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# Markets, Institutions, and the Quality of Agricultural Products: Cotton Quality in India

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Abstract

The modern global textile industry requires cotton with strong and consistent fibers in order to produce high quality goods at the high speeds necessary to recover capital costs. The introduction of high volume instrument (HVI) measurement of cotton fiber quality has strengthened the link between cotton prices and attributes on world markets. The spread of genetically modified (GMO) cotton in India has driven India to the second ranked producer and exporter of cotton in the world. However, contamination and other quality problems are endemic to Indian cotton. Using a unique data set of Indian cotton prices and quality attributes from 5 Indian states, this study uses hedonic price modeling to demonstrate that the linkages between cotton quality and price are weaker in India than they are in the United States.

## Introduction

Markets use prices as signals to allocate resources efficiently. The result is the maximization of output, income, and welfare given the available technology, factors of production, and natural resources. Economics typically examines this phenomenon as maximizing the output of discrete products, but an alternative perspective is to consider the output of the components or attributes that comprise these products.

For example, soybeans and other oilseeds are seldom consumed in their entirety, but are valued for the components—protein meal and oil—extracted from them. Similarly, households do not consume cows, but specific cuts of meat. Other products embody

attributes which are not separable from the product or consumed discretely from one another, but that consumers value and seek to consume. A cellular phone cannot be separated into so many units of signal quality and battery life, but these and other functions guide the consumer's choice and consumption of the phone to provide communication. Similarly, cotton is purchased by textile mills based on variables like the length and color of the fibers in order to produce yarn. Mills can blend units of fiber with different attributes, but cannot separate a fiber's length from its strength or color.

Different industries have resolved the optimization problem of matching supply and demand of product attributes in different ways. Market institutions become the medium through which consumers and producers of goods communicate their preferences for certain attributes (consumers) and their willingness to supply them (producers). In some cases, the useful components of the goods have well-developed markets with open price discovery and opportunities for arbitrage and trade. Vegetable oils and meals fall into this category, and shifts in the prices of oils and meals drive the prices of oilseeds, guiding producers around the world to shift from oilseeds of higher or lower oil or meal content based on the relative demand for these components.

Livestock raised for meat also can be physically separated into components with distinct uses and demand. However, differentiation is higher for meats than vegetable oils and the markets for different cuts and qualities of meat are different than those for the relatively undifferentiated oilseed meals and oils. When live animals are marketed, the yield of meat of any particular quality is difficult to anticipate, and equally difficult to

factor into the animal's price. Jones, et al (1991) concluded that wholesale beef price variation with respect to quality was poorly reflected in live cattle prices. Other studies showed beef's loss of market share of U.S. meat consumption was in part related to problems with beef quality (Smith 1995). Structural shifts in the U.S. livestock industry have occurred partly in response to the need to better communicate the demand for particular meat attributes.

Cotton and quality in the United States and India

The U.S. cotton industry at the beginning of the 20th century faced a problem analogous to the one that has confronted livestock and meat-packing. While the attributes of cotton purchased from farmers was of crucial importance to textile producers, these attributes were largely unknown at the time of the transaction. Merchants accumulated cotton from farmers, tested it for quality[i] and marketed it to domestic mills and overseas customers that required fiber of particular characteristics and quality. However, farmers' compensation was poorly linked with the demands of these downstream customers.

During the first half of the 20th century, the U.S. cotton industry was transformed through a combination of producer initiatives and government institutions. Producers began organizing into "one-variety" groups that collaborated with seed companies, and state and the federal departments of agriculture began providing timely and cost-effective classing to producers. Vertical coordination was also a factor, and today approximately half of the U.S. cotton crop now marketed through cooperatives (AMCOT, 2010), and one

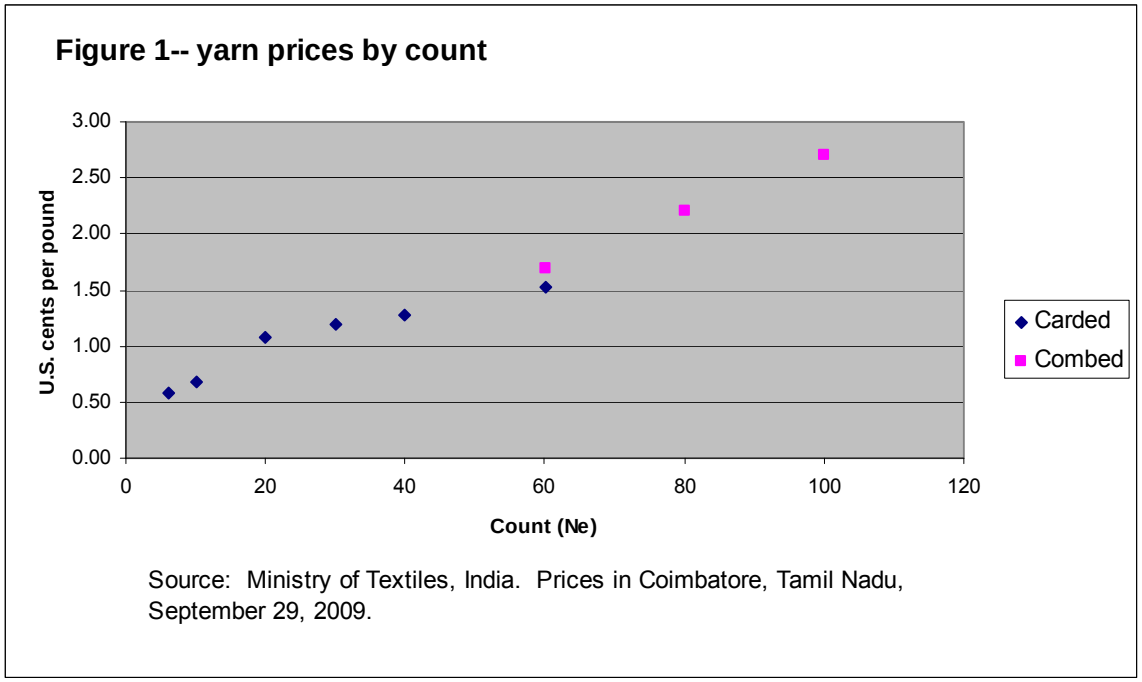
cooperative integrating downstream to build and purchase integrated textile plants, and sell denim clothe and apparel (PCCA, 2010).

India's cotton sector is now in a situation analogous to the U.S. beef and pork industries in the 1980's and the U.S. cotton sector in the 1930's. Production is through small farms, demand is changing, and there are questions regarding the transmission of the demand for quality to producers. The analogies are not complete of course, because India's cotton sector has recently undergone a transformation with the introduction of genetically modified (GM) cotton.

## The Transformation of Cotton Fiber into Textile Products

The three characteristics that most fundamentally define the value of cotton to spinners are the fibers' length, strength, and fineness. Yarn is a bundle of fibers, so the longer the fibers, the fewer needed in a cross-section of the bundle to impart strength to the yarn. Similarly, the stronger the fibers, the fewer needed to impart strength. And, the finer the fibers, the larger the number of fibers that will be in a cross-section of yarn of a particular size, enabling the production of stronger yarn of a given fineness. The increasing speed at which textile machinery is designed to perform, and its increasing automation, is increasing the premium on yarn strength around the world. But fineness of yarn remains an important determinant of its value (figure 1), so cotton is valued for its ability to profitably balance yarn fineness and strength[ii]. Other important characteristics include

the color of the fibers, their ability to absorb dye predictably and uniformly, and the absence of extraneous matter which alters the appearance of fabric, discounting its value.

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Determining Cotton Attributes

Genetic inheritance is one factor determining cotton characteristics. Commercial cotton production utilizes four species of the genus *Gossypium*, with 3 distinct groups distinguishable in part by fiber length. The species with the longest fibers and highest prices is typically *G. barbadense*, known as Pima or Extra Long Staple Cotton (ELS). In the United States, ELS cotton is typically close to 2 inches in fiber length, and ELS fibers are typically finer than those of other species (USDA, 2009a mp_cn831). *G. arboreum* and *G. herbaceum* are the shortest and coarsest of the 4 species, and account for a very

small share of world production. *G. hirsutum* accounts for about 98 percent of the world's cotton, and is typically referred to as upland or American upland cotton. In the United States, upland cotton typically has fibers of 1-2/16$^{th}$ inches (i.e. 36 staple), while global trading is based on fibers of 1-3/32s inches (or 35 staple).

Fiber length and maturity are largely determined by the availability of water.[iii] Cotton fibers are derived from hairs attached to the seed, and the water requirements for cotton production steadily rise as the plant grows, reaching a peak during the main fruiting period. Irrigated crops account for more than 70 percent of the world's output, given this need for sufficient, well-timed water. (About 50 percent of global area planted to cotton is irrigated.)

Cotton is largely produced in developing countries, where hand cultivation is the primary form of weed control. This labor-intensive operation often faces competition from the labor demands of other crops, leading to delays. Late weeding leads to declines in both the yield and quality of the crop. Insect control is also a labor-intensive process in developing countries, and the cost, timing, and efficacy of the insecticide application also influence the ability of pest control efforts to protect cotton quality.

Hand harvesting also carries significant contamination risks, since seed cotton is typically gathered using burlap or polyurethane bags. Fibers from these bags, as well as from human hair and clothing are significant contaminants affecting the quality of cotton from many developing countries (ITMF, 2008).

Measuring Cotton Attributes and Quality

The global nature of the cotton industry means a variety of cotton classification systems exist. The best known is the Universal Cotton standards system developed in the United States, starting in 1907. Traditionally, trained classers manually examined cotton samples in special rooms with proper lighting, temperature, and humidity. The United States initiated a fee-based system of public classing that year, and following a significant reduction in fees in 1937, farmer participation in USDA's classing began rising sharply. By 1945, one-third of U.S. cotton production was classed by USDA, and ten years later it was more than three-quarters of the crop.

Visual classing permitted discernment of fiber length, color, and proportions of extraneous matter. Instruments were later developed to assess these and other fiber characteristics such as fiber diameter, its strength, and elasticity. In the 1970's an instrument-based system of classing was introduced that eventually replaced manual classing in the United States. High Volume Instrument (HVI) testing measures the previously mentioned characteristics of cotton samples rapidly, and is now used to class 30-40 percent of the world's cotton (van der Slijiun, 2009). In the United States, official measurements for Fiber Length, Length Uniformity Index, Fiber Strength, Micronaire, Color, and Trash are performed by HVI, and virtually the entire U.S. crop undergoes HVI classing by USDA's Agricultural Marketing Service.

Hedonic Price Models

Lancaster (1966, 1971) developed a model of consumer utility based on the attributes embodied in goods rather than on the goods themselves. Rosen (1974) extended Lancaster's model to the hedonic analysis of prices: the perspective that the price of a good is a function of the characteristics associated with it. Based on Lancaster and Rosen, we can start from a traditional production function for yarn,

$$Q_{yarn} = f\,(L, K, Q(cotton)),$$

where the output of yarn is a function of the quantity of labor (L), capital (K), and cotton. This can be respecified to be a function of the attributes cotton embodies,

$$Q_{yarn} = f\,(L, K, Q(length), Q(strength)),$$

where yarn output is a function of the cotton fiber's length and strength rather than simply a function of the volume of cotton. Profit maximization means that given a level of capital and labor, there will be a given marginal productivity of strength and length with respect to yarn output, e.g. $MP_{strength} = \frac{\partial f}{\partial Q_{length}}$. Incorporating the production function into a profit function for yarn and accounting for a cotton strength supply function, the market for cotton strength will be in equilibrium when $P_{strength} = MP_{strength} * P_{yarn}$. Under these conditions, the resources needed to produce cotton strength and length will be efficiently allocated, maximizing the income of India's agricultural producers.

In the short run, the supply of cotton and/or cotton attributes can be taken as given. After harvest, supply is pre-determined, and price determination will be a function of demand. This simplifies the development of the reduced-form equation used to specify the hedonic price relationship, and simplifies the estimation of that equation. (Ladd and Martin 1976 Implicit component model ) Under these circumstances, the basis for attributing the price of cotton to a function of the implicit prices of its component attributes was developed by Rudstrom (2004) in a study of U.S. hay prices. Rudstrom demonstrates that a production function incorporating input characteristics leads to the following relationship between the price of cotton and its attributes:

$$P_{\cot ton} = P_{yarn} MP_{z1} \frac{\partial Z_1}{\partial \cot ton} + P_{yarn} MP_{z2} \frac{\partial Z_2}{\partial \cot ton} + ..... + P_{yarn} MP_{zi} \frac{\partial Z_i}{\partial \cot ton},$$

where the characteristics of cotton are $Z_1$ through $Z_i$. In other words, given the technology of yarn production, the market for yarn, and the supplies of cotton with various characteristics, the price of cotton will be a function of its attributes:

$P_{cotton} = g$ *(length, strength, color, maturity).*

The Market for Cotton Quality in India

Data for this study were gathered during October 2006 to February 2007 at 19 different markets in India in five states (Punjab, Haryana, Rajasthan, Gujarat, and Karnataka). The

markets were spread across major cotton growing states and were in each of the 3 major zones for cotton production. In each market, the realized prices were recorded and samples taken for the lots of cotton marketed at that time. The samples were later subjected to HVI analysis using instruments from Premier Evolvics, Ltd, to quantify their quality parameters.[iv]

A hedonic price model was estimated for cotton in each of the 5 states (Punjab, Haryana, Rajasthan, Gujarat, and Karnataka) using this data, with the price of cotton a function of a variety of variables measuring the characteristics of the cotton as determined through HVI testing. The model's general specification is,

*P = f (len, str, elg, mic, rd, +b, trash, market).*

Broadly speaking, these variables describe the cotton's suitability for profitable yarn production. The variables measured and used in the model are:

len: fiber length, measured as the 2.5 percent span length. Span length is the distance spanned by a specific percentage of fibers in the specimen. The initial point of the spanning is considered 100 percent.. Data are reported in inches

str: strength, measured as the force in grams required to break the fiber, and is reported in grams/tex (a tex unit is equal to the weight in grams of 1,000 meters of fiber)

elg: elongation, measured as the extension of the fibers before a break occurs when measuring strength, and reported in percentage.

mic: micronaire, is an indication of the fineness and maturity of cotton. It is a function of a sample's permeability to air, and is generally understood be expressed as weight in micrograms per inch of fiber length

rd: reflectance, measures the brightness or dullness of the sample, and is reported as a percentage of light reflected

+b: yellowness, measures the degree of pigmentation, and is reported in a unit particular to measuring this attribute (ranging from 4 to 18)

trash: trash is the amount of extraneous material, and is reported as a percentage

market: within a given state, data was collected at different markets on different days. In some cases, cotton at the same market was indicated to be of a different variety, or purchased by a cooperative rather than a merchant. In very case, variety and purchase type proved to have insignificant

parameters and were dropped. However, in a few models, dummy variables indicating the market where the data were collected remained significant.

Since the profitability of yarn production varies positively with fiber length, strength, and whiteness, $E(\beta_i) > 0$ for len, str, elg, and rd. Negatively signed parameters are expected for +b and trash: $E(\beta_i) < 0$.

Theory provides little guidance on the appropriate functional form of hedonic price models. Linear models are common in the extensive literature on information technology (see Triplett 2009), but models for cotton price typically use non-linear forms. This may reflect non-linearities in the production function for yarn[v]. Micronaire's impact on cotton price is inherently non-linear due to the nature of the metric. Micronaire measures a combination of fiber fineness and maturity, so low micronaire may result from a positive attribute (fineness) or a negative one (immaturity).

Past studies have used a variety of functional forms, including semi-log or double-log specification of the entire model, or a mix of these specifications for different independent variables. Micronaire is virtually always included in quadratic form, but some models also include other variables quadratically.

Results

Hendry's (1995) general-to-specific approach was used to determine which variables had quadratic and non-quadratic price effects. Information criteria, linearity tests, and encompassing tests were used to determine the optimum combination of quadratic, log-linear, and double-log treatment of cotton attributes in the models while minimizing the impact of the idiosyncratic attributes of the individual samples. For each state, estimates of linear models failed tests for non-linearity and realized substantially poorer information criteria than did non-linear models. The resulting models are:

$$P_{Punjab} = e^{\beta_0+\beta_1 len+\beta_2(len^2)+\beta_3 str+\beta_4 e\lg+\beta_5 mic+\beta_6(mic^2)\beta_7 rd+\beta_8(+b)+\beta_9 trash+\beta_i market_i}\varepsilon$$

$$P_{Haryana} = \beta_0 e^{\beta_1 len+\beta_2 str+\beta_3 e\lg+\beta_4 mic+\beta_5 rd+\beta_6(rd^2)+\beta_7(+b)+\beta_8 trash}\varepsilon$$

$$P_{Gujarat} = \beta_0 e^{\beta_1 len+\beta_2 str+\beta_3 e\lg+\beta_4 e\lg^2+\beta_5 mic+\beta_6(mic^2)+\beta_7 rd+\beta_8(+b)+\beta_9 trash}\varepsilon$$

$$P_{Karnataka} = \beta_0 e^{\beta_1 len+\beta_2 str+\beta_3 e\lg+\beta_4 e\lg+\beta_5 mic+\beta_6(mic^2)+\beta_7 rd+\beta_8(+b)+\beta_9 trash}\varepsilon$$

$$P_{Rajasthan} = e^{\beta_0+\beta_1 len+\beta_2(len^2)+\beta_3 str+\beta_4 e\lg+\beta_5 mic+\beta_6(mic^2)\beta_7 rd+\beta_8(+b)+\beta_9 trash+\beta_i market_i}\varepsilon$$

Each model was estimated with ordinary least squares, and tested for heteroscedasticity. Generalized least squares was applied when groupwise heteroscedasticity was detected, and the Huber/White/sandwich estimator was used in cases of non-groupwise heteroscedasticity. $R^2$ values for the models for the 5 states ranged from 0.25 to 0.70 (adjusted-$R^2$ ranged from 0.19 to 0.68).

With only one exception, the signs were as expected for all the variables with significant (at the 5 percent level) parameter estimates. Fiber length and reflectance were the variables most consistently determined to have a significant impact on cotton prices. In four out of 5 states examined, length and reflectance had significant parameters in the estimated models. Micronaire was the next most typically significant attribute (3 out of 5 models). Trash content and strength were not significant in any model.

The model for Gujarat was the only model where the sign of significant parameter estimate was not as expected. The estimate for the parameter on yellowness (+b) has a counter-intuitive sign ($\beta_{+b} > 0$, indicating a preference for discolored cotton). However, the Gujarat model was also the one showing the weakest relationship between price and attributes (adjusted-$R^2$ of 0.19), and the only model for which fiber length did not have a significant parameter estimate.

Indian farmers market cotton before ginning, so the prices recorded for this study are in rupees per quintal of seedcotton. Previous hedonic models for cotton have examined U.S. cotton, which is marketed as lint after having been ginned. In the discussion below, model results are converted to fiber ("lint") equivalents to facilitate comparison with earlier work.[vi]

Punjab

The estimated model for Punjab showed the second strongest relationship between price and attributes of the 5 states in this study (table 3). $R^2$ was 0.58 (adjusted $R^2$ = 0.55). The data from different marketplaces was distinct both in terms of mean prices (with significant values for most of the marketplace dummies) and with respect to the error terms. Levene's test for homogeneity indicated significantly different variances for the errors when grouped by marketplace, and generalized least squares was used to correct for heteroscedasticity when estimating the Punjab model. Quadratic terms were included for both length and micronaire (squared length and micronaire variables were included in the model) since models without these variables failed Ramsey's reset test. Examination of the variance inflation factors (VIF) for these variables indicated significant collinearity. The parameters for both micronaire and micronaire-squared were not significantly different from zero, so principal component analysis was used to reduce this pair of variables down to one factor that accounted for 99 percent of their total variance. While the VIF for length and squared length were still extremely high (>350) after this adjustment, reducing the two length variables to one factor did not result in any other variables changing sign or significance. This latter specification also realized less favorable results in information criteria and was misspecified according to the Ramsey Reset test.

Table 3--Estimation results for hedonic price model: Punjab

| Variable or statistic | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| Len | 2.955 | 0.699 | 4.230 | 0.000 |
| len2 | -1.278 | 0.333 | -3.840 | 0.000 |
| Str | -0.001 | 0.002 | -0.550 | 0.583 |
| Elg | 0.020 | 0.012 | 1.670 | 0.097 |
| mic3 | 4.1E-04 | 0.001 | 0.580 | 0.565 |
| reflectance | 0.003 | 0.001 | 2.310 | 0.022 |

| | | | | |
|---|---|---|---|---|
| yellowness | 0.002 | 0.004 | 0.450 | 0.654 |
| Trash | 0.003 | 0.014 | 0.200 | 0.842 |
| date_1 | -0.016 | 0.006 | -2.470 | 0.015 |
| date_3 | -0.048 | 0.015 | -3.290 | 0.001 |
| date_4 | -0.030 | 0.013 | -2.410 | 0.017 |
| _cons | 5.613 | 0.386 | 14.540 | 0.000 |
| | | | | |
| R-squared | 0.587 | -- | -- | -- |
| Adjusted R-squared | 0.555 | -- | -- | -- |
| Sum squared resid | 0.092 | -- | -- | -- |
| F-statistic | 17.990 | -- | -- | 0.000 |

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Punjab had the largest number of observations for any state among the 5 studied. Punjab cotton's average micronaire and trash were the second-highest of any state (table 4), with the former not unexpected given that Northern Zone cotton is typically coarser than cotton from other regions of India. The average length was 1 2/32s inches (34/32), which close is the international standard of 35/32. The estimated discount between staple 34 and 30 was 3.6 cents, which was smaller than the base grade discount in the U.S. loan schedule, which was 5.5 cents. Reflectance had a significant impact on price, but not yellowness or trash.

Table 4--Summary statistics on cotton quality data[1]

| | Attributes: | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | LEN | STR | ELG | MIC | Reflec-tance | Yellow-ness | trash | price |
| Mean: | inches | grams /tex | Percen -tage | µg/in ch | Rd | +b | Percen -tage | rupees/ quintal |
| Punjab | 1.06 | 20.26 | 5.66 | 4.52 | 74.61 | 8.71 | 0.42 | 1,984 |
| Haryana | 1.05 | 20.17 | 5.65 | 4.59 | 73.40 | 8.22 | 0.41 | 2,011 |
| Rajasthan | 0.92 | 17.97 | 5.18 | 4.49 | 69.55 | 8.73 | 0.40 | 1,702 |
| Karnataka | 1.21 | 22.39 | 6.23 | 3.24 | 77.78 | 7.83 | 0.43 | 2,110 |
| Gujarat | 1.08 | 19.26 | 5.63 | 3.45 | 72.43 | 9.76 | 0.39 | 1,835 |
| | | | | | | | | |
| Standard deviation: | | | | | | | | |
| Punjab | 0.08 | 1.49 | 0.34 | 0.68 | 2.85 | 1.08 | 0.17 | 116 |
| Haryana | 0.05 | 1.29 | 0.35 | 0.40 | 2.11 | 0.47 | 0.20 | 10 |
| Rajasthan | 0.07 | 1.98 | 0.43 | 1.09 | 3.94 | 0.61 | 0.17 | 146 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Karnataka | 0.06 | 1.33 | 0.20 | 0.32 | 2.61 | 0.56 | 0.15 | 104 |
| Gujarat | 0.20 | 3.53 | 1.02 | 0.82 | 11.84 | 1.76 | 0.18 | 408 |
| Observations: | | | | | | | | |
| Punjab | 151 | | | | | | | |
| Haryana | 43 | | | | | | | |
| Rajasthan | 124 | | | | | | | |
| Karnataka | 67 | | | | | | | |
| Gujarat | 126 | | | | | | | |

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[1]Note that ICC calibration values for staple length and strength are not exactly equivalent to HVI values.

## Haryana

Haryana is another Northern Zone state, and the average micronaire of the samples from Haryana was the highest of this study (table 5). The relationship between price and attributes for Haryana's cotton was relatively weak, with an $R^2$ of 0.52 (adjusted $R^2$ = 0.41). Like Punjab, length and reflectance were the only variables with significant parameter estimates. While significant, the estimated value for the responsiveness of price to length was low. As a result, the estimated discount from staple 36 to 30 was a negligible 0.6 cents/pound.

Table 5--Estimation results for hedonic price model: Haryana

| Variable or statistic | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| len | 0.052 | 0.017 | 3.100 | 0.004 |
| str | -0.001 | 0.001 | -1.420 | 0.163 |
| elg | -0.004 | 0.002 | -1.910 | 0.064 |
| mic | 0.003 | 0.002 | 1.640 | 0.111 |
| rd | -0.055 | 0.017 | -3.190 | 0.003 |
| rd2 | 0.000 | 0.000 | 3.190 | 0.003 |
| b | 0.000 | 0.001 | 0.060 | 0.949 |
| trash | 0.001 | 0.003 | 0.210 | 0.838 |
| _cons | 9.577 | 0.625 | 15.330 | 0.000 |

| | | | | |
|---|---|---|---|---|
| R-squared | 0.524 | -- | -- | -- |
| Adjusted R-squared | 0.412 | -- | -- | -- |
| Sum squared resid | 0.001 | -- | -- | -- |
| F-statistic | 4.680 | -- | -- | 0.001 |

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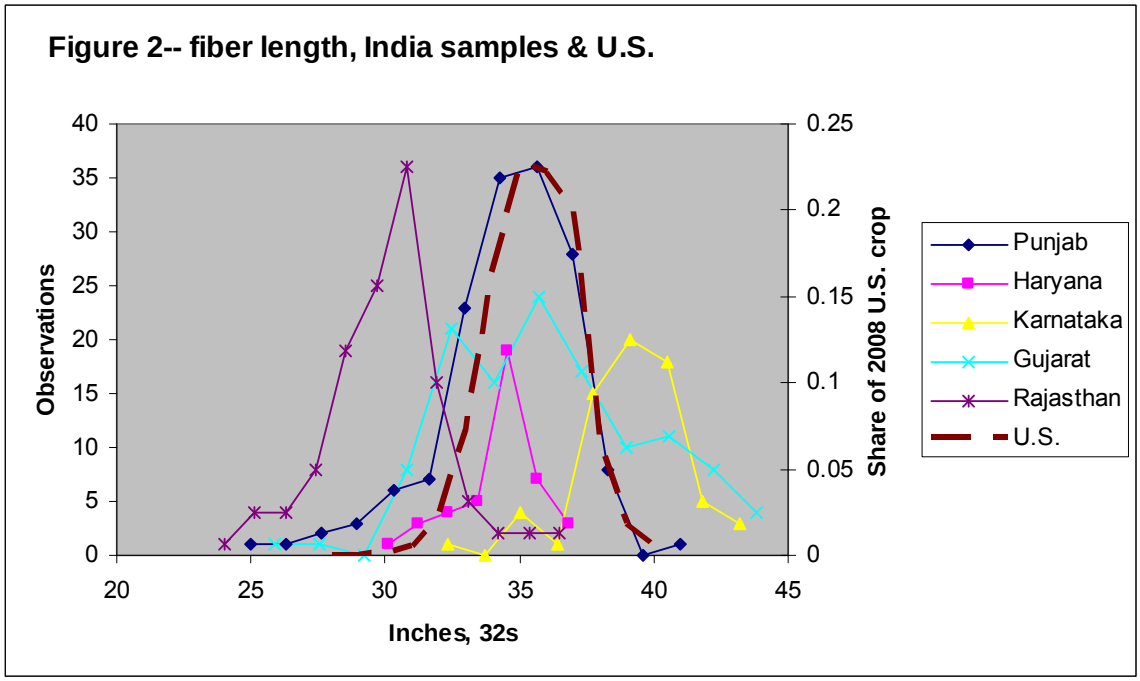
Only 43 observations were recorded for Haryana, and the variance of the prices recorded was by far the lowest of any state. Only two markets were visited in Haryana to collect data, and the sample may have been too small to avoid the idiosyncratic impact of unobservable variables like the reputation of sellers.

Rajasthan

Rajasthan is also an irrigated, Northern Zone producer, with high micronaire, and relatively short-staple cotton. Samples from Rajasthan were the shortest on average, 24 percent shorter than Karnataka's, and well below the international standard at 30/32s of an inch (figure 2). Price and attributes had the strongest relationship in Rajasthan of all the states, with an $R^2$ of 0.70 (adjusted $R^2$ = 0.68). Other than Punjab, Rajasthan was the only other state where there were any significant differences in the mean values between marketplaces or days, but there was no indication of heteroscedasticity.

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The resulting model shows both length and micronaire and their squared values significantly affecting price (table 6). The estimate for the impact of reflectance was also significant.

For length, the estimated discount from 36/32 to 30/32 inches is 7.2 cents/lb, larger than the U.S. loan schedule (5.5 cents). The estimated discount for a change in micronaire from 3.5 µg to 2.5 µg is 1.7 cents, considerably smaller than the U.S. loan schedule for base grade (9.25 cents), but closer to the average received by the Texas-Oklahoma crop in recent years (4.7 cents)(Sanders et al). Texas cotton in 2003 averaged micronaire of 4.4 µg, quite close to Rajasthan's 4.5 µg.

Table 6--Estimation results for hedonic price model: Rajasthan

| Variable or statistic | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| Len | -4.795 | 1.922 | -2.490 | 0.014 |
| len2 | 2.670 | 1.021 | 2.620 | 0.010 |
| Str | 0.000 | 0.003 | 0.000 | 0.997 |
| Elg | 0.015 | 0.014 | 1.080 | 0.281 |
| Mic | 0.087 | 0.035 | 2.440 | 0.016 |
| mic2 | -0.009 | 0.004 | -2.260 | 0.026 |
| Rd | 0.009 | 0.002 | 4.940 | 0.000 |
| B | 0.002 | 0.008 | 0.270 | 0.788 |
| Trash | -0.013 | 0.028 | -0.450 | 0.653 |
| Date_1 | 0.103 | 0.011 | 9.510 | 0.000 |
| _cons | 8.607 | 0.899 | 9.570 | 0.000 |
| | | | | |
| R-squared | 0.704 | -- | -- | -- |
| Adjusted R-squared | 0.677 | -- | -- | -- |
| Sum squared resid | 0.260 | -- | -- | -- |
| F-statistic | 26.580 | -- | -- | 0.000 |

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Gujarat

The weakest relationship between price and attribute levels was observed in Gujarat, with an $R^2$ of 0.26 (adjusted-$R^2$ = 0.20). Gujarat's was the only model lacking a statistically significant parameter with respect to any length variable, and the only model with a statistically significant but counter-intuitive sign for any quality attribute (table 7).

The number of observations for Gujarat is relatively high (126), but there are indications of quality problems with the cotton sampled in Gujarat. Micronaire is exceptionally low for the varieties grown there, indicating likely immaturity. The averages also indicate the most discoloration of any of the states examined in this study. The variability across all variables, including price, was typically the highest of all states in the Gujarat sample. Data from one market, Karjan, showed less variability than average across the state, and Levene's test for homogeneity showed the variance of the estimated errors for data from

this market was significantly different from the data from the other 4 markets sampled in Gujarat. The model was estimated with generalized least squares to correct for heteroscedasticity.

Table 7--Estimation results for hedonic price model: Gujarat

| Variable or statistic | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| Len | 0.089 | 0.192 | 0.460 | 0.644 |
| str | 0.003 | 0.011 | 0.260 | 0.797 |
| elg | -1.267 | 0.404 | -3.140 | 0.002 |
| mic | 0.538 | 0.204 | 2.630 | 0.010 |
| mic2 | -0.063 | 0.026 | -2.410 | 0.018 |
| rd | -0.002 | 0.004 | -0.470 | 0.638 |
| b | 0.043 | 0.014 | 3.000 | 0.003 |
| trash | 0.052 | 0.066 | 0.790 | 0.433 |
| elg2 | 0.116 | 0.036 | 3.230 | 0.002 |
| _cons | 9.392 | 1.181 | 7.950 | 0.000 |
| | | | | |
| R-squared | 0.259 | -- | -- | -- |
| Adjusted R-squared | 0.199 | -- | -- | -- |
| Sum squared resid | 1.606 | -- | -- | -- |
| F-statistic | 4.320 | -- | -- | 0.000 |

(E:\India\Results\Model_results5.xls)

The estimated discount for micronaire from 3.5 µg to 2.5 µg is 10.1 cents, a larger discount than estimated for the Karnataka and Rajasthan, but close to the U.S. loan rate discount schedule. Micronaire and micronaire-squared were highly collinear (VIF > 175), but reducing them to one factor had no notable effect on the other parameter estimates, and the model with this alternative variable achieved a notably less favorable Akaike information criterion value.

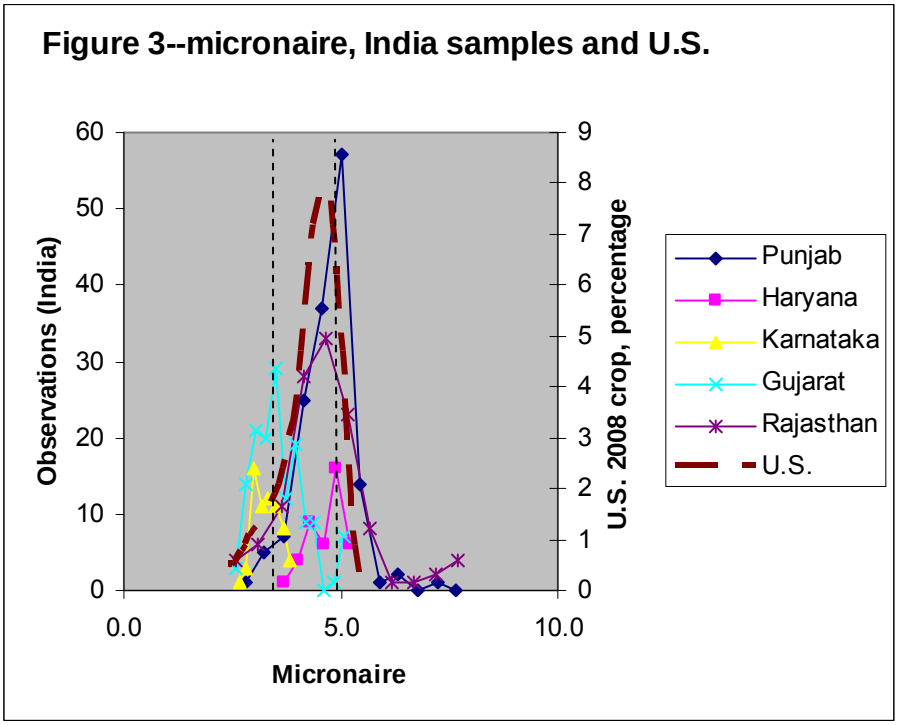
Karnataka

Karnataka represents India's southern growing zone in this study, and cotton cultivation there is quite distinct from the other states studied in terms of both the timing of cotton cultivation and the varieties grown. Karnataka also differs from Gujuarat and the northern states studied in that it is located in the region where most of India's cotton is consumed. Varieties in the region also tend to have greater fiber length and fineness, and all of India's *G. barbadenese* (extra-long staple, or ELS) cotton is grown in this region.

The model estimated for Karnataka showed a relatively strong relationship between price and attributes, with an $R^2$ of 0.54 (adjusted-$R^2$ of 0.48). Karnataka and Rajasthan had the broadest range of attribute variables that had statistically significant parameter estimates, including reflectance as well as length and micronaire (table 8). As was the case with Gujarat and Rajasthan, the 2 collinear micronaire variables resulted in much more preferable model according to information criteria than did the single-factor micronaire variable, and did not seem to affect the other parameter estimates despite their collinearity.

Micronaire was discounted 2.9 cents from readings of 3.5 µg to 2.5 µg. This is low, but note that the distribution of micronaire in this sample is consistent with a much lower mean micronaire, and the discount in this region would be less (figure 3). Length discount from 34 to 30 is 4.7 cents, similar to the U.S. loan schedule. The discount for 38 staple to 34 staple of 3.4 cents is larger than the U.S loan schedule (1.4 cents), but this average length of the samples from Karnataka was significantly longer than the U.S. base

grade. Buyers of cotton from these markets in Karnataka would be counting on it falling into this higher range, and would more heavily discount shorter staples.




(E:\India\Results\cleaned data with dumimies - regression_MACD_092909.xls)

Table 8--Estimation results for hedonic price model: Karnataka

| Variable or statistic | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| len | 0.432 | 0.082 | 5.270 | 0.000 |
| str | 0.002 | 0.005 | 0.450 | 0.656 |
| elg | -0.015 | 0.026 | -0.560 | 0.576 |
| mic | 0.567 | 0.274 | 2.070 | 0.043 |
| mic2 | -0.087 | 0.041 | -2.100 | 0.040 |
| reflectance | 0.009 | 0.002 | 4.940 | 0.000 |
| yellowness | -0.005 | 0.009 | -0.620 | 0.539 |
| trash | -0.096 | 0.031 | -3.110 | 0.003 |
| _cons | 5.672 | 0.519 | 10.920 | 0.000 |
| | | | | |
| R-squared | 0.544 | -- | -- | -- |
| Adjusted R-squared | 0.481 | -- | -- | -- |
| Sum squared resid | 0.072 | -- | -- | -- |
| F-statistic | 8.650 | -- | -- | 0.000 |

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## Discussion

In the 5 Indian states studied, the estimated relationships between cotton characteristics and price indicate that transmission of demand for product attributes is weaker than in the United States. The U.S. market serves as the basis of comparison due to the availability of studies there. Also, the complete adoption of HVI testing has both broadened and deepened the link between cotton quality and price in the United States, making it an appropriate benchmark. This study's estimates of the implied premiums and discounts for length and micronaire in Rajasthan, Karnataka, and Punjab were consistent with those for comparable cotton in the United States. This indicates that the market in India for directly observable cotton attributes is functioning to some extent. However, the $R^2$ for the models estimated for these states averaged 0.61, well below the estimates realized in virtually every study on U.S. cotton.[vii] Bowman and Ethridge (1992) found an $R^2$ for their demand model of 0.87, but their approach was the most dissimilar to this study's out of the past work examined. Other past studies of U.S. cotton have like this one estimated separate models for different producing regions. Ethridge and Davis'(1982) study found model $R^2$s with a range of 0.76 to 0.91. Chen, Ethridge, and Fletcher (1997) had a range of 0.63 to 0.86. Ethridge, Swink, and Chakraborty (2000) had a range from 0.43 to 0.63 Lyford, Jung and Ethridge (2004) ranged from 0.51 to 0.88, and with most well above 0.60.

Similarly, most studies of other agricultural products have also found a stronger relationship between variation in the attributes of goods and their prices than has been observed for Indian cotton. Rudstrom's (2004) study of hay prices had an $R^2$ of 0.99. These prices were gathered at auction sites where hay was tested just before auctioning. Chavas and Kim's $R^2$s for time series models of diary products range from 0.68 to 0.98. Coatney et al. had a system-weighted $R^2$ for feeder cattle resulting from three-stage least squares of 0.51. The lowest $R^2$ found was Jones et al (1991) who reported adjusted $R^2$s of 0.39 and 0.29 for models of prices of steers and heifers, respectively. Based on these results, Jones et al concluded that the linkages between prices and quality were poor for U.S. cattle markets. Note that the studies with the weakest observed qualtity-price relationship are both for cattle, where, like unginned seed cotton, the attributes of the product realized through processing are difficult to assess at the point of sale.

## Indian Cotton Production and Marketing

The relatively weak linkage between cotton attributes and seedcotton prices is reflected in India's reputation and performance on world markets. Indian cotton often trades at a discount to otherwise similar growths, in part due to the relative newness of large-scale Indian exports and contract sanctity issues, but also due to the characteristics of Indian cotton. ITMF biannual surveys through 2007 consistently reveal that Indian cotton is among the most contaminated in the world (ITMF, 2008).

Ginners market cotton fiber, and it is only at this stage, after the cotton has changed hands perhaps several times, that the attributes can be fully assessed. Thus, cotton does not receive any formal classing until well after it has been sold by the farmer. While a number of mills and research institutions have HVI units, only a small proportion of the crop is instrument classed, so manual classing still accounts for most of the quality assessment of Indian cotton domestically.

## Sources of Improvement

Experiences in other countries suggest avenues for improved linkages between price and quality. China embarked on an expansion of its inspection system in 2005, and in 2008 made international bale size and government HVI classing preconditions for acceptance of cotton into the reserves established by the government for price support. With world cotton prices low due to the world financial crisis, about 70 percent of all cotton in Xinjiang, China's largest cotton producing province, received HVI classing to ensure that sales to the reserves were an option. China's Agricultural Development Bank has also at times linked the receipt of preferential loans to subsequent documentation of classing of the cotton produced.

The ascendance of public classing in the United States was also facilitated by government policy, with AMS classing a precondition of participation in the U.S. Department of Agriculture's cotton support programs. The advent of HVI classing was an important development, especially for cotton from Texas which is now the largest cotton producer

in the United States. Objective measurement improved grower returns in the region, sustaining production. Large merchants maintained independent classification systems through the 1990's, but in recent years these have largely disappeared in the United States, and all transactions rely on AMS HVI data.

One important difference between U.S. and Indian cotton is that U.S. farmers market the fiber after ginning, rather than the combination of fiber and seed before ginning, as occurs in India. The experience of U.S. cattle producers indicates the difficulty of matching sellers of an unprocessed good with the needs of consumers of the processed good. In China, however, the similarity in that farmers sell cotton before processing has not prevented the increased role of classing in the cotton sector.

While a number of the practices that damage the quality of Indian cotton seem distinct from issue of how farmers are paid for cotton, the strengthening of the price-quality linkage at the marketing yard level could be stimulate the development of institutions that change practices elsewhere. The transformation of the U.S. cotton industry in the middle of the 20$^{th}$ century involved transformation of the seed industry as well. The opportunities offered by improvement in one segment of the cotton industry can provide incentives for improvement elsewhere in the supply chain.

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[i] The cotton industry's term of art for inspecting and grading cotton is "classing." The process of classing is described below.

[ii] Fineness an important measure of yarn quality, and is measured as its "count." Count (symbolized by Ne in the English system used for cotton and polyester) is a function of the ratio of weight to length, so the finest yarns have the lowest counts. Count measures the number of "hanks" (840 yards) of yarn per pound. Yarn counts range from 10 Ne and below for canvas, denim, and towels, 20 to 40 for most products, and up to 240 for fine fabrics.

[iii] Cotton requires 1900 degree-days to mature, and the absence of minimum temperatures below 10-14 degrees C (Wright and Sprenkel, 2005). Assuming cotton production only occurs where these conditions are met, water can be considered the limiting factor.

[iv] Note the calibration mode of the instruments was the International Calibrated Cotton (ICC) mode used for 90 percent of India's domestic cotton trade (Hindu Business Line, 9/5/2006). Since 1996, in the United States and most other countries, calibration has been based on the HVI mode. ICC calibration cotton has produced by the Central Institute on Cotton Technology since USDA's Agricultural Marketing Service ended its sales of ICC calibration samples.

[v] Lord (2003) demonstrates the non-linearity of cost functions for yarn production (page 311).

[vi] Conversion was accomplished based on the following relationship: if the prices of seedcotton, cottonseed, and lint are indicated, respectively, by $A$, $B$, and $C$; the proportions of cottonseed and lint in seedcotton are $\alpha$ and $\beta$; and the cost of processing (ginning) is $P$, then the value of seedcotton is:

$A = \alpha B + \beta C - P$, and $C = \dfrac{A - \alpha B + P}{\beta}$. Estimated values of the $\alpha$, $\beta$, $P$, and basis for local cottonseed prices were collected from industry sources and 2006/07 cottonseed prices were retrieved from Indian Department of Agriculture and Cooperation website (http://dacnet.nic.in/).

[vii] While the limits of R2 as a metric of model suitability and fit are well known, it is a widely reported statistic, allowing comparison between studies.