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

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

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Abstract

India is the world's second largest exporter of cotton, but quality problems with Indian cotton are evident in surveys of international textile mills and the discount Indian cotton receives on world markets. 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. Fiber quality attributes measured by High Volume Instrumentation (HVI) were found to account for about 50 percent of the variation in observed prices. Comparable studies in the United States have determined quality attributes can account for about 75 percent of price variation.

Cotton appears relatively undifferentiated compared with breakfast cereals or automobiles, but the attributes of cotton are crucial to its users and can vary considerably. 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 (GM) 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.

What is the Issue?

India has become the world's second largest producer and exporter of cotton, but its cotton remains among the most contaminated in the world according to international surveys of textile mills. Indian cotton also typically trades at a discount on world markets. Opportunities may exist to improve the incomes of cotton producers in India and of global cotton consumers by improving the communication of consumers quality needs to the farm level. Other industries and other countries have faced similar problems and developed public and private market institutions to facilitate solutions.

What Did the Study Find?

The linkage between prices paid for cotton in India's marketing yards and the quality of the cotton is weaker than the linkages for cotton in the United States, and also weaker than those documented for many other agricultural products. Fiber attributes measured by High Volume Instrumentation (HVI) were found to account for about 50 percent of the variation in observed prices. Comparable studies in the United States have determined attributes can account for about 75 percent of price variation.

How was the Study Conducted?

Transaction prices were recorded at 19 marketing yards in 5 Indian states, and samples of the cotton traded were instrument tested for quality. Hedonic price models were estimated for each state, and the results compared with previous studies of cotton and other products. The mechanisms of price-quality communication in other cotton producing countries and in other agricultural industries were also examined to consider their applicability to India's cotton sector.

Introduction

Markets use prices as signals to allocate resources efficiently. The result is the maximization fare given the available technology, factors of production, and natural resources. Economics typically examines this phenomenon as optimizing 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. The shift in relative prices and output in recent years as high energy prices and policies favoring biodiesel illustrates this. In 2006 and 2007, world vegetable oil prices soared. Subsequently, global output among the world's 4 major oilseeds shifted, with production of the higher oil content oilseeds like canola and sunflower rising more than soybeans and cottonseed (Table 1).

Table 1--World production changes of top four oilseeds and oil their content

	Oil content	Change from 2005 to 2008
	Percent	Percent
Rapeseed	40	22
Sunseed	38	19
Cottonseed	22	-7
Soybean	19	-3

Sources: USDAd and Scharnow,
(E:\Commodities\Oilseeds\Oilcontent_versus_production_1109.xls)

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. U.S. cattle marketing shifted first from live-weight pricing to dressed-weight pricing, and more recently to value-based or "grid" pricing. Grid pricing relies on traceability back to producers to ensure that after processing packers can vary prices depending on the yield of valuable attributes of cattle that cannot be discerned before processing. Grid pricing has come to account for a substantial share of U.S. cattle marketings. Certification programs administered by USDA but developed and controlled by producer groups have also grown in importance, accounting for 12 percent of all commercial cattle marketed in 2002. Process verification has been applied on a limited scale in the United States, but is in wider use by Australia's export-oriented cattle industry. In the United States, marketing contracts are also growing in importance, but this kind of contracting still remains limited. The U.S. pork industry on the other hand has become much more vertically integrated in part to improve this communication between packers and livestock producers from the marketplace (Martinez et al 1998).

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. Merchents accumulated cotton from farmers, tested it for quality[1] 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, and the quality of U.S. cotton was steadily declining through the latter half of the 19th century and early 20th century. The average length of U.S. cotton fibers fell 12 percent between 1880 and 1930 (Olmstead and Rhode, 2003). A post-Civil War reduction in the scale of production in farming and increased scale in ginning became part of a viscous circle in marketing and seed breeding. As cotton farms became smaller, steam-power meant gins became larger, processing for many farms and mixing their seeds. Merchants purchased cotton in local markets through "pooling," in which the same price was offered to all producers based on a sample of a few local bales.

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 cloth and apparel (PCCA, 2010).

India's Cotton Market

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.

In 2005, the United States relinquished its longstanding position as the second largest cotton producer in the world to India. India's role in the global cotton market has been substantially transformed in recent years, thanks in part to the introduction of Bt cotton. India's share of world cotton production has soared from 12 percent in 2002 to 23 in 2009 (USDAc, 2009). India has become the world's second largest exporters of raw cotton, usurping the longstanding role of Uzbekistan. India's textile production has also soared , partly in response to global textile trade liberalization, but also in response to rapidly growing domestic incomes. A liberalization process that began in the early 1990's has culminated in one of the highest GDP growth rates in the world, and has seen a transformation of India's clothing industry away from home and local production and informal marketing towards a growing reliance on ready-made garments and marketing through department stores and retail shops and chains. The process is far from complete, with a 2008 Ministry of Textiles survey indicating that two-thirds of men's shirts are

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

stitched at home or by local tailors rather than purchased as ready-made garments (Ministry of Textiles, 2009).

India has also become the world's largest exporter of yarn and the second largest exporter of fabric. The greater role for exports and higher-income domestic consumers in India's textile sales increases the importance of quality. Defects that might be acceptable or negotiable in lower quality fabric can mean complete rejection by consumers and textile mills producing higher quality products. The status of India's cotton quality is to some extent indicated by its persistent presence as one of top ranked sources of contaminated cotton by the International Textile Manufacturers Federation's mill surveys over the last 10 years (ITMF, 2008).

Substantial concern has been also been evinced by components of India's textile industry about India's cotton quality, but formal explorations of the relationship between the supply and demand of cotton quality in India have not been undertaken to date. This study fills that gap in the literature, by formally testing the role of markets in determining Indian cotton quality and then reviewing the characteristics of Indian cotton production and processing associated with market performance.

The Transformation of Cotton Fiber into Textile Products

Achieving an understanding of how the textile industry utilizes fiber, and how quality is measured is the first step to fully understanding how India's market for cotton quality does or does not function, and its potential future direction.

Cotton is primarily used as in input into yarn production. Cotton accounts for 40-60 percent of the cost of yarn production[2], with the lowest cost shares in higher-income countries with higher costs for labor, energy, and capital (ITMF, 2003). Weaving and knitting then transforms yarn into fabric and fabric is used to produce clothing and other consumer goods.. The characteristics of the yarn affect the appearance of the fabric and its tactile characteristics. The yarn's characteristics also affect the profitability of fabric production: the strength of the yarn determines the speed of weaving; the uniformity of the fiber, its maturity, and the absence of foreign matter determine the uniformity of dying; and the fineness and smoothness of the yarn determines the feel or "hand" of the fabric.

Yarn is a continuous strand of overlapped and twisted fibers (Ethridge, 2005)[3]. Twisting enables inter-fiber friction to result in self-locking compression of the yarn when stretched. The conversion of cotton to yarn involves opening, cleaning and blending raw fibers, and then carding them into an untwisted bundle of parallel fibers. This cord of fibers is subjected to drawing to improve the evenness of the fibers, and then in the most common yarn production technology (ring spinning), the cord is given a slight twist and wound on a package before being placed on the spinning frame. The yarn is then twisted again and wound onto another package (the bobbin) which is an integral part of the

[2] Reportedly, some of the most advanced mills have 70 percent of their costs in the form of fiber (Lord).
[3] Ethridge's description of cotton spinning is the source of this and the following paragraph.

spinning process. A ring spins around the bobbin imparting the twist. The physical limitations on bobbin size and speed are limiting factors in the speed of ring spinning, and speed is a factor in the cost of yarn production. An additional step of combing out short fibers can be added between carding and drawing, and the smoother combed yarns receive a premium compared with carded yarns, but entail a greater loss of fiber.

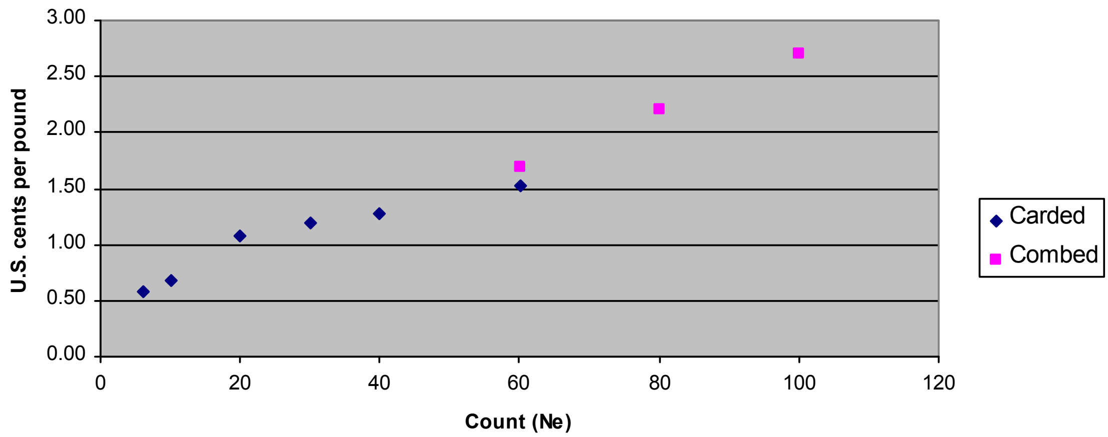
Since its introduction in the early 1970's, a more high-speed technology—rotor, or open-end, spinning—has come to account for almost 20 percent of the world's cotton yarn, including much of the yarn used for denim. Rotor spinning takes the cord of fibers after drawing and feeds it directly into the spinning process. Twist is formed by a rapidly turning grooved rotor, and the name open-end is applied because the end of each fiber separates from the others before it is incorporated into the yarn. Fibers in ring-spun yarn never lose contact with one another. Yarn comes from the rotor ready to be wound onto a package suitable for weaving or knitting, in contrast to ring-spinning which is only ready for further use after the third time it is wound. Rotor spinning is 10 times faster than ring spinning and 25 percent less expensive.[4] However, ring spun yarns are generally of higher quality, with greater strength and preferable tactile qualities.

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[5]. 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.

[4] The United States has the highest share of rotor spinning outside of Eastern Europe in its textile industry (44 percent, ICAC, 2009). In the United States, ring-spinning is used exclusively for yarn counts of 36 and above. Both technologies are used in the most common yarns produced in the United States, the 16 to 25 count yarns that account for about 45 percent of all yarn. However, rotor spinning is relatively uncommon outside of Europe (including Turkey) and North America, so even the coarsest yarn counts are produced with ring spinning throughout much of the world.

[5] 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.

Figure 1-- yarn prices by count



Source: Ministry of Textiles, India. Prices in Coimbatore, Tamil Nadu, September 29, 2009.

(E:\India\yarn prices.xls)

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. In India, where they are most widely grown, varieties of these species are collectively referred to as "desi" cotton, and typical fiber length is less than 1 inch (21 to 23 millimeters)[6]. *G. hirsutum* accounts for about 98 percent of the world's cotton (*G. barbadense* accounts for nearly all the rest), and is typically referred to as upland or American upland cotton. In the United States, upland cotton typically has fibers of 1-2/16th inches (i.e. 36 staple), while global trading is based on fibers of 1-3/32s inches (or 35 staple). USDA's Agricultural Marketing Service reports that 126 varieties of upland cotton were planted in the United States in 2009, but 14 varieties accounted for 69 percent of the area planted (USDA, 2009b mp_cn833). Three varieties accounted for 34 percent of all area planted: Delta-Pine 555 BG/RR (16 percent of U.S. area), and FiberMax 9058 F and FiberMax 9063 B2F (9 percent each).

However, U.S. cotton is generally marketed to textile mills according to its region of origin, as well as other measurable characteristics. In part this may reflect regional

[6] By convention, fiber length is often measured as a the number of 32's of an inch. So desi cotton has a staple length of less than 32, while the predominant length for the U.S. crop in recent years is 36 (USDA, 2009b).

preponderance of certain varieties, but more importantly follows from the role of growing conditions and cultivation practices in determining cotton's attributes. The U.S. growths quoted on world markets illustrate this. Acala varieties from the San Joaquin Valley are typically the highest priced reflecting their fiber length but also the uniformity and maturity of this irrigated crop. Memphis/Orleans/Texas cotton is typically lower-priced than California/Arizona cotton of the same staple length or Eastern cotton. (Table2).

Table 2--U.S. cotton price quotes[1] in Far East ports, 2004-08.

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

	Memphis/ Orleans/Texas	Memphis, Eastern	California/ Arizona
	U.S. cents per pound		
2004	54	55	60
2005	58	59	63
2006	60	61	63
2007	73	74	76
2008	61	62	66

Source: *Cotton Outlook*, Cotlook Limited.
[1]Based on middling 1-3/32 inch cotton.

Growing conditions strongly influence the ability of the cotton plant to realize its genetic potential. Rainfall, temperature or degree-days, and soil conditions are important variables that are largely beyond producers' control. Producers often do have discretion with respect to the amount and timing of irrigation, weed control, insect control, and the regulation of plant growth. Harvest practices and post-harvest treatment or also crucial factors determining the characteristics of the cotton marketed by producers or ginners to textile mills.

Fiber length and maturity are largely determined by the availability of water.[7] 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.) However, even carefully regulated irrigation can be disrupted by late-season rainfall, which induces the production of additional fruit (bolls) at the expense of the maturation of the existing fruit. Cotton fibers are hollow, and the final stage of maturation is the thickening of the inner walls of the fiber, determining the final shape, strength, and dye-uptake of the fiber.

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.

[7] 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.

At harvesting, two key variables influence cotton quality. Timing is important since fiber quality begins to deteriorate 7 days after bolls open, depending on weather conditions. Open bolls are potentially subject to bacterial infection, seed-sprouting, changes in color, and leaching of protective waxes by rain. With hand harvesting (in developing countries, virtually all cotton is harvested by hand), labor availability can be a constraint. With mechanically harvested systems, harvesting capacity can also be a constraint, and rainfall can prevent machinery from entering fields. Another variable is the treatment of immature bolls. In developing countries, training of harvesting labor and incentives for farmers are necessary to keep mature and immature bolls separated. In some cases, farmers will collect unopened bolls and extract the immature fibers to boost yields. Mechanical harvesting is typically facilitated with harvest aid chemicals that help create crop uniformity. Hormonal aids induce boll opening and both hormonal and herbicidal defoliants induce abscission of immature bolls.

Seedcotton that has been mechanically harvested contains substantially more extraneous matter ("trash") than hand harvested cotton. Defoliation reduces the harvesting of leaves and the staining of cotton, but does not necessarily eliminate it. Horizontal spindle pickers are the most efficient in this respect, harvesting seedcotton with 15 percent trash compared with 35 percent for vertical spindle pickers, and 55 percent for stripper harvesting.[8] Hand harvesting results in 8 percent trash (Gillham, et al., 1995). Ginning removes much of this additional trash associated with mechanical harvesting, but this necessitates additional, costly equipment at the gin. Efforts to remove trash through ginning can also break fibers and introduce small-particle contamination that textile mills may find difficult to remove. 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).

Ginning separates cotton fibers from their seeds. Roller-ginning is an older, slower technology that stresses fibers less. ELS cotton is roller-ginned and most cotton in India is roller-ginned, the exceptions primarily in the Northern Zone. Saw-ginning has come to dominate ginning of upland (*G. hirsutum)* cotton around the world due to its speed and reduced power requirements. Speed has relevance to quality since stored seedcotton can be subject to deterioration, particularly if moisture is above 10-12 percent. Seedcotton is cleaned before ginning, but the inclusion of lint cleaners in a gin to remove trash after ginning is not universal. After ginning, cotton is compressed into bales, which shelters much of the fiber, but still requires appropriate storage and handling to preserve quality. The importance of proper storage is illustrated by comparing the cost of storing cotton to the cost of storing grain in the United States: cotton warehousing charges of $4 per bale month (Cargill, 2009) are more than 19 times higher than monthly storage charges for an equivalent weight of grain (Edwards, 2008).

[8] Vertical spindles are technology developed in the former Soviet Union and used in Central Asia in areas that continue to harvesting mechanically. Strippers harvest the entire plant and have traditionally been used primarily in West Texas. In recent years, some U.S. producers have embraced a combination o f ultra-narrow row cultivation and stripper harvesting.

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. While terminology like "middling" still used today were developed in Liverpool in the early 1800's, the terms were applied inconsistently from market to market. This led to an international agreement establishing the Universal Standards Agreement in 1923 (Deathridge, 2006). 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. Official classer determinations are made manually for leaf grade, and extraneous matter. Other instruments are available to test attributes like the presence of seed coat fragments, prevalence of short fibers, and fiber maturity (micronaire is an imperfect maturity measure), but not all of these have been incorporated into HVI, or are awaiting widespread adoption as official standards.

The United States is unusual in its adoption of public classing, and the extent to which HVI testing has come to dominate. Thanks to the long history of public classing the United States, and to the rich set of data generated by HVI classing, a number of studies have examined the role of cotton quality and attributes in U.S. cotton pricing. This study uses a smaller, unique data set for India to explore similar issues.

Measuring Quality-Price Linkages in India's Cotton Market

Hedonic Price Models

Economics is in part concerned with studying the satisfaction of demand through production, and this is generally thought of in terms of products or goods. Lancaster (1966, 1971) developed a model of consumer utility based on the attributes embodied in goods rather than on the goods themselves. This provides the foundation to examine the role of market forces in determining cotton quality.

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. Studies on the relationship between prices and quality (such as Waugh's 1929 study of vegetables and Griliches 1961 work on automobiles) preceded these theoretical developments. Further theoretical advances have established the neo-classical foundations of the relationship between consumer demand and producers' willingness to supply attributes (e.g. Gorman (1980), Arguea, Hsiao, and Taylor (1994), Pakes (2003), and Ekeland, Heckman, and Nesheim (2004)). Recent applications of hedonic price modeling to agricultural products includes Coatney, Mekhaus, and Schmitz (1996), Rudstrom (2004), and Chavas and Kim (2005).

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:

$$P_{cotton} = P_{yarn} MP_{z1} \frac{\partial Z_1}{\partial cotton} + P_{yarn} MP_{z2} \frac{\partial Z_2}{\partial cotton} + \dots\dots\dots + P_{yarn} MP_{zi} \frac{\partial Z_i}{\partial cotton},$$

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.[9]

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

[9] 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.

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[10]. 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). Furthermore, high micronaire cotton is discounted for its coarseness, and low micronaire cotton is discounted for immaturity. Premiums and discounts for micronaire are also specific to different varieties or growths of cotton, as indicated by the different discounts in the U.S. cotton support program for upland and extra-long staple (ELS) cotton (table 2)[11]. The upland discounts clearly illustrate nonlinearity, and the discounts for low micronaire ELS cotton are much larger. Based on pattern in the upland micronaire premium and discount schedule, for a model including $\beta_i$mic and $\beta_j$mic^2, $E(\beta_i) > 0$ and $E(\beta_j) < 0$.

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.

[10] Lord (2003) demonstrates the non-linearity of cost functions for yarn production (page 311).
[11] The loan schedule is based on the spot market prices collected and, in some cases, estimated by USDA's Agricultural Marketing Service. The spot price data's ability to correctly capture the value of combinations of attributes outside of the set determining the base grade has been criticized (see Hudson, Ethridge, and Brown, 1996). However, the general pattern shown here has been found elsewhere.

Table 2—2008-crop upland cotton schedule of premiums and discounts: micronaire differences

	Upland	ELS
Micronaire Reading	Cents/pound	Cents/pound
2.4 and Below	-9.6	-13.55
2.5 through 2.6	-9.25	-13.55
2.7 through 2.9	-6.95	-9.45
3.0 through 3.2	-4.05	-5.5
3.3 through 3.4	-2.45	-3.9
3.5 through 3.6	0	0
3.7 through 4.2 a/	0.15	0
4.3 through 4.9	0	0
5.0 through 5.2	-1.85	0
5.3 and Above	-3.25	0

a/ Premium applies only to selected cotton.

Source: Farm Services Administration, USDA.

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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.[12]

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

[12] 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 α and β; and the cost of processing (ginning) is P, then the value of seedcotton is:

$A = \alpha B + \beta C - P$, and $C = \frac{A - \alpha B + P}{\beta}$. Estimated values of the α, β, 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/).

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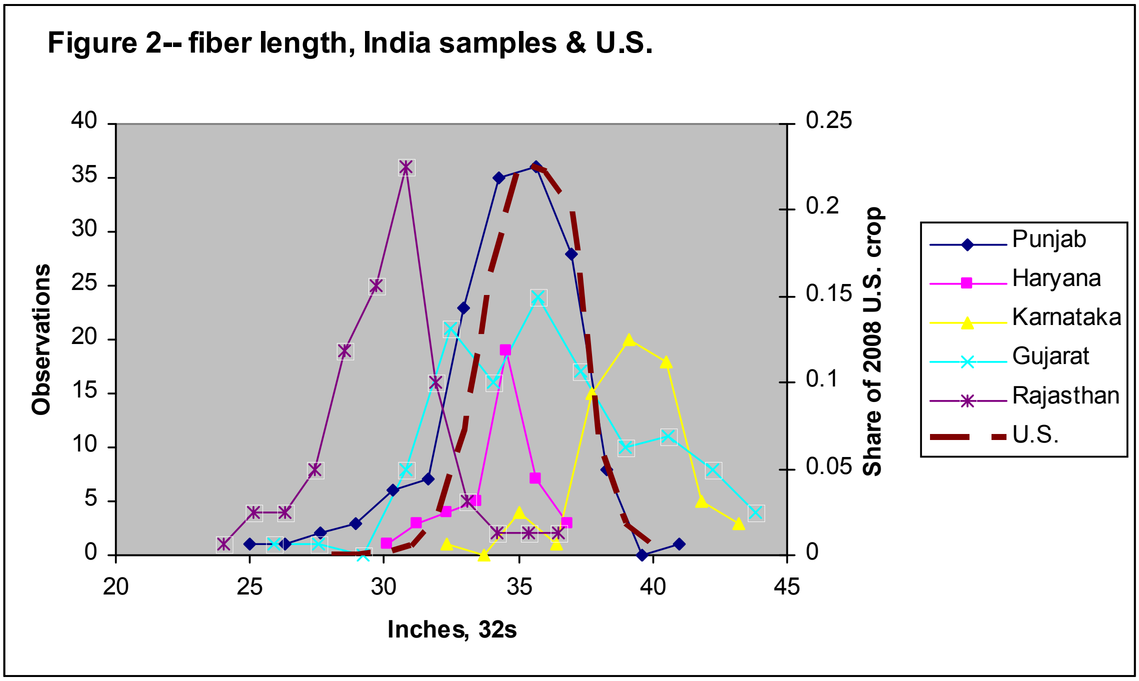
Only 43 observations were recorded for Haryana, and the variance of the prices recorded was by far the lowest of any state. Only two markets were visited in Haryana to collect data, and the sample may have been too small to avoid the idiosyncratic impact of unobservable variables like the reputation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

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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.

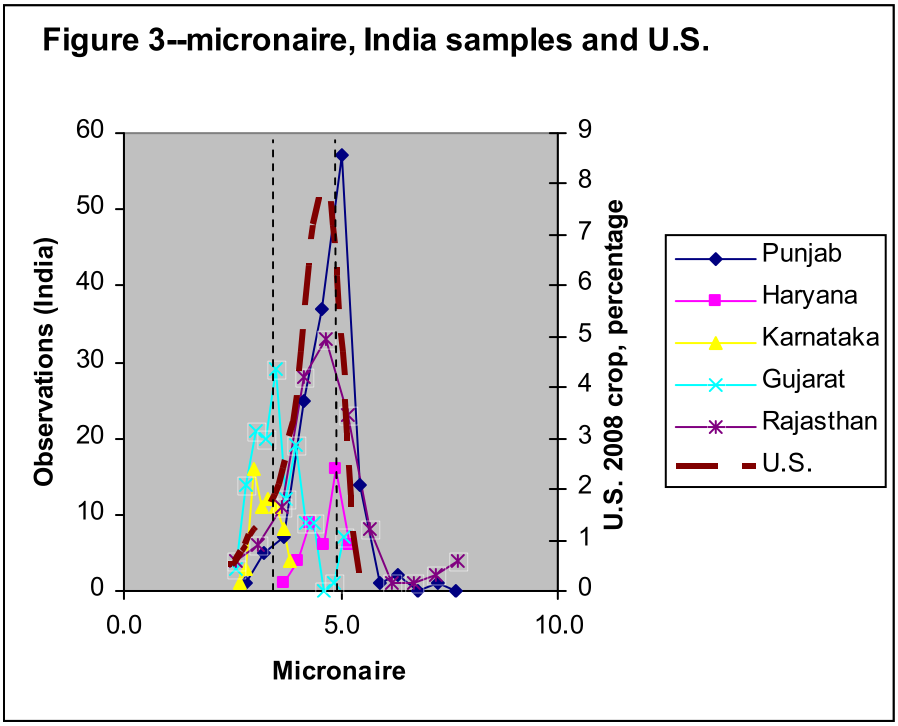

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Table 8--Estimation results for hedonic price model: Karnataka

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 have a median of 0.54, well below the estimates realized in virtually every study on U.S. cotton.[13] 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^2s 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. The median value for R^2 in these studies was 0.77.

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. Rustrom'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^2s 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^2s 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 quality-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.

The attributes that seem to have an impact on cotton prices in India are those most amenable to observation without instruments: length is relatively easily observed by experienced manual classers as is color, and manual classing is part of most cotton merchants' skill set. Fineness of cotton fibers is also observable without instruments to skilled observers, although micronaire is function of maturity as well as fineness. In four out of the five states, significant values were estimated for both length and color attributes. Micronaire was significant in the models for 3 states, and elongation was significant in only one state.

Previous studies exhibit a similar mix of variable significance, even with the prevalence of instrument classing in the United States. A number of studies fail to find significance for micronaire, while length less frequently insignificant and color is often significant. When strength is included in other studies, it is at least as often insignificant as significant (significant in only 4 of the 9 models estimated in Lyford, Jung and Ethridge, and 1 of 3 models in Ethridge Swink Chacrobarty) extraneous matter (as measured by leaf grade in U.S. studies) is significant more often than not. In this study, trash was not significant in any state's model, but the correlation between observable extraneous matter in unginned cotton and trash content after ginning may be particularly weak.

[13] While the limits of R^2 as a metric of model suitability and fit are well known, it is a widely reported statistic, allowing comparison between studies.

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). Growths from India often dominate the lists of the most contaminated, and never appear on the lists of least contaminated. As much as 40-50 percent of the samples of Indian cotton are described as "seriously contaminated" with strings of hessian or jute. By contrast, typically, 95 percent of the samples from the United States are described as uncontaminated.

Indian cotton production and domestic marketing contribute to the problems that result in these discounts. Indian cotton is generally of shorter staple length than the international standard, and India is also unique in producing a large volume of desi, or *G. arboreum* and *G. herbaceum*, cotton. The spread of GM cotton has raised the average fiber length and reduced desi's share of output. Desi cotton, in addition to being coarser and shorter often has problems with locules adhering to the fiber.

Despite the spread of GM cotton, other structural impediments to producing and marketing quality cotton exist. India has a large number of varieties, with 284 government approved GM varieties, 40 to 50 illegal GM varieties, and the non-GM varieties that make up the remaining 10 percent of planted area (USDA, 2010). Production is far less concentrated among the set of leading varieties than it is in the United States. This reduces the ability of any merchant to market large lots of uniform cotton.

The average Indian cotton farm is approximately 10 acres (4 hectares)(Quaim, 2003, and Bennet, et al, 2006), only little more than 30 percent of India's cotton area is irrigated, and there is very little mechanization. Most cultivation and all harvesting is done by hand. At times, there are as many as 6 pickings in a given year, and the quality tends to decline in later pickings as the share of immature bolls increases. Many farmers lack facilities for on-farm storage, so cotton is stored within the home where it can be contaminated with human and animal hair.

Growing conditions affect cotton quality, and studies have shown that 50 percent or more of India's planted cotton area is affected by circumstances detrimental to quality. Delayed sowing limits the ability of fibers to mature properly, and dependence on monsoon rains limits the flexibility of farmers to time their planting. Noncertified seeds and improper plant protection are also factors that constrain yields and quality (P. Ramasundaraman and H. Gajbhiye, 2001). Double-cropping is also common in India, so the need to plant a following crop could force compromises in cotton maturation, and lead to conflicting demands for labor during harvest.

While 80 percent of India's cotton is marketed through the regulated marketing yards managed by Agricultural Produce Marketing Committees (APMC) (source?), where it is sold in seedcotton form. However, it is quite common for producers to market their crop at an earlier stage, and about 70 percent of cotton has its first point of sale between a farmer and an agent at the farm or local village (Kalikarni, 1999). In India, the merchants who purchase at the APMC marketing yards are primarily ginners, buying cotton for their own account or as a representative of a mill.

Ginning is typically more labor intensive in India, which manual cleaning of the seed cotton and manual feeding of cotton to the gin stands. This extensive physical contact between gin employees and the cotton creates opportunities for contamination. A large number of gins in India lack the facilities for compressing and baling the ginned cotton, necessitating transportation to another facility with increased opportunities for damage and contamination. Gins lack climate controls, so maintaining ideal moisture levels for preventing damage during ginning can be difficult. Most Indian gins have installed less cleaning equipment than U.S. gins, but the prevalence of hand-harvesting means this equipment is largely unnecessary.

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.

Market Institutions to Improve Quality

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. In 2007, 7 million bales were HVI classed, and in 2008 the number exceeded 10 million bales. China's Agricultural Development Bank has also at times linked the receipt of preferential loans to subsequent documentation of classing of the cotton produced.

Cotton is classed by gins in many cases in China. China has 10,000 gins, and classing is only consistently available from the larger gins and those owned by firms that were originally part of the Supply and Marketing Cooperatives of the Ministry of Commerce. Gin classing is subject to spot checks by China's Fiber Inspection Bureau (CFIB). When cotton is delivered to a textile mill, CFIB classes 10 percent of the bales, and the CFIB results become the basis for payment. Note, however, that contamination remains a serious problem in China. As in India, mills in China often maintain teams of employees who manually sift through cotton, removing contaminants before the fiber is fed into the spinning machinery.

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.

Note that there are two aspects to the introduction of classing. One is the importance of classing in any form, and the second is the use of HVI classing. The transformation of the U.S. cotton industry in part through classing documented by Olmstead and Rhode predated the introduction of machine classing. Virtually the entire U.S. crop was classed manually or visually by the 1960's. Recall that as much as one third of the U.S. crop was classed by USDA as early as 1945. The impetus for this came not just from the U.S. government, but through producer initiatives, like the organization of "one-variety" groups that collaborated with seed companies. India's heritage of cooperative agricultural institutions like its dairy coops and the cotton coops in Gujarat suggest a potential for such organization. Note that in the United States in 1949, the average U.S. cotton farm was 24 acres, which with average yields means an output of 14 bales (480 pounds each). A 4 hectare Indian cotton farm with average yields would produce 12 bales (170 kilograms each). This is a large enough volume to create a small, but distinct volume of cotton that would presumably be marketable as a consistent lot, and enable efficient communication of price signals for quality.

Experiments with vertical coordination through mills contracting with farmers in India have make only limited progress (contract farming arrangements often succumb to principal-agent problems), but an increased role for public or third-party classing might induce a virtuous circle, improving price communication and quality outcomes for Indian cotton. The vertical integration undertaken by the Plains

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 20th 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. Note, however, that even the institution of a robust classing system like in China cannot guarantee the elimination of every quality problem, such as the risk of fiber contamination in a hand-harvested, labor-intensive production system.

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