PASS-THROUGH ANALYSIS OF COTTON PRICES

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Abstract

A common question when analyzing supply chains is how much a change in input costs at one stage in the supply chain affect prices downstream. To address this question, research has been conducted that examines the extent that changes in prices are "passed-through." Much of the pass-through research that has been conducted has been focused on changes in prices at the beginning of supply chains - at the commodity-level. To date, however, there is no known research analyzing the effect of changes of cotton fiber prices on cotton textile goods, neither at different stages in the cotton supply chain, nor at the retail level. While pass-through analysis of the cotton supply chain presents certain challenges in terms of data collection, it also presents great opportunity in terms of understanding the many relationships involved in the manufacture of cotton apparel. The purpose of this paper is to develop a greater understanding of price relationships throughout the cotton supply chain and to inform interested parties about the extent that changes in cotton prices influence changes in yarn, fabric, and apparel prices. Findings suggest that the sharp increases in cotton fiber prices in the fall of 2010 have resulted in increases in yarn and fabric prices, but have yet to influence prices for assembled garments or retail prices for cotton apparel.

Introduction

A common question when analyzing supply chains is how much a change in input costs at a given link in the supply chain affects prices downstream. To address this question, research has been conducted that examines the extent to which changes in prices are "passed-through" supply chains. In agricultural economics, pass-through analysis has explored the extent to which changes in commodity prices result in changes in consumer prices. Examples of such research include efforts looking at the effect of changes in prices of agricultural commodities such as coffee (Leibtag, Nakamura, Nakamura, & Zerom, 2007), milk (Kim & Cotterill, 2008), and grains (Berck, Leibtag, Solis, & Villas-Boas, 2009). However, there is no known research analyzing the effect of changes in cotton fiber prices on prices for cotton textile goods. Given the dramatic increases in cotton prices in the fall of 2010, the objective of this research is to investigate relationships between changes in cotton fiber prices and changes in prices for cotton textile goods throughout the supply chain.

Due to the multiple processes involved in the manufacture of cotton textiles (i.e., spinning, fabric manufacturing, and apparel construction), there is potential for constructing a pass-through analysis for cotton prices at different stages in the textile manufacturing process. For the purposes of this analysis, the cotton supply chain is defined in stages including fiber, yarn, fabric, garment assembly, and retail. Price data for a range of cotton fiber qualities from a range of cotton producing countries are readily available, as are price data for many qualities and sources of cotton yarn. More challenging, in terms of data availability, are prices further downstream in the supply chain. There is a wide range of fabrics used in a wide range of apparel items, and this variability, along with the fact that fabric prices are negotiated privately, introduces difficulty in terms of collecting representative price data for fabric. Nonetheless, cotton textile supply chains are highly globalized, and trade data can be used to derive prices for fabric. Similarly, trade data can be used to collect prices following the cut and sew stage of the manufacturing process required to assemble garments. Consumer price indexes are used to measure retail apparel prices.

In addition to measuring the extent to which the magnitude of price increases are passed through supply chains, pass-through analysis also allows researchers to investigate how long it takes changes in prices at one stage in the supply chain to result in changes in prices further downstream. This research examines both the magnitude and temporal nature of price relationships. Evidence was found that the increases in cotton fiber prices have been completely passed-through the fiber-to-yarn link in the supply chain and changes in cotton fiber prices are passed through almost immediately to yarn prices. At the yarn-to-fabric link, some evidence was found that the recent increases in yarn prices have led to higher fabric prices. However, given that the sharpest increases in cotton prices occurred in fall of 2010 and that this publication is being released in the winter of 2011, evidence has yet to surface regarding relationships between fabric prices, prices for assembled garments, or retail prices for cotton apparel.

Considering the fact that cotton fiber prices more than doubled between August and December 2010, it could be expected that costs following garment assembly and retail prices will eventually be affected. With it taking several months between the time that retailer orders are placed and the time that those goods arrive in ports or on retail shelves, changes in prices at these late stages in the supply chain may not become detectable in the data until several months after this paper is published. As a result, current and future research is focused on continued monitoring of prices.

Time series methods were used to examine relationships between prices. Findings indicate that the time series characteristics of the data change depending on the time period being examined. Once evidence of the effect of the recent sharp increases in cotton fiber prices begin to surface at later stages in the cotton supply chain, these methods will be used to describe the impact of changes in cotton fiber prices on prices through each stage of the manufacturing process.

Data

For this general examination of the cotton supply chain, an effort was made to use the most aggregated data available in order to best represent the effects of changes in world cotton prices on the highly globalized cotton supply chain. At the first link in the supply chain, the fiber-to-yarn stage, figures generally recognized as being reflective of world prices are readily available. For fabric and garment stages in the supply chain, trade data were used. At the garment and retail stage, U.S. data are used. As a result, this analysis represents an investigation of price movement in the highly globalized cotton textile supply chain as it impacts the U.S. consumer.

Brief descriptions of the data used in this analysis appear below. All data used are monthly averages or totals. The period for the analysis is from the onset of the 2004-5 crop year to December 2010. Analysis began with the 2004/05 season because this was the first complete crop year where A Index values represented delivery quotes to the Far East.

Fiber

Cotlook Ltd., a company serving the cotton marketing community, has been publishing the A Index since the 1960s. Generally accepted as a proxy for the world price of cotton, the A Index is a cost and freight (CFR) price for of 1-3/32 inch staple Middling cotton delivered to ports in the Far East, where the majority of the world's cotton is spun into yarn (Cotlook).

Yarn

In addition to the A Index, Cotlook Ltd. publishes a yarn index. Cotlook's yarn index is a trade-weighted average of 20s and 30s Ne carded ring spun weaving yarn of what Cotlook considers "average" quality. Ring-spun yarn (as opposed to open-end yarn) is estimated to represent more than 80% of the world's spinning capacity (International Cotton Advisory Committee (ICAC), 2009). Free-on-board (FOB) prices for these yarns are collected by Cotlook from China, India, Pakistan, Indonesia, and Turkey. Collectively, these countries represent nearly 75% of the world's consumption of raw cotton fiber into yarn (USDA Foreign Agricultural Service). Weightings are based on average export volumes for the two most recent calendar years.

Fabric

Being a more differentiated product than fiber or yarn, fabric price data were derived from trade data. Given that volume and value data are collected when goods traverse international borders, trade data are a potential solution to the problem of data availability at the fabric stage of the cotton supply chain. Import, rather than export, figures were used since tariffs are collected on imports, and import figures are commonly accepted as slightly more reliable than export figures.

Data were gathered from Global Trade Information Services' Global Trade Atlas. The fabric prices that were used in the analysis were those for cotton woven fabric (Harmonized Schedule codes 5208 and 5209) imports into China, the world's largest importer of these fabrics. Woven, rather than knit, fabric prices were used because Cotlook's yarn index reflects prices for weaving yarns. Traded values, expressed in dollars, were divided by volumes in terms of square meters of fabric in order to give prices in dollars per square meter of fabric.

Garment

Fabric is cut and sown to make garments. With the world apparel trade being highly globalized, landed import values can be used to describe prices at this stage of the supply chain. The U.S. Department of Commerce's Office of Textiles and Apparel (OTEXA) publishes value and volume data for each apparel category represented by the U.S. Harmonized Tariff Schedule. In addition to publishing data for individual categories, OTEXA also publishes figures for aggregations of apparel categories. One of these aggregated categories represents cotton dominant apparel imports, describing both the volume, in terms of square meter equivalence, and value of apparel imports made from fabric containing more than fifty-one percent cotton fiber content. Using the figures for volume and value, a cost per square meter equivalent can be derived. These values are used to describe prices at the garment stage of the supply chain.

Retail

Since garment prices are those for the U.S., monthly U.S. apparel consumer price index (CPI) data are used to describe prices at retail. Cotton textile products represent between 60 to 70% of all textile items sold at retail. With cotton products representing the majority of apparel products, the apparel CPI, which covers apparel goods of all items, is thought to be representative of the effect of changes in cotton fiber prices on retail apparel prices.

Theoretical Pass-Through

One way to begin a discussion of the pass-through of cotton prices is to look at how much cotton is required to manufacture various types of cotton apparel goods. With such an amount expressed in terms of weight, any changes in cotton prices expressed in terms of cents/lb can be multiplied by this weight in order to derive a theoretical increase in the cost of fabricating apparel goods if the change in cost was solely a function of the change in cotton prices.

To track cotton consumption in the U.S., Cotton Incorporated has collected data regarding the average weight of apparel sold at retail. Given that some cotton fiber can be assumed to be lost in the manufacturing process, a compensation for this waste should be added to retail weights to come up with a representation of the total amount of cotton required to manufacture certain cotton products. Examples of waste include the small percentage of a bale that is field trash and the amount of fabric lost in the cut-and-sew process to assemble garments. In order to estimate the amount of cotton lost in manufacturing for different items of apparel, the USDA has come up with a set of waste factors. In addition to waste, these conversion factors also account for blending with other fibers and non-fiber content (e.g., leather). When paired with retail product weights collected by Cotton Incorporated, these conversion factors can be used to estimate the total amount of cotton fiber used to manufacture different apparel items. The total amount of cotton estimated to be required to manufacture several of the most commonly purchased cotton apparel products appears in Table 1.

Table 1. Estimated impact on cost of cotton apparel goods with an 80 cents / lb. increase in cotton prices for select apparel items

Common cotton apparel products	Total cotton estimated for the manufacture of apparel goods (lbs)	Theoretical effect of 80 cents/lb increase in fiber prices
T-Shirt	0.41	$0.33
Polo Shirt	0.54	$0.43
Woven Shirt	0.50	$0.40
Jeans	1.92	$1.54

Sources: Cotlook, Cotton Incorporated, USDA

To these estimates for the total amount of cotton fiber in apparel goods, we can multiply changes in cotton prices. Retailer orders for garments are commonly discussed in terms of quarters. As a result, it could be appropriate to frame this discussion of theoretical increases in prices in terms of year-over-year differences by quarters. Cotton prices in the fourth quarter of 2010 (150 cents/lb) were about 80 cents/lb higher than they were during the same period in 2009 (72 cents/lb). This price difference is multiplied by the total amount of cotton estimated for the manufacture of cotton apparel goods in order to derive a theoretical increase in the cost of fabricating apparel goods if the change in costs was due only to the change in cotton prices. These theoretical increases appear in Table 1.

To put the magnitude of these theoretical increases into context, it may be helpful to look at them in relation to average retail prices. Through Cotton Incorporated's Retail Monitor™, retail prices are tracked for a range of apparel products. Using this data, the theoretical increases resulting from the 80-cents/lb increase in cotton prices can be compared to average retail prices. Results suggest that the impact of cotton prices should be less than five percent for the items examined, and that lighter weight apparel items goods (e.g., t-shirts) would be less affected than heavier apparel items that contain more cotton fiber (e.g., jeans).

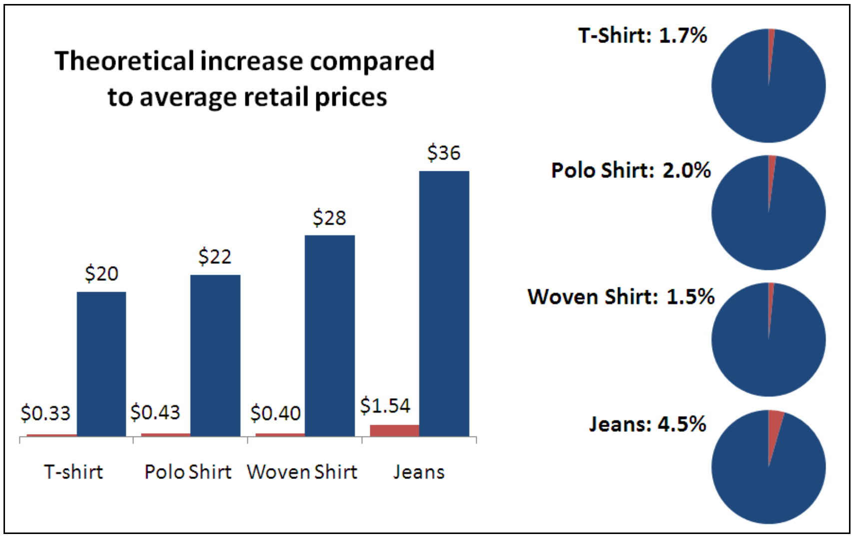

Figure 1. Theoretical impact on apparel costs relative to average retail prices
Sources: Cotton Incorporated's Retail Monitor™, USDA

Further context can be provided by examining these hypothetical increases in relation to the percentage of consumers' overall budgets. The Department of Commerce estimates that consumers spend about three percent of their disposable income on garments. Assuming a three percent increase in the price of apparel resulting from the recent increases in cotton prices, simple multiplication would imply an effect on consumers' budgets of about one tenth of one percent. With this hypothetical effect being so small, and with prices for other commodities including those related to food and energy also rising, the impact of cotton prices on consumer budgets and levels of consumer apparel purchases may be less than the impact of rising oil and food prices.

Descriptive Statistics

With the approach described in the previous section, it is possible to obtain a theoretical description of what could be expected in terms of the effect of changes in retail prices given the recent increase in cotton fiber prices. In reality, however, textile supply chains are complex. Many firms involved in the textile industry are non-vertical, with manufacturers at one stage often having to purchase their raw materials from manufacturers at previous stages. Specifically, fabric manufacturers often have to make purchases of yarn and garment manufacturers often have to make purchases of fabric. In order to track the effect of the recent sharp increase in cotton prices on the textile supply chain, prices at each stage in the supply chain are examined and discussed in this section.

Fiber-to-yarn

Price data for fiber and yarn are widely available from a range of national and trade sources. In order to frame discussion at the global level, the A Index and yarn index from Cotlook were used in this fiber-to-yarn portion of the analysis. Since August, the A Index doubled from values near 85 cents/lb to values over 170 cents/lb (Figure 2). Over the same time period, values for the yarn index increased 45%.

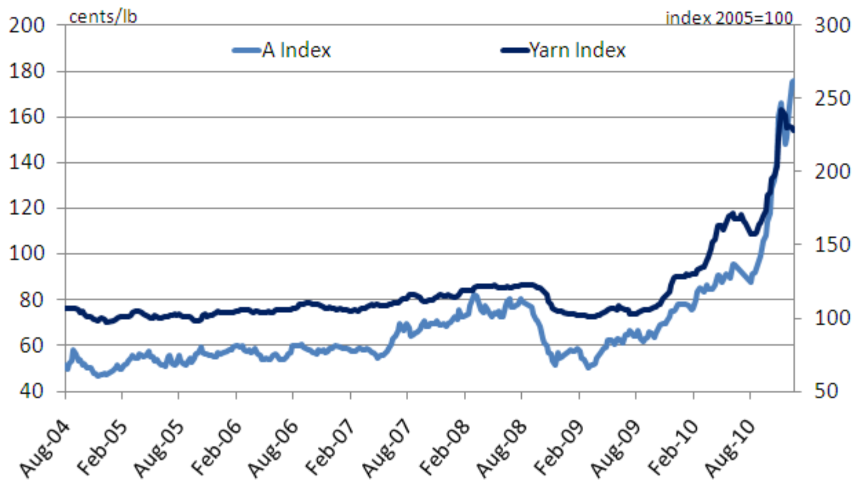

Figure 2. Fiber and yarn prices
Source: Cotlook

With cotton fiber prices quoted in terms of cents/lb and yarn prices quoted in terms of currency/weight, it is possible to directly compare fiber and yarn prices in terms currency/unit. Cotlook regularly publishes yarn price data for several countries in terms of USD/kg. After converting cotton fiber prices to USD/kg, the difference between the yarn and fiber can be examined to look at the extent to which changes in fiber prices are passed through to yarn prices. These differences appear in Figure 3.

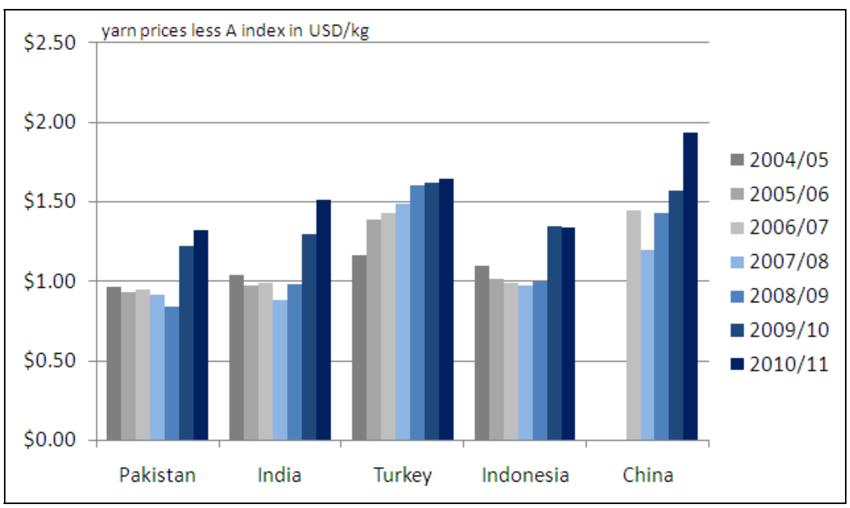

Figure 3. Yarn prices less fiber prices
Source: Cotlook

What is evident in Figure 3 is that the difference between fiber prices and yarn prices widened in both the 2009/10 and the 2010/11 crop years. Cotton prices first began to consistently rally in March 2009, with the most dramatic increases in prices occurring after the onset of the 2010/11 crop year. The widening of the yarn-fiber difference suggests that the increases in fiber prices have been passed through the yarn stage. In addition, during this period, there have been increases in labor, energy, and other costs associated with spinning. Correspondingly, these results should not be interpreted as margins. Rather, they should be taken as evidence of pass-through of cotton prices.

Another way of looking at the relationship between fiber and yarn prices is to look at fiber prices as a percentage of yarn prices. In Figure 4, it is notable that the proportion of yarn prices that comes from fiber prices was about five percent higher in 2010/11 than it was in 2008/09 and 2009/10. The other spike in the proportion of yarn prices that is fiber prices was in 2007/08, the last time that cotton prices saw consistent increases.

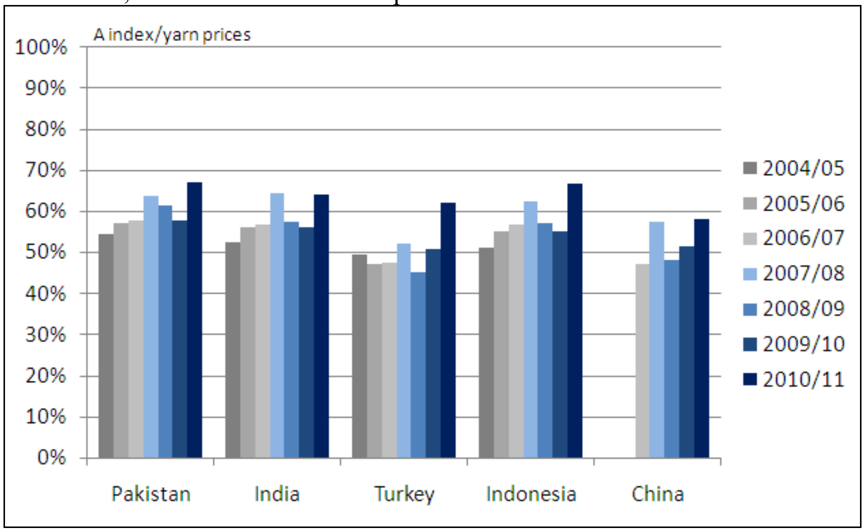

Figure 4. Fiber prices as a percentage of yarn prices
Source: Cotlook

Additionally, it may be useful to examine temporal correlations between yarn and fiber prices. Typically spinning mills will hold several months of inventory. As a result, cotton will not likely be transformed into yarn until several months after it was purchased. This may lead to expectations that yarn prices will have a lagged correlation with fiber prices. However, the results in Figure 5 show that the strongest correlation between yarn and fiber prices is with contemporaneous prices (fiber and yarn prices from the same month).

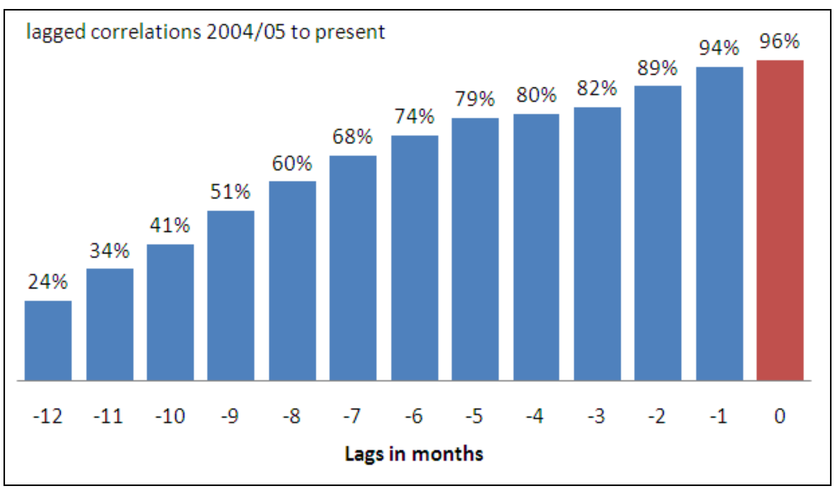

Figure 5. Lagged correlations between fiber and yarn prices
Source: Cotlook

To further investigate the temporal relationship between fiber and yarn prices, rolling correlations can be used. The results shown in Figure 6 represent rolling correlations between contemporaneous and fiber and yarn prices over 100 week time periods. What is evident from Figure 6 is that the contemporaneous correlation between fiber and yarn prices has strengthened to levels approaching 100% in the most recent data. Indicating that as cotton prices increased sharply over the past few months, yarn prices also increased sharply. In combination with the results concerning the yarn-fiber differences, it could be inferred that the recent fiber prices are not only being passed-through, but that they are being passed-through almost immediately.

Yarn-to-fabric

Given that fiber prices appear to have been passed-through to the fiber-to-yarn link in the supply chain, it could be expected that effects of the increase in fiber prices will also be evident in fabric price data. To examine fabric prices, the average cost per square meter equivalent of woven cotton fabric into China was used. Woven fabric (as opposed to knit fabric) was selected because the yarn prices used to derive the Cotlook's yarn index are ring spun yarns for woven fabric. China was selected because China is the world's largest importer of woven cotton fabric. At the time of publication, the latest data available for Chinese imported fabric were from November.

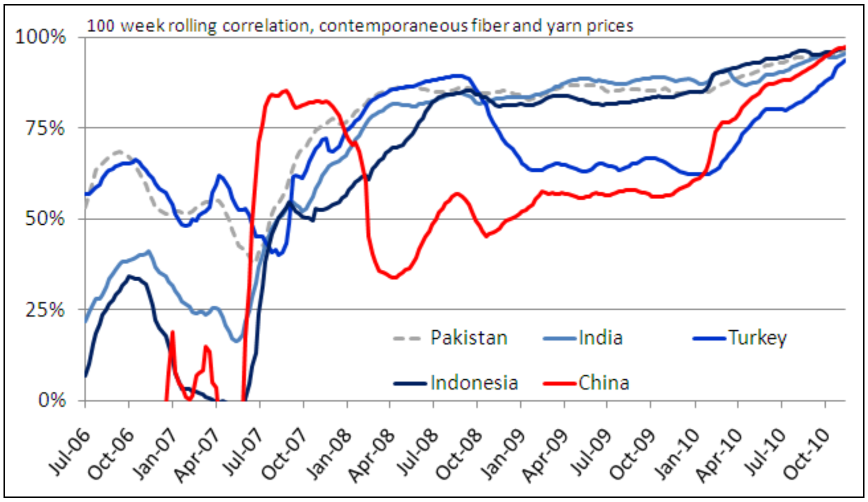

Figure 6. Rolling correlations between fiber and yarn prices
Source: Cotlook

In November, the woven fabric prices were 12% higher than they were in August (Figure 7), when the sharp increase in fiber prices began. Considering that fabric prices are derived from trade data, the full effect of the increase in fiber prices may have yet to surface. Due to the time necessary for manufacture, fabric prices negotiated for orders during the run-up in prices in the fall of 2010 might not have been imported into China yet. As a result, some of the increases reported from industry sources to be as high as 30% have yet to surface in trade figures for fabric prices. The temporal correlation structure in Figure 8, where correlations of about 60% exist between lags of one to ten months, suggests that changes in yarn prices may take some time to fully affect fabric prices.

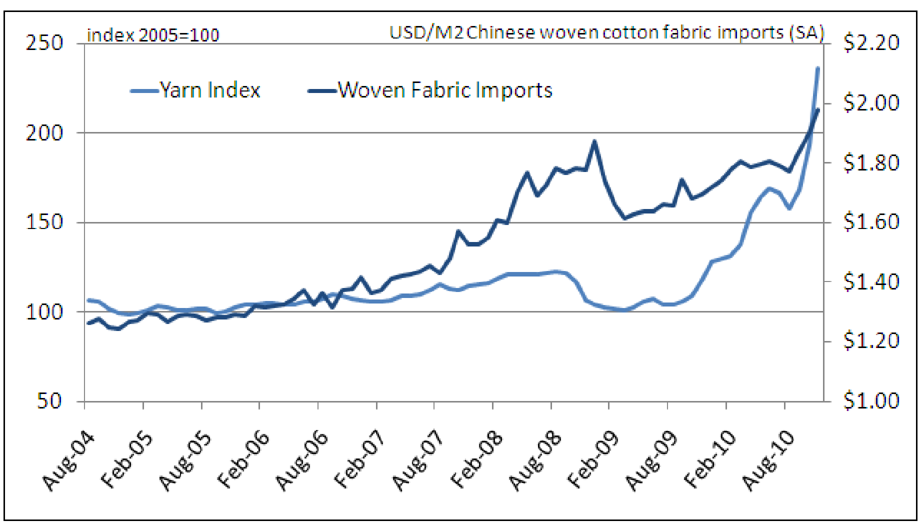

Figure 7. Yarn and fabric prices
Sources: Cotlook, Global Trade Atlas

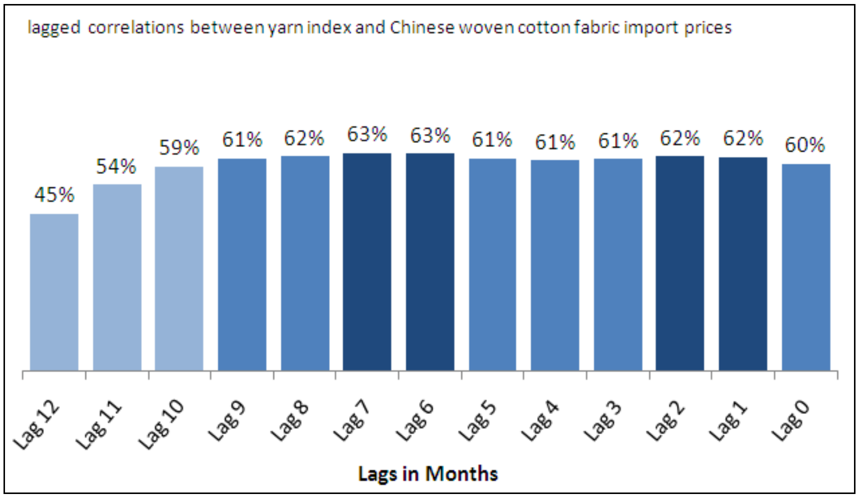

Figure 8. Lagged correlations between yarn and fabric prices
Sources: Cotlook, Global Trade Atlas

Fabric-to-garment

Significant transformation occurs at the garment manufacturing stage of the cotton supply chain (Figure 9). At this stage, fabric is cut and sewn in order to assemble complete garments. Finishes and dyeing can also occur. More labor is required at this stage in the apparel manufacturing process than at any other. With the time lag and value added at the garment assembly stage, and with fabric prices showing only some evidence of the effect of the recent increase in cotton prices, it could be expected that there would not be much evidence of the recent movement in cotton prices on prices for assembled garments.

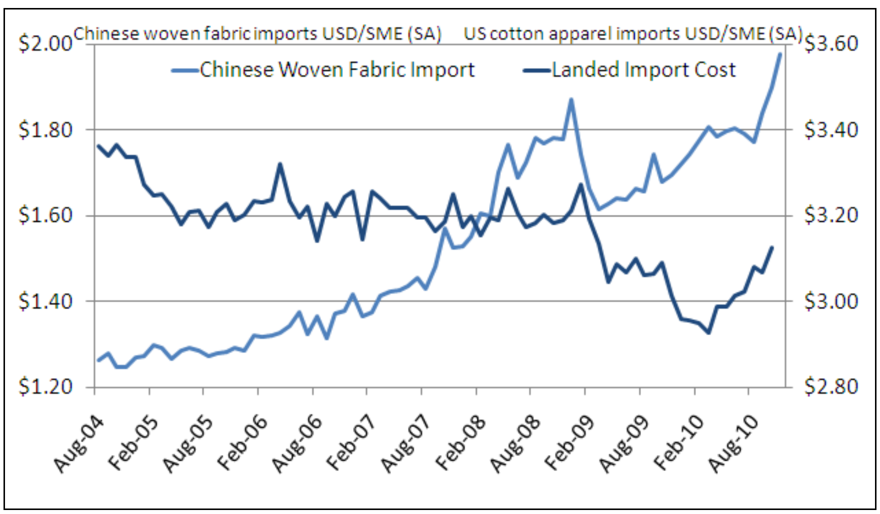

Figure 9. Fabric and garment prices
Sources: Global Trade Atlas, OTEXA

Garment-to-retail

While there were periods of decline in the average costs of imported apparel, the general pattern for retail apparel prices has been relatively flat for the period under investigation, with movement of only one to two percent (Figure 10). Over the past decade, U.S. apparel prices have fallen with increased trade liberalization and price pressures from the emergence of mass merchant retailers. In the latest data for November, the apparel CPI was about one percent higher than it was when the recent sharp increase in fiber prices began.

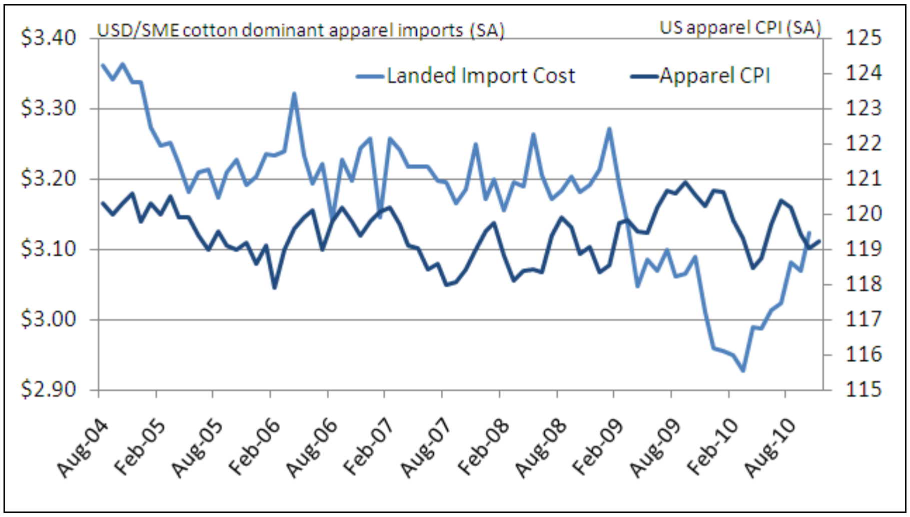

Figure 10. Garment and retail prices
Sources: OTEXA, U.S. Bureau of Labor Statistics

Price data indicate there has not been much upward movement in garment prices that could be traced to movement in fiber prices. In the latest data available from OTEXA for U.S. cotton-dominant apparel imports (through October), average imported prices increased only a marginal one percent. Examining the pattern of movement in imported garment prices, it appears that this movement may reflect a rebound in price per square meter equivalent of imported apparel following the decrease that occurred during the recession rather than from the recent run-up in cotton prices. There is little evidence of correlation, regardless of the lag, between fabric and garment prices. Due to the lack of correlation between fabric and garment prices, a chart analogous to those in Figures 5 and 8 is not shown. The lagged correlations between fabric and garment prices are even weaker than they are at the garment-to-retail stage (Figure 11).

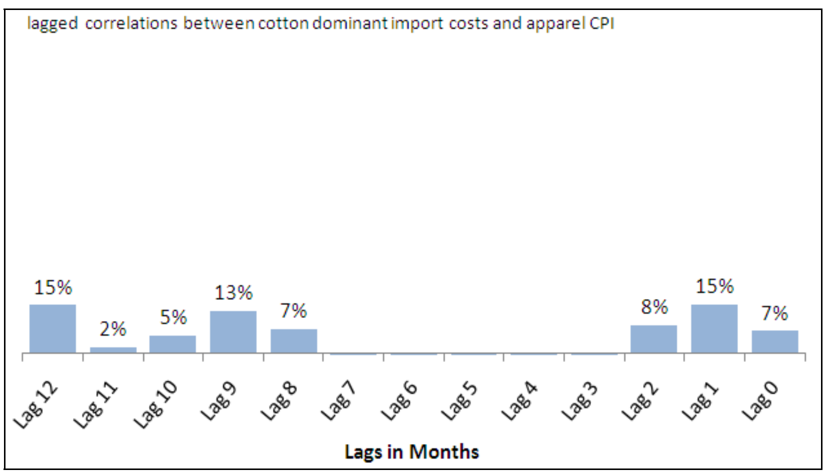

Figure 11. Garment and retail prices
Sources: OTEXA, U.S. Bureau of Labor Statistics

As was the case at the fabric-to-garment link in the supply chain, the relationship between garment and retail prices is weak, even when examined over a range of lagged correlations (Figure 11). One potential reason for the weakness in correlation is the magnitude of retail prices relative to the magnitude of imported apparel prices. The average landed or import cost/unit for two commonly purchased cotton apparel items, t-shirts and jeans, was $1.80 and $7.60 in 2009. Meanwhile, the average retail prices for these items in 2009 were $19.90 and $36.40 (Cotton Incoportated). The breadth of the difference between the garment and retail prices suggests some ability for retailers to absorb fluctuations in garment prices that would weaken. It should be emphasized, however, that the average retail prices presented are the average prices collected across all retail channels. Mass merchants, whose business strategies rely in higher volumes of lower margin goods, would have relatively less ability to absorb higher garment prices than specialty retailers who can sell garments at higher retail prices.

Time Series Methods

To formalize the process of describing how prices at various stages of the cotton supply chain are linked, time series methods were implemented. In order to obtain a parsimonious representation of the relationship between cotton prices and prices of processed textile product, a multi-step approach is followed, starting from a very general unrestricted model. The first step is to analyze the time series properties of individual price series. The second step is to test for cointegration among collections of prices. The third step is to test for alternative restrictions on the parameters to arrive at a parsimonious model.

The classical regression model requires that all series be stationary and that the errors have a zero mean and finite variance to avoid the "spurious regression" problem, which consists of high statistical significance of the estimated model, but lack of a causal connection. A series is said to be (weakly or covariance) *stationary* if the mean and autocovariances of the series do not depend on time. Correspondingly, the first step of the modeling process is to analyze the time series properties of each price series with Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests. If prices in levels are non-stationary, the series must be differenced *n*-times until the hypothesis of stationarity cannot be rejected. A series is said to be integrated of order *n*, *I(n)*,.for the minimum *n* required to achieve stationarity.

If a collection of time series are integrated of the same order and *n>0*, a long-run linear relationship might exist between the series expressed in levels in which the error term is stationary despite the fact that the individual time series expressed in levels are non-stationary. If such a long-run relationship exists, the series are said to be *cointegrated*. When series are cointegrated, they cannot move independently from each other. In that case, an error-correction model is used to capture short- and long-term relationships among prices. The (Johansen, 1988) methodology is used to test the null hypothesis of no cointegration among prices.

The (Johansen, 1988) approach requires the following error correction model (ECM) be estimated:

$$\Delta x_t = Bz_t + \pi_0 x_{t-1} + \sum_{i=1}^{p-1} \pi_i \Delta x_{t-i} + \tilde{\varepsilon}_t \tag{1}$$

where x_t is the vector of prices, z_t is a vector of deterministic variables, B, π_0 and the π_i's are matrices of coefficients, *p* is the lag length of the vector autoregression (VAR), and $\tilde{\varepsilon}_t$ is the vector of white noise errors. Since results depend on the number of lags considered, the general-to-specific modeling approach delineated in Enders (2004) is followed to determine the appropriate number of lags to consider: unrestricted VAR models in levels ($x_t = \alpha_0 + \alpha_1 x_{t-1} + \ldots + \alpha_p x_p + \varepsilon_t$) with alternative lag structures are estimated and the appropriate lag structure (*p*) is indicated by the model with the lowest Akaike Information Criteria (AIC).

The number of independent cointegrating vectors equals the rank of π_0, $r(\pi_0)$. If $r(\pi_0) = 0$ then prices are not cointegrated; if $r(\pi_0) = M$, the vector process is stationary, i.e. all prices are jointly stationary; if $r(\pi_0) = 1$, there is a single cointegrating vector and the expression $\pi_0 x_{t-1}$ is the error-correction term; if $2 \leq r(\pi_0) < M$, there are multiple cointegrating vectors. The Trace (λ_{trace}) and Maximum Eigenvalue (λ_{max}) tests are used to test alternative hypotheses on $r(\pi_0)$.

$$\lambda_{trace}(r) = -T \sum_{i=r+1}^{n} ln\left(1 - \hat{\lambda}_i\right) \tag{2}$$

$$\lambda_{max}(r, r+1) = -T\, ln\left(1 - \hat{\lambda}_{r+1}\right) \quad (3)$$

where the $\hat{\lambda}_i$'s are the estimated values of the eigenvalues obtained from the estimated $\hat{\pi}_0$ matrix, T is the number of usable observations, and $n=0,1,2,\ldots,M$. λ_{trace} tests the null hypothesis that the number of distinct cointegrating vectors is less than or equal to r against a general alternative (greater than r). λ_{max} tests the null hypothesis that the number of cointegrating vectors is r against the alternative of $r+1$ cointegrating vectors.

If prices in levels are non-stationary and not cointegrated, then a VAR model in the stationary differenced prices is estimated:

$$\Delta x_t = A_0 + \sum_{i=1}^{p-1} \pi_i \Delta x_{t-i} + \varepsilon_t \quad (4)$$

In this framework, since differenced prices are stationary, tests of hypothesis can be conducted using classical regression techniques.

Cross-equation restrictions in the final model are tested with the LRT suggested by Sims (1980):

$$LR = (T - c)\left(ln|\Sigma_r| - ln|\Sigma_u|\right) \quad (5)$$

where $ln|\Sigma_r|$ is the natural logarithm of the determinant of the variance-covariance matrix of the residuals of the restricted model, $ln|\Sigma_u|$ is the natural logarithm of the determinant of the variance-covariance matrix of the residuals of the unrestricted model, c is the maximum number of regressors contained in the longest equation, and T is the number of observations in the time space. The LRT follows a Chi-square distribution with degrees of freedom equal to the number of restrictions in the system.

In particular, we are interested in determining whether one or more prices do not receive significant feedback from changes in other prices and therefore do not need a VAR representation, i.e. they can be treated as weakly exogenous and their equation can be eliminated from the system. This is done by testing for block causality. The test for block-causality restricts all lags of one series of prices in the other series of prices to zero. The unrestricted model in (4) consists of the VAR equations of the 2 endogenous prices including p lags of the potentially block-exogenous price. The restricted model excludes all lags of the potentially block-exogenous price. The LRT test has $2p$ degrees of freedom, since p lags are excluded in each of the equations of the model. If the hypothesis of block causality is rejected, then that price is said to Granger-cause the other price.

The forecasting power of the final model is tested by estimating the model for a shorter period, T_1 $(T_1<T)$ and comparing the forecasts ($\hat{y}_t$) with the out-of-sample observed values, y_t ($T_1 < t \leq T$). The forecast evaluation is conducted through a graphical analysis, a decomposition of the mean squared forecast error, and the Theil Inequality coefficient. The mean squared forecast error, $\sum(\hat{y}_t - y_t)^2 / T_2$, where $T_2 = T - T_1$, is decomposed into a bias proportion, $T_2\left(\sum(\hat{y}_t / T_2) - \bar{y}\right)^2 / \sum(\hat{y}_t - y_t)^2$, a variance proportion, $T_2\left(s_{\hat{y}} - s_y\right)^2 / \sum(\hat{y}_t - y_t)^2$ and a covariance proportion, $2T_2(1-r)s_{\hat{y}}s_y / \sum(\hat{y}_t - y_t)^2$, where $\sum(\hat{y}_t)/T_2$, $\bar{y}$, $s_{\hat{y}}$, s_y are the means and (biased) standard deviations of $\hat{y}_t$ and y_t, respectively, and r is the correlation between $\hat{y}_t$ and y_t. The greater the covariance proportion and the smaller the bias and variance proportions, the greater the proportion of forecasting errors stemming from non-systematic sources and the better the quality of the forecasts are (EViews, 2007). The Theil Inequality coefficient (TIC) takes values between 0 and 1, zero indicating a perfect fit of the forecast to the observed series. The TIC is calculated as (EViews, 2007):

$$TIC = \sqrt{\sum_{t=T_1+1}^{T} (\hat{y}_t - \bar{y}_t)^2 / T_2} \Bigg/ \left[\sqrt{\sum_{t=T_1+1}^{T} \hat{y}_t^2 / T_2} + \sqrt{\sum_{t=T_1+1}^{T} y_t^2 / T_2}\right] \quad (6)$$

The stability of the final model, i.e. the absence of structural breaks, is tested with the Quandt-Andrews (Q-A) and the Chow Forecast tests (EViews, 2007). These tests evaluate whether the parameters of the model are stable across various sub-samples of the data. The Chow's Forecast test estimates two models using the whole sample: the restricted regression uses the original set of regressors, while the unrestricted regression adds a dummy variable for each forecast point. The Chow Forecasts log likelihood ratio statistic compares the maximum of the (Gaussian) log likelihood function of each model and has an asymptotic Chi-squared distribution with T_2 degrees of freedom.

The logic behind the Q-A test is that a single Chow Breakpoint test is performed at every observation between two dates, τ_1 and τ_2. The Breakpoint Chow test fits the model separately for each subsample and one (restricted) model for the entire period, and tests whether there are significant differences in the estimated parameters across models. The resulting test statistics are then summarized into one test statistic to test the null hypothesis that there are no breakpoints between τ_1 and τ_2. The test trims a small percentage of observations at the beginning and the end of the full sample period to avoid the degeneration of the non-standard distribution followed by the test. The Maximum Q-A statistic, MaxF, is the maximum of the individual Chow F-statistics, calculated as:

$$MaxF = \max_{\tau_1 \le \tau \le \tau_2} \left(F(\tau) \right) \tag{7}$$

$$F(\tau) = \frac{\left(\bar{u}'\bar{u} - \left(u_1'u_1 + u_2'u_2\right)\right)/k}{\left(u_1'u_1 + u_2'u_2\right)/\left(T - 2k\right)} \tag{8}$$

where $\bar{u}'\bar{u}$ is the restricted sum of squares and $u_i'u_i$ is the sum of squared residuals from subsample *i*. Each F-statistic follows an F-distribution with (*k, T-k*) degrees of freedom, where *k* is the number of parameters in the equation, and *T* is the number of observations in the time space. Therefore, failing to reject the null hypothesis of the Q-A test indicates stability of the model over the trimmed sample.

Results from Time Series Analysis

Given that evidence regarding the effect of cotton prices on the latter end of the supply chain has yet to surface, a comprehensive model describing the entire cotton supply chain has not yet been constructed. However, as discussed in the descriptive statistics section, there is evidence of the recent run-up in fiber prices affecting yarn prices. As a result, models were developed to investigate the time series characteristics of fiber and yarn prices. To explore other relationships and to experiment with other linkages in the cotton supply chain, time series model were also explored across the yarn-to-garment stages. Results regarding the time series characteristics were collected for different periods and there is evidence that prices throughout the cotton supply chain have different time series characteristics during different periods.

Table 2. One-sided p-values for H_0: The series ln(A Index) has a unit root

	Augmented Dickey-Fuller Test			Phillips-Perron Test		
Time Period	Levels	Differences	2nd Differences	Levels	Differences	2nd Differences
2004/05-2007/08	0.925	0.000	0.000	0.966	0.000	0.000
2004/05-2009/10	0.743	0.000	0.000	0.887	0.000	0.000
2004/05-2010/11	0.989	0.000	0.000	1.000	0.000	0.000
2007/08-2010/11	0.987	0.048	0.044	0.999	0.077	0.000

The A Index is *I(1)* over the entire sample and for all sub periods starting in 2004/05 (Table 2). However, for the sub periods 2008/09-2010/11 and 2009/10-2010/11, the A Index is *I(2)*. The shortest and most recent sub period for which the A Index is *I(1)* is 2008/09-2010/11. Therefore, the analysis will focus on four sub periods: the entire sample (2004/05-2010/11), the pre-2010/11 period (2004/05-2009/10), the pre-2008/09 period (2004/05-2007/08), and the post-2006/07 period (2007/08-2010/11). The Yarn Index is *I(1)* over the pre-2010/11 period, the pre-2008/09 period, and the post-2006/07 period, but it is *I(2)* over the entire sample (Table 3). Garment prices are *I(1)* over the entire sample, the pre-2010/11 period, and the post-2006/07 period, but it is stationary over the pre-2008/09 period (Table 4).

Observing the level of integration of each series of prices in different periods, cointegration analyses between the A Index and the Yarn Index are run on the pre-2010/11 period, the pre-2008/09 period, and the post-2006/07 period. The cointegration analyses between the Yarn Index and garment prices are run on the pre-2010/11 period and the post-2006/07 period.

Table 3. One-sided p-values for H_0: The series ln(Yarn Index) has a unit root

	Augmented Dickey-Fuller Test			Phillips-Perron Test		
Time Period	Levels	Differences	2^{nd} Differences	Levels	Differences	2^{nd} Differences
2004/05-2007/08	0.849	0.000	0.000	0.939	0.001	0.000
2004/05-2009/10	0.779	0.001	0.000	0.994	0.004	0.000
2004/05-2010/11	0.951	0.351	0.003	1.000	0.000	0.000
2007/08-2010/11	0.996	0.001	0.123	1.000	0.022	0.202

Table 4. One-sided p-values for H_0: The series ln(Garment) has a unit root

	Augmented Dickey-Fuller Test			Phillips-Perron Test		
Time Period	Levels	Differences	2^{nd} Differences	Levels	Differences	2^{nd} Differences
2004/05-2007/08	0.001	0.000	0.000	0.003	0.000	0.000
2004/05-2009/10	0.156	0.000	0.000	0.066	0.000	0.000
2004/05-2010/11	0.183	0.000	0.000	0.007	0.000	0.000
2007/08-2010/11	0.501	0.000	0.000	0.501	0.000	0.000

Table 5. Trace and max-eigenvalue tests for the number of cointegrating relations between ln(A Index) and ln(Yarn Index)

	Lags	Trace test specifications (significance at 5% level)					Max-eigenvalue specifications (significance at 5% level)				
Period	(p-1)	(a)	(b)	(c)	(d)	(e)	(a)	(b)	(c)	(d)	(e)
2004/05-2007/08	2	0	0	0	1	2	0	0	0	0	0
2004/05-2009/10	2	0	0	0	0	0	0	0	0	0	0
2007/08-2010/11	10	0	0	0	0	0	0	0	0	0	0

Specifications: (a) No deterministic trend in the data, and no intercept or trend in the cointegrating equation.
(b) No deterministic trend in the data, and an intercept but no trend in the cointegrating equation.
(c) Linear trend in the data, and an intercept but no trend in the cointegrating equation.
(d) Linear trend in the data, and both an intercept and a trend in the cointegrating equation.
(e) Quadratic trend in the data, and both an intercept and a trend in the cointegrating equation.

Table 6. Trace and Max-Eigenvalue Tests for the Number of Cointegrating Relations between ln(Yarn Index) and ln(Garment Prices)

	Lags	Trace Test Specifications (significance at 5% level)					Max-Eigenvalue Specifications (significance at 5% level)				
Period	(p-1)	(a)	(b)	(c)	(d)	(e)	(a)	(b)	(c)	(d)	(e)
2004/05-2009/10	2	0	0	1	1	1	0	1	1	1	1
2007/08-2010/11	10	0	0	0	0	0	0	0	0	0	0

Specifications: (a) No deterministic trend in the data, and no intercept or trend in the cointegrating equation.
(b) No deterministic trend in the data, and an intercept but no trend in the cointegrating equation.
(c) Linear trend in the data, and an intercept but no trend in the cointegrating equation.
(d) Linear trend in the data, and both an intercept and a trend in the cointegrating equation.
(e) Quadratic trend in the data, and both an intercept and a trend in the cointegrating equation.

Results from the trace test and the Max-Eigenvalue test suggest that there are no cointegrating vectors between the Yarn Index and the A Index for any of the three periods under analysis (Table 5). The trace test detects a possible cointegrating vector for the period pre-2008/09, but the Max-Eigenvalue test contradicts that finding. Since the null hypothesis of the Max-Eigenvalue test is more specific than the one for the trace test, then the results of the former

test override the results of the latter. Therefore, the appropriate methodology to analyze the relationship between cotton fiber and yarn prices consists of a VAR model in first differences for each sub period but the entire sample.
Cointegration tests indicate that one cointegrating vector exists between the Yarn Index and garment prices over the pre-2010/11 period (Table 6). However, the series are not cointegrated over the post-2006/07 period. Therefore, an ECM will be estimated over the pre-2010/11 period, and a VAR in first differences will be estimated for the post-2006/07 period. The analysis will be complemented with an ordinary least squares regression of the garment price on the first difference of the Yarn Index.

Summary and Conclusions

The sharp increases in cotton prices that began with the onset of the 2010/11 crop year have been unprecedented and led to a series of all-time record cotton prices across the globe. The dramatic movement in fiber prices doubled values for the A Index, widely accepted as representative of a world price for cotton, between August and December 2010. Due to the magnitude of price increases, it is reasonable to anticipate that there will be consequences on pricing throughout the cotton textile supply chain.

Descriptive statistics suggests that cotton fiber prices are being passed through the yarn stage of the manufacturing process and that yarn prices have become increasingly responsive to movements in fiber prices. There is also evidence that fabric prices have been affected by recent price movement in yarn and fiber prices. However, there is little evidence that garment prices, represented by the landed value of cotton textile imports into the U.S., or U.S. retail apparel prices, have been affected by the recent rise in cotton fiber prices. This result was expected since retailer orders for manufactured apparel items are typically placed about six months to a year before they arrive in U.S. ports or on retailer shelves.

As a result, evidence has not yet surfaced regarding the effect of the recent increases in cotton prices on latter stages of the supply chain. Due to the fact that it may be several months until the full effect of the recent increases in fiber prices may appear in price data for garment and retail stages of the supply chain, a central element of future work will be continued monitoring of prices. Once the impact of the recent run-up in cotton fiber prices becomes evident, modeling efforts will be expanded.

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