Characteristic Supplies and Demands in a Hedonic Framework: U.S. Market for Cotton Fiber Attributes

Kenneth R. Bowman and Don E. Ethridge

Hedonic price analysis has frequently been used to determine agricultural commodity characteristics' values. While hedonic price theory consists of a two-stage process, second-stage commodity characteristics' equations have not been successfully estimated until now. The estimated system consisted of 11 first-stage equations to determine cotton characteristics' values. The second stage consisted of 24 characteristic demand and 20 characteristic supply equations to model the underlying characteristic market structure. Cotton characteristic values were shown to vary across regions and over time as characteristic supplies and demands varied.

Key words: agricultural commodity, characteristic valuation, cotton, hedonic price analysis.

Since Rosen's landmark article on characteristic pricing for differentiated products in 1974, hedonic analysis has been increasingly used to determine the value of product characteristics and their impacts on product prices. While hedonic analyses have been conducted for several agricultural commodities (Perrin; Ethridge and Davis; Brorsen, Grant, and Rister; Jordan et al. Ethridge and Neeper), none have addressed the issue of changes in characteristics' values emanating from supply and demand forces. That is, none have modeled the market for characteristics so as to provide *ex ante* explanatory (predictive) capability; using Brown and Rosen's terms, all the work on agricultural commodities has been on stage-one estimation with none on stage two. In fact, the only prior empirical application that analyzes both supply and demand of characteristics (estimates of stage two) is for residential housing (Witte, Sumka, and Erikson), a market fundamentally more stable than commodity markets.

We present in this paper a study of cotton fiber attribute pricing which separates demand and

supply elements affecting attribute values. Our framework provides the means to understand the market in more depth and to conditionally predict attribute values as well as determine past attribute values. A modification of the original hedonic model based on price and characteristic differences is developed and empirical results from it are presented.

The remainder of the paper consists of a brief explanation of the hedonic procedure developed by Rosen, and Brown and Rosen, and a description of the first-stage model for cotton based on price and characteristic differences. Second-stage demand and supply models of fiber attributes and empirical results for the U.S. cotton market during 1976-77 to 1986-87 are then presented.

The General Hedonic Model

When estimating models to explain market values of characteristics, a vector of implicit marginal values is obtained by differentiating $P(Z)$ with respect to its i th argument, Z_i , and evaluating the derivative at the level of the characteristics purchased or sold (Rosen).

$$P = f(Z_i)$$

$$P_i(Z) = \delta P(Z) / \delta Z_i$$

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Review coordinated by Steven Buccola.

where P is price of the good, Z_i are the characteristics, and P_i are the characteristics' marginal values.

A regression of product price, P , against product characteristics yields estimates of marginal implicit prices but says nothing about the structure of characteristics' markets. Markets exist for commodities and from these markets for product characteristics are derived. Demand for attributes is a function of a vector of shifters, which influences buyer purchasing decisions. The supply of characteristics is a function of a vector of shifters influencing sellers' supply decisions. If the supply and demand for characteristics are both price-dependent, they are determined simultaneously.

In equilibrium,

$$P_i(Z) = g(Z_1, \dots, Z_n, Y_1) \text{ for demand}$$

$$P_i(Z) = h(Z_1, \dots, Z_n, Y_2) \text{ for supply.}$$

The demand equation states that the marginal demand price of a characteristic is a function of product characteristic levels and a set of shifters, Y_1 , which influence characteristic demand. The supply equation expresses the marginal supply price of a characteristic as a function of commodity characteristic levels and a set of shifters, Y_2 , which influence the supply of attribute i . Because there are demand and supply functions for each characteristic, the structural model is a set of $2n$ equations.

Hedonic Cotton Model Using Price and Characteristics Differences

Numerous identifiable characteristics are embodied in cotton fiber. The most widely recognized, and the characteristics on which data on individual bales of cotton are universally available, are trash content (indicated by the first digit of a grade code), color (indicated by the second digit of the grade code), fiber length, and micronaire (an indicator of fiber fineness and maturity). Two other characteristics, fiber strength and fiber length uniformity, have become more widely measured and understood and information about them more widely disseminated. These six characteristics are hypothesized to be the attributes affecting the price of cotton.¹

Hedonic theory recognizes heterogeneity in

goods. A commodity's price(s) may be conceptualized as simultaneously affected by the commodity's quantitative and qualitative dimensions. The quantitative dimension consists of supply and demand forces affecting the price of the homogeneous good. For example, as cotton's general supply increases, *ceteris paribus*, cotton's general price (or the price of cotton if it were homogeneous) decreases; as demand increases, *ceteris paribus*, general price increases. The qualitative dimension is the effect on price as quality characteristics change. Under this conceptualization, a base set of quality attributes and a base price for cotton with those quality attributes may be defined to capture movements in the overall cotton market, while differences from those base values capture the price effects of quality variations. Defining base quality to be grade 41, staple length 34/32nds inch, micronaire 3.5–4.9 range, and strength 20 grams/tex, and hypothesizing a linear additive model,² the hedonic model for fiber properties may be expressed as

$$P - P_b = b_0 + b_1(TR - TR_b) + b_2(C - C_b) + b_3(L - L_b) + b_4LM + b_5HM + b_6(S - S_b)$$

where P is price of cotton with characteristics TR , C , L , HM or LM , and S ; P_b is the price of cotton with base quality characteristics;³ TR is trash content as indicated by the first digit of grade code; C is color as indicated by second digit of grade code; L is length measured in 32nds of an inch; LM is low micronaire (below the 3.5–4.9 range = 3.5–M) HM is high micronaire (above the 3.5–4.9 range = M–4.9); S is strength measured in grams/tex with a stameter; subscript b denotes base quality ($TR = 4$, $C = 1$, $L = 34$, $S = 20$); and b_i are parameters. Implicit values of attributes are determined as $\delta P / \delta TR = P_{tr} = b_1$; $\delta P / \delta C = P_c = b_2$; and so forth.

Price differences may be positive, negative, or zero, depending on property mix; for the base quality, $P - P_b$ is zero. Individual parameters reflect premiums (+) or discounts (–); b_1 , b_2 ,

² There are conceptual reasons for expecting the relationship between price and fiber attributes to be nonlinear. Prior studies suggest, however, that when data consist of large numbers of observations on individual lot sales, nonlinear formulations work well (Ethridge and Neeper; Ethridge and Mathews). However, when data are limited or aggregated, the linear formulation is more effective (Hembree, Ethridge, and Neeper; Ethridge and Davis). The hypothesized form, in fact, provided better statistical results than did the nonlinear forms attempted.

³ Base prices are published by the Cotton Division of the Agricultural Marketing Service (AMS) and are known to all market participants. Characteristic values and factors that influence them are unknown. Data limitations on characteristics prohibited estimation of base prices in this study.

¹ Ethridge and Neeper, Hembree, Ethridge, and Neeper, and we found no significant impact of length uniformity on cotton prices. Therefore, length uniformity is omitted from the remainder of this paper.

b_4 , and b_5 are expected to be negative because increases in those values or differences lower the value of cotton lint, and b_3 and b_6 are expected to be positive.

There also are regional differences in prices based on real or perceived quality differences not explicitly measured. Many buyers believe the San Joaquin Valley produces the highest quality cotton. Consequently, a San Joaquin Valley cotton sample with a given set of characteristics will bring a higher price than a cotton sample with equal characteristics produced in another area. Differences are reflected in the quality and price data used in the present study. Data on quality attributes and prices in each of the four U.S. regions—southeast (Ala., Ga., Fla., N.C., S.C., Va., E. Tenn.), midsouth (Ark., La., Miss., Mo., W. Tenn.), southwest (Okla., Tex.), and west (Ariz., Calif., N.M., Nev.)—over the period 1976–1986 were used. Observations on fiber attributes consisted of 2,967 samples collected and analyzed by the U.S. Department of Agriculture (1977–1989) from each of the four production regions. Spot market prices corresponding to those dates and locations were from market news reports (U.S. Department of Agriculture, 1976–1988). The linear difference model was modified to include region intercept and slope-shift dummy variables to capture regional differences.

The regression model, estimated with ordinary least squares, thus became

$$P_r - P_b = b_0 + b_1(TR_r - 4) + b_2(C_r - 1) \\ + b_3(L_r - 34) + b_4(3.5 - LM_r) \\ + b_5(HM_r - 4.9) + b_6(S_r - 25) \\ + b_7(TR_r - 4)R_i + b_8(C_r - 1)R_i \\ + b_9(L_r - 34)R_i + b_{10}(3.5 - LM_r)R_i \\ + b_{11}(HM_r - 4.9)R_i + b_{12}(S_r - 25)R_i \\ + b_{13}R_i + e$$

where subscript r denotes values in region r , R_i denotes region dummy variables ($R_1 = 1$ for the southeast, $R_2 = 1$ for the midsouth, $R_3 = 1$ for the southwest; when $R_1 = R_2 = R_3 = 0$, region is the west), and e is the stochastic error term. A separate hedonic equation was estimated for each of the 11 years, 1976–1986, in order to obtain an average annual implicit price (premium or discount) for each of six fiber attributes in each region and year. These constitute “observed” implicit prices to be explained by characteristics’ demand and supply relationships. R^2 s in the 11 equations ranged from 0.90 to 0.96.⁴

⁴ All variables in the first stage equations were significant at the 10% level except the 1978 and 1986 intercept variables and the high micronaire variable in 1985. The high micronaire variable was significant at the 15% level.

Cotton Characteristics Value Model

Characteristics’ demands were hypothesized to be price-dependent and supplies to be quantity-dependent. Although annual supplies of attribute characteristics were assumed dependent on environmental circumstances, characteristics’ prices were not.⁵ Consequently, the market for cotton fiber characteristics was not modeled as the simultaneous system suggested by Rosen’s generalized framework. Such absence of simultaneity, resulting from the lags in the production process, often occurs in general models of agricultural commodity markets.

Characteristic Demands

Characteristic demand equations express each implicit market price as a function of demand shift variables and characteristics inherent to cotton. The conceptual basis of these equations is that all products are bundles of characteristics incompletely separable from one another, so levels of one characteristic may affect values of other characteristics (Rosen). Characteristic values may also be affected by noncharacteristic demand shifters. Shifters included in our demand model were base prices and changes in the proportion of rotor spinning to ring spinning. Spinning method was included because it is a determinant of buyer demand for characteristics.

Base price indicates conditions in the cotton market in general (as if the commodity were homogeneous). As general supply/demand conditions in the cotton market move to change the general price level (base price), individual characteristics’ prices may be altered. For example, if cotton in general is relatively scarce and base prices are high, trash discounts may decline because buyers cannot discount trash as much as when cotton is relatively plentiful. Spinning technology shifts the derived demand for cotton fiber attributes. Two types of textile spinning systems predominate in the U.S.: ring spinning, the conventional, more mechanically based method, and rotor spinning, which uses air flow to twist fibers into yarn. The U.S. textile industry has gradually adopted more rotor spinning, with a much higher throughput rate, for which cleanliness and strength are more important and fiber length and micronaire less important.

⁵ Supply equations with lagged characteristics’ prices were estimated, but none of the characteristics’ price coefficients were statistically significant.

Demand theory offers little guidance on the form of these demand relations, so linear and semi-log forms were hypothesized; double log was empirically infeasible because of negative implicit prices. The linear form (but including a quadratic term for micronaire) fitted best and is presented here. The quadratic micronaire term was used to capture potentially different implicit price responses at low, midrange, and high micronaire levels. The model was specified with a zero intercept because if all regressors are zero, the difference in price because of characteristics must be zero also; nonintercept models have previously been employed in hedonic analysis (Eastwood, Brooker, and Terry). Demands for fiber attributes in each of the four regions were thus specified as

$$\begin{aligned}
 P_{tr} &= a_1 TR + a_2 C + a_3 L + a_4 M \\
 &\quad + a_5 M^2 + a_6 S + a_7 P_b + a_8 T \\
 P_c &= a_9 TR + a_{10} C + a_{11} L + a_{12} M \\
 &\quad + a_{13} M^2 + a_{14} S + a_{15} P_b + a_{16} T \\
 P_l &= a_{17} TR + a_{18} C + a_{19} L + a_{20} M \\
 &\quad + a_{21} M^2 + a_{22} S + a_{23} P_b + a_{24} T \\
 P_{lm} &= a_{25} TR + a_{26} C + a_{27} L + a_{28} M \\
 &\quad + a_{29} M^2 + a_{30} S + a_{31} P_b + a_{32} T \\
 P_{hm} &= a_{33} TR + a_{34} C + a_{35} L + a_{36} M \\
 &\quad + a_{37} M^2 + a_{38} S + a_{39} P_b + a_{40} T \\
 P_s &= a_{41} TR + a_{42} C + a_{43} L + a_{44} M \\
 &\quad + a_{45} M^2 + a_{46} S + a_{47} P_b + a_{48} T
 \end{aligned}$$

where a_i are parameters, M represents average micronaire, and T is the change in the proportion of rotor to ring spindles in U.S. textile mills. Data on characteristic demands were drawn from attribute prices and base prices in the first-stage hedonic model. Data on T were from U.S. Department of Commerce (1990).

Characteristic Supplies

The principal long-run determinant of fiber characteristics is variety, although annual variations occur with environmental fluctuations. In the U.S., varieties are somewhat region-specific, being developed to suit factors such as length of growing season, rainfall and temperature patterns, and cultural and harvest practices. Varieties within a region change over time, although slowly, and there is a large number of varieties in some regions. Here, effects of varieties on fiber qualities were accounted for by examining separate regional supply relations

such that varietal factors are captured by regional delineation.

Annual fiber characteristic averages were hypothesized to be functions of weather variables. Rainfall and temperature data were from the U.S. Department of Commerce (1975–1988); seasonal and annual totals and averages for locations closest to each production region were used. Rainfall, both pre-season and growing season, impact plant physiology and fiber development. Temperature affects the fiber development process, particularly during parts of the growing season. Specific seasonal delineations were judged to be an empirical matter and several definitions of seasonal divisions were tested. Seasonal definitions presented in the models below resulted from that process.

Neither theory nor prior empirical work provided insight into the mathematical structure of characteristic supply models. Box-Cox (Spitzer) is appropriate and was applied. The functional form models specified for characteristic supplies were

$$\begin{aligned}
 TR &= f(RF_{t-1}, WNR, SPR, SMR, FLR, SPT, \\
 &\quad SMT, FLT, t) \\
 C &= g(RF_{t-1}, WNR, SPR, SMR, FLR, SPT, \\
 &\quad SMT, FLT, t) \\
 L &= h(RF_{t-1}, WNR, SPR, SMR, FLR, SPT, \\
 &\quad SMT, FLT, t) \\
 M &= i(RF_{t-1}, WNR, SPR, SMR, FLR, SPT, \\
 &\quad SMT, FLT, t) \\
 S &= j(RF_{t-1}, WNR, SPR, SMR, FLR, SPT, \\
 &\quad SMT, FLT, t)
 \end{aligned}$$

where RF_{t-1} is total inches of rainfall in the previous calendar year; WNR , SPR , SMR , and FLR are inches of rainfall in winter (January and February), spring (March–May), summer (June–August), and fall (September and October); SPT , SMT , and FLT are average spring, summer, and fall daily temperatures in degrees Fahrenheit; and t is time (1976 = 1) as a proxy for varietal improvements over time. A characteristic supply relation was estimated for each characteristic in each region using 11 years of time-series data.

Estimation Procedures

Because characteristic supplies are independent of current prices, a simultaneous equations system was not appropriate. Correlation of error terms across region demand and supply equations was anticipated, because regional relations

are affected by the same or similar forces (Zellner). Hence, the set of regional characteristic demand and supply equations was estimated using seemingly unrelated regression (SUR). All analyses were conducted using the Statistical Analysis System (SAS). Estimation of supply relationships was performed as follows: Box-Cox was used to establish the exponent maximizing the log likelihood of the relationship between the fiber characteristic and the set of weather variables; then the set of equations for each region was estimated using SUR. Parameter estimates not significant at the 10% level were deleted and the equations were reestimated.

Model Projections

Data on all environmental variables (temperature and rainfall) were gathered for each region and supplies of each characteristic in each region were projected over 1987–88 and 1988–89. Combining these estimated characteristic supplies with characteristic demands provided characteristic price estimates (premiums and discounts). Estimated values were compared to actual values to provide an indicator of model accuracy in the two years following the study period.

Findings

Characteristic demand and supply relationships are presented and discussed, then projections of characteristic prices are offered to illustrate the advantage of this *ex ante* approach compared to the *ex post* applications in earlier literature.

Characteristics Demands

Estimated characteristic demand relationships (table 1) show that factors affecting demands vary among regions. The base price, that is the general market condition variable, affects all characteristics' prices except fiber length (length premium). Length value was affected by the base price only in the southwest, the region which traditionally has produced the shortest fibers and had the lowest base price. In contrast, effects produced by changes in the adoption rate of rotor spinning technology were greatest on the price of the length attribute. This result may indicate a significant relationship between the base price and the technology variable.

The trash discount was responsive to trash levels in the three easternmost regions. In the southeast, price decreased (discount increased) by -0.231 cents/lb. for each unit increase in trash. In the midsouth and southwest, the effects were -0.311 and -0.335 cents/lb., respectively. In the west, demand was perfectly price elastic, that is the trash discount per unit of trash was constant over the range of trash content observed. In at least one region, the trash discount was affected by all other fiber characteristics, the main effects being from color, then length, then micronaire.

Demand for color was responsive to color in all regions. Demand for color was also shifted by the level of micronaire in all regions, by the level of trash in all regions except the west, and by length in all regions except the southwest.

Demand for length was affected by the length levels except in the southwest. While the sign of the length regressor was expected to be positive, it was negative in all regions where significant. This provides information in two ways. First, the technology parameter estimate was negative and significant in all regions, confirming the belief that rotor spinning technologies depend less on length for processing efficiency than do ring spinning methods. Furthermore, the region where the shortest fibers are produced, the southwest, was the only region where a significant negative coefficient was not observed.

Both low (below 3.5) and high (above 4.9) micronaire prices responded in a linear fashion to micronaire. As expected, low micronaire prices reacted positively to increases in micronaire while high micronaire prices reacted negatively. Demand for low micronaire reacted to fiber length in all regions except the midsouth and to strength in the southeast and midsouth, while demand for high micronaire was reduced by trash and color in midsouth markets, by trash in the southwest, and by color in the west.

Demand for strength was perfectly price elastic in all markets. However, strength premiums were responsive to length in all regional markets and to color in all markets except the west. Because strength levels are often unreported at point of sale and because high color levels indicate weakened fibers, color was expected to impact strength prices.

Characteristic Supplies

The characteristic supply equations (table 2) show the effects of environmental factors on charac-

Table 1. Estimated Parameters of Characteristic Demand Equations, by Region

Dep. var.	Region	Independent variables							<i>T</i>
		<i>TR</i>	<i>C</i>	<i>L</i>	<i>M</i>	<i>M</i> ²	<i>S</i>	<i>P_b</i>	
<i>P_{ir}</i>	SE	-0.231	-0.253	-0.292	4.576	-0.490	0.044	-0.056	
		(-2.09)	(-2.81)	(-4.82)	(4.48)	(-4.03)	(1.49)	(-7.75)	
	MS	-0.311	-0.233	-0.226	2.470	-0.333	0.147	-0.027	
		(-4.92)	(-3.00)	(-6.72)	(4.58)	(-5.25)	(5.54)	(-6.466)	
	SW	-0.335	-0.131		1.599	-0.214		-0.055	-208.636
		(-10.92)	(-4.44)		(15.50)	(-13.49)		(-22.63)	(-31.09)
	W		-0.624	-0.172				0.047	
			(-4.16)	(-13.54)				(7.26)	
<i>P_c</i>	SE	-0.244	-0.474	-0.188	3.014	-0.410		-0.009	
		(-2.64)	(-6.31)	(-3.82)	(3.53)	(-4.02)		(-1.58)	
	MS	-0.252	-0.547	-0.239	2.434	-0.266	0.184	-0.042	
		(-6.13)	(-10.66)	(-9.18)	(5.73)	(-5.30)	(10.84)	(-14.49)	
	SW	-0.424	-0.261		1.056	-0.146		-0.036	
		(-13.07)	(-8.68)		(10.81)	(-9.82)		(-14.96)	
	W		-0.632	-0.150	2.622	-0.308		-0.031	
			(-4.17)	(-4.54)	(4.76)	(-4.59)		(-4.86)	
<i>P₁</i>	SE			-0.076	1.706	-0.205			-34.057
				(-5.33)	(7.53)	(-7.59)			(-4.54)
	MS		-0.043	-0.431	0.870	-0.077			-17.761
			(-2.10)	(-3.80)	(4.94)	(-3.67)			(-3.64)
	SW	-0.041			0.380	-0.048		0.006	-30.337
		(-4.83)			(12.95)	(-10.81)		(7.43)	(-13.86)
	W			-0.026	0.845	-0.097			-8.148
				(-2.20)	(4.16)	(-3.93)			(-2.33)

P_{hm}	SE			-0.192 (-2.74)	2.090 (6.55)	0.155 (1.86)	-0.252 (-18.99)	669.885 (14.77)
	MS				0.441 (2.61)	0.296 (7.77)	-0.274 (-31.02)	225.958 (8.26)
	SW			0.181 (8.34)	0.996 (7.01)		-0.305 (-35.02)	
	W			0.242 (6.45)	0.326 (1.33)		-0.281 (-21.83)	
P_{hm}	SE			-0.037 (-1.08)	-0.546 (-2.55)		-0.021 (-2.13)	
	MS	-0.323 (-3.33)	-0.708 (-6.17)	0.104 (4.37)	-1.034 (-8.72)		-0.032 (-4.86)	
	SW	-0.646 (-8.50)		0.042 (2.55)	-0.464 (-5.19)		-0.035 (-5.95)	
	W		-0.307 (-1.81)		-0.116 (-1.15)		-0.063 (-9.70)	
P_s	SE			-0.072 (-5.52)	-0.007 (-3.61)		0.010 (9.54)	
	MS			-0.040 (-3.12)	-0.009 (-5.85)		0.010 (13.22)	
	SW			-0.049 (-6.57)	-0.009 (-8.02)		0.011 (18.11)	
	W				-0.022 (-13.54)		0.016 (19.13)	

SE = southeast, MS = midsouth, SW = southwest, W = west.

Numbers in parentheses are *t*-values.

Southeast MSE = 0.94, $R^2 = 0.94$, and $df = 2288$.

Midsouth MSE = 0.95, $R^2 = 0.90$, and $df = 5183$.

Southwest MSE = 0.95, $R^2 = 0.94$, and $df = 6184$.

West MSE = 0.97, $R^2 = 0.87$, and $df = 4042$.

MSEs are system-weighted.

Table 2. Estimated Parameters of Characteristic Supply Equations, by Region

Dep. var.	Region	Independent variables										λ
		Intercept	R_{t-1}	WNR	SPR	SMR	FLR	SPT	SMT	FLT	t	
TR	SE	5.549 (18.10)	0.052 (3.56)		0.262 (11.74)	-0.137 (-5.51)	0.064 (3.45)			-0.434 (-7.56)	0.154 (12.85)	0.41
	MS	3.772 (137.16)		-3.8E-7 (-2.55)	7.6E-7 (12.69)	1.4E-6 (1.92)	7.9E-8 (2.80)	-1.1E-10 (-6.05)	1.6E-10 (22.78)		-1.2E-6 (-17.76)	5.0
	SW	2.965 (21.49)	-0.026 (-8.67)	0.119 (7.93)	-0.105 (-8.75)	0.104 (13.00)	0.171 (28.50)		0.129 (9.92)	-0.106 (-7.57)	0.129 (21.50)	0.62
	W	3.055 (50.92)	0.056 (3.36)	-0.382 (-20.11)	0.999 (26.29)		0.306 (21.86)				-0.249 (-11.86)	0.34
C	SE	7.103 (6.38)	-1.903 (-2.79)	-2.303 (-6.25)	-1.727 (-3.89)		2.670 (9.76)				-1.454 (-6.81)	0.07
	MS	0.702 (17.12)		3.6E-6 (13.30)	7.8E-7 (7.29)	1.0E-5 (8.32)	4.0E-7 (8.50)	-1.3E-10 (-7.42)	1.7E-10 (13.72)		3.3E-6 (31.14)	4.96
	SW	8.611 (36.18)		1.815 (18.52)	-1.728 (-9.55)		-3.905 (-34.25)				-3.491 (-21.03)	-0.04
	W	1.248 (33.03)	6.8E-5 (6.78)	0.003 (5.75)	0.018 (12.21)	0.015 (9.55)	0.008 (12.97)	-1.0E-4 (-21.44)	2.1E-4 (6.06)	2.1E-5 (6.80)	0.001 (30.97)	2.25

L	SE	34.729 (375.57)	3.0E-5 (5.60)	0.015 (2.77)	-0.005 (-9.07)	0.007 (11.70)	-0.007 (-11.57)	-1.0E-5 (14.27)	-1.0E-4 (-7.33)	0.007 (33.90)	2.09	
	MS	35.761 (308.28)		-0.870 (-20.42)	-0.535 (-4.78)		-0.295 (-4.92)	-25.983 (-1.76)		-0.807 (-38.43)	-1.17	
	SW	29.970 (315.47)		0.989 (17.35)	-0.712 (-10.32)	1.756 (29.57)					0.21	
	W	34.367 (245.48)			1.403 (13.71)					-0.631 (-4.89)	-0.14	
M	SE	4.689 (36.03)	-0.005 (-9.71)	-0.063 (-17.16)	-0.013 (-3.29)	-0.040 (-9.59)	0.032 (9.04)	0.002 (10.92)	-0.010 (-13.06)	0.016 (9.64)	-0.014 (-8.02)	1.04
	MS	4.981 (34.35)	7.796 (15.69)	0.283 (8.58)	-0.133 (-1.85)		0.352 (7.82)	-23.676 (-8.41)				-0.71
	SW	3.867 (322.25)	12.585 (6.34)	-4.6E-5 (-3.01)	-0.037 (-14.98)	0.080 (9.46)	-0.063 (-17.00)				0.353 (14.65)	-1.80
	W	4.581 (92.92)	1.0E-4 (7.61)	0.004 (6.36)	0.016 (8.41)	0.022 (10.74)	0.007 (8.94)	-1.7E-4 (-25.00)	4.6E-5 (9.59)	3.3E-5 (7.91)	0.001 (23.64)	2.24
S	SE	9.818 (7.02)	0.664 (4.10)	-2.021 (-14.91)	0.803 (4.94)			0.713 (4.48)		3.882 (6.28)	1.245 (15.50)	0.22
	MS	25.264 (64.95)	-0.002 (-4.23)			-0.027 (-3.86)	-0.017 (-4.25)	0.030 (10.00)		-0.049 (-12.25)	0.058 (19.37)	1.08
	SW	21.807 (160.35)		0.116 (7.73)	0.046 (6.37)		-0.049 (-14.40)	0.039 (20.10)		-0.040 (-19.90)	0.120 (52.86)	1.10
	W	23.987 (272.89)	7.765 (21.24)		0.598 (20.13)	-0.012 (-10.26)	0.022 (13.46)			-2.255 (-22.96)		-0.72

See footnote under table 1.

Southeast MSE = 0.95, R^2 = 0.74, and df = 5143.

Midsouth MSE = 0.87, R^2 = 0.86, and df = 4310.

Southwest MSE = 0.93, R^2 = 0.78, and df = 1890.

West MSE = 0.89, R^2 = 0.63, and df = 3350.

teristic levels. Equation interpretation is as follows: lambdas (λ) are estimated exponents of independent variables and a coefficient estimate followed by $E-i$ is the coefficient with the decimal i places to the left. As with demand relationships, there were differences among regions in characteristics' supply relationships. Time as a proxy for technology had the most consistent effect overall, affecting all attributes except length in the southwest and micronaire in the mid-south.

Cotton trash levels are affected by rainfall in the previous year and rainfall in each season of the current year. Rainfall the previous year tends to increase trash in the southeast and west, but decrease trash by a small amount in the southwest. Increased spring rainfall was associated in three regions with greater trash, suggesting more vegetative matter produces more trash. Fall rainfall increased trash in all regions. Temperature variations had effects in each region except the west, possibly because annual temperature fluctuations are lowest there. Spring temperatures affected trash level only in the midsouth. Summer temperature affected trash in three regions, with the largest effect in the southwest. Color was likewise affected by rainfall variation more than by temperature. Temperature variations had no effect on color in the southeast and southwest.

Rainfall and temperatures effects on length tended to be small. Temperature had no effect on length in the southwest or west. Fiber length was determined largely by variety, as reflected in the small number of significant environmental variables and large intercept values. Micronaire was affected by both variety and environment; it was generally influenced by both rainfall and temperature, although somewhat less by temperature than by rainfall. The trend has been for micronaire to increase in the southwest and west and decrease in the southeast.

Fiber strength was likewise affected by both sets of environmental factors and variety, although summer rainfall had little effect on fiber strength. Fall rainfall decreased strength in the southwest and midsouth, possibly from fiber deterioration in the field. Spring rain increased strength in regions where the variable was significant, suggesting that initial plant development may affect fiber strength. Temperature had greater effects on strength in the southeast and declined in impact the further west production occurred. Fibers are gradually becoming stronger in all regions except the West, where they have weakened slightly.

Projections

Projected values of fiber characteristics and characteristics' prices were made for 1987 and 1988. For this purpose, weather data in the two years and each of the four regions were provided for the supply equations. Base prices in the four regions in each of the two years (U.S. Department of Agriculture 1987-1988) and the change in the proportion of rotor to ring spindles in textile mills were provided for the demand equations (U.S. Department of Commerce, 1990).

Observed values of fiber characteristics were drawn from the same source as data used in estimating model parameters. Observed strength readings were converted from High Volume Instrument (HVI) measures of strength reported since 1986 to the stelometer readings used as a basis for data prior to 1987. The conversion⁶ used was stelometer reading = $6.03 + 0.693$ (HVI reading). Because characteristic values are not directly observable, "observed" values were derived by estimating stage-one equations for 1987 and 1988.

Characteristic supply equations generally predicted well for most characteristics. Predicted mean characteristic levels were within 7.5% of actual values for all characteristics except color, which had a mean absolute deviation of almost 36%. Across all regions, supply equations predicted length and micronaire levels most accurately. The strength relationship was next most precise, with six of eight predicted values less than those observed. The trash relationship had six of eight predicted values greater than observed, but the mean absolute deviation was about twice as large as for the strength characteristic. The color relationship predicted less accurately than did other characteristic relationships. The reason for this is not known, but part of the explanation may lie with the color data. The color portion of the grade code encompasses two different dimensions of color, yellowness and grayness.

Characteristics' demand equations predicted prices less effectively than supply equations predicted characteristic levels. Percentage deviations were large and some comparisons were not possible. Limited observations on samples of cotton outside the base micronaire range in 1987 and 1988 made estimates of "observed" prices

⁶ This unpublished conversion factor, based on a regression analysis ($R^2 = 0.58$), was provided by Paul Deaton, AMS, USDA, Clemson, SC.

difficult. In fact, the total number of observations in the USDA data set has declined over time, presenting problems for all first-stage equation estimates in later years. Estimation problems aside, predicted prices from the time-series data show consistent bias: predicted discounts for trash, color, and low micronaire were greater than actual discounts in all cases and predicted strength premiums were greater than observed premiums in all cases. Model parameters and projections based on time-series data may consequently overestimate projected discounts/premiums. A larger, more current data set might mitigate these problems and provide more predictive accuracy.

Summary and Conclusions

This study represents the first successful attempt we know of with an agricultural commodity to estimate the complete hedonic system as developed by Rosen and Brown and Rosen. Adaptations to a commodity market included (a) a characteristics difference, first-stage hedonic model to adjust for general commodity supply and demand movements, and (b) treatment of characteristic supply relationships as perfectly inelastic with respect to current characteristic values, because of the delay between production decisions and production results.

The estimated system of relationships consisted of 11 first-stage hedonic equations and 24 characteristic demand and 20 characteristic supply equations in the second stage. First-stage relations revealed premium/discount values of six quality characteristics in each of four regions. Second-stage demand relations provided premiums/discounts for each of the six quality characteristics in each of the four regions as functions of demand variables. Supply relations provided average characteristic levels for five quality characteristics (low and high micronaire were not considered separately) in the four regions. All were based on 11 years of data from 1976 through 1986.

Statistical results were generally encouraging, with R^2 s ranging from 0.90 to 0.96 for the first-stage equations, 0.87 to 0.94 for characteristics' demands, and 0.63 to 0.86 for characteristics' supplies. Parameter signs and magnitudes in final equations were all reasonable and intuitive interpretations of the model were logically consistent. As an explanatory model, therefore, the system is logically and empirically viable. It provides quality premiums and discounts (where

most hedonic analyses stop) and, in addition, indicates factors which caused the premiums and discounts to behave as they did. The characteristics' demand model fails to predict characteristics' premiums/discounts accurately, although the supply model does a better job in this regard. Failure to predict characteristics' prices may be associated with trends in these prices and with inadequate empirical data.

[Received April 1991; final revision received December 1992.]

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