.366*
	(-2.98)	(-1.99)	(-1.245)	(-2.463)
MYB	-0.598			12.58*
Pop	(-0.102)			(2.04)
WMJ		10.03*		-15.5*
Pop		(2.36)		(-3.97)
GCI			3.613*	-2.682*
Pop			(2.088)	(-2.21)
R^2	0.94	0.86	0.95	0.85

Table 3. Parameter estimates and t-statistics for linear directed graph model, 1973-1992.

	Shirts	Jeans	Hosiery	Sheets
Constant	6486.5*	-814.9*	-105.07	-104.71
	(3.182)	(-6.899)	(-0.671)	(-0.571)
DPI	0.671*		0.0613*	
	(5.515)		(2.387)	
CPI			-2.45*	
			(-1.774)	
Cotton				
Price				
Poly Price				
MYB	-0.071*			
Pop	(-3.181)			
WMJ		0.0111*		
Pop		(8.965)		
GCI			0.008*	0.017*
Pop			(2.148)	(3.044)
R^2	0.92	0.82	0.91	0.31

Table 4. Parameter estimates and t-statistics for logarithmic directed graph model, 1973-1992.

	Shirts	Jeans	Hosiery	Sheets
Constant	-91.49*	-47.23*	-57.58*	-6.55
	(-9.3)	(-8.51)	(-4.311)	(-1.384)
DPI			0.6836*	
			(3.947)	
CPI				
Cotton				
Price				
Poly Price	-0.643*			
	(-2.654)			
MYB	8.7143*			
Pop	(9.457)			
WMJ		4.596*		
Pop		(9.489)		
GCI			5.3991*	1.216*
Pop			(3.901)	(2.673)
R^2	0.90	0.83	0.89	0.25

Table 5. Forecast accuracy statistics for linear full model.

	Theil's U	RMSE	MAPE
Shirts	1.765	266.59	0.125
Jeans	0.664	67.75	0.111
Hosiery	0.748	24.71	0.098
Sheets	1.524	49.96	0.069

Table 6. Forecast accuracy statistics for logarithmic full model.

	Theil's U	RMSE	MAPE
Shirts	2.206	331.54	0.172
Jeans	0.965	106.68	0.21
Hosiery	1.306	43.614	0.251
Sheets	4.100	123.67	0.172

Table 7. Forecast accuracy statistics for linear directed graph model.

	Theil's U	RMSE	MAPE
Shirts	1.695	249.82	0.133
Jeans	1.634	156.57	0.24
Hosiery	1.029	33.67	0.165
Sheets	4.04	126.65	0.191

Table 8. Forecast accuracy statistics for logarithmic directed graph model.

	Theil's U	RMSE	MAPE
Shirts	3.101	450.16	0.233
Jeans	1.381	133.35	0.209
Hosiery	1.093	35.809	0.198
Sheets	2.848	101.50	0.152

Table 9. Coefficient and t-statistic estimates on differences in bias and variance components of the full and directed graph's MSEs.

Regression	Bias	Variance
Shirts	80.52	-0.2724
	(0.5197)	(-0.4916)
Jeans	-67.64*	-0.2044*
	(-4.923)	(-2.2367)
Hosiery	-18.31	-0.0338
	(-0.7997)	(-0.0432)
Sheets	-130.86*	0.866*
	(-4.4044)	(1.749)

* indicates statistical significance at the 0.05 level or better.