FIRST DRAFT
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PASS-THROUGH ANALYSIS OF COTTON PRICES

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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 agricultural commodity prices result in changes in consumer prices. Examples of such research include those looking at the effect of changes in coffee prices (Leibtag, Nakamura, Nakamura, & Zerom, 2007), milk prices (Kim & Cotterill, 2008), and grain prices (Berck, Leibtag, Solis, & Villas-Boas, 2009; Roeger & Leibtag, 2011). 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 during the 2010/11 crop year, the objective of this research is to investigate relationships between changes in cotton fiber prices and changes in prices for intermediate textile goods in the cotton textile supply chain.

Due to the multiple processes involved in the manufacture of cotton apparel (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, assembled garment, 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 and finished textile goods, and this variability, along with the fact that fabric prices are negotiated privately, introduces difficulty in terms of collecting representative fabric price data. Nonetheless, cotton textile supply chains are highly globalized, and trade data can be used to derive fabric prices. 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 produce 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 on a cost per weight basis at the fiber-to-yarn link in the supply chain and that changes in cotton fiber prices are almost immediately passed through as changes in yarn prices. At the yarn-to-fabric link, evidence was found that the recent increases in yarn prices have led to higher fabric prices.

Given that sharp increases in cotton prices began in the fall of 2010 and that this research is based on data available in the spring of 2011, the full extent of higher cotton fiber prices likely has yet to completely surface in prices at the end of the cotton supply chain fabric prices. It is anticipated that further price increases will be observed for fabric, assembled garments, and retail apparel prices in coming months. It typically takes several months and sometimes as long as a year, between the time that retailer orders are placed and the time that apparel goods arrive in ports or on retail shelves. As a result, changes in prices at later stages in the supply chain may not be fully observable until several months after this draft is published. An element of current and future research is continued monitoring of prices in order to analyze and describe the impact of higher cotton prices as it becomes feasible.

Following a discussion of changes currently observable in the supply chain, results stemming from time series methods are used to examine relationships between prices. Findings indicate that the time series characteristics of the data are sensitive to the time period being examined. Due to the instability of the time series properties inherent in the data examined, time series analysis was conducted across several time period samples in order to adequately represent the characteristics of the pass-through of fiber prices throughout the supply chain.

Data

For this examination of the prices in 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. The time period covered by the analysis is from the onset of the 2004/05 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, where the majority of the world's cotton is spun into yarn.

Fiber

Cotlook Ltd., a company serving the cotton marketing community, has been publishing the A Index since the 1960s. Widely 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 (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. Weightings assigned to prices used to derive the index are based on average export volumes for the two most recent calendar years. Collectively, these countries represent nearly 75% of the world's consumption of raw cotton fiber into yarn (USDA Foreign Agricultural Service).

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. Due to the fact that tariffs are collected on import figures, they are commonly accepted as 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 code 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. (OTEXA data), 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 these weights 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 collects 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 apparel items, the USDA ERS developed 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.

Crop-year-to-date (August to March), cotton prices in 2010/11 are up and average of 86 cents/lb relative to their levels during the same time period in 2009/10. Considering that at the time of publication cotton prices remain well above their 2009/10 levels and there remain four months in the crop year, a hypothetical increase this crop year of 90 cents/lb is used in Table 1. This price increase for cotton fiber 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 retail apparel prices were solely due only to change in fiber prices. These theoretical increases appear in Table 1.

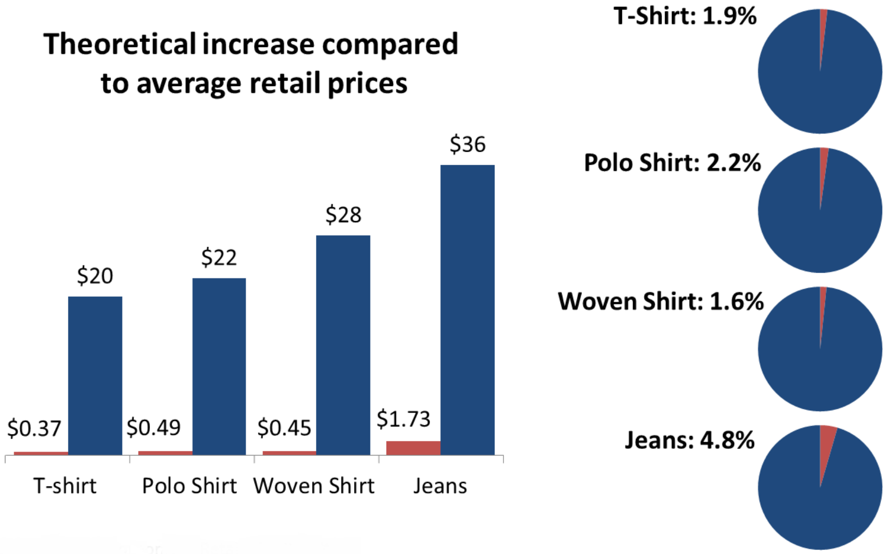
Table 1. Estimated Impact on Cost of Cotton Apparel Goods with a 90 cents/lb Increase in Cotton Prices for Select Apparel Items

Common Cotton Apparel Products	Total Cotton Estimated for the Manufacture of Apparel Goods (lbs)	Theoretical Effect of 90 cents/lb Increase in Fiber Prices
T-Shirt	0.41	$0.37
Polo Shirt	0.54	$0.49
Woven Shirt	0.50	$0.45
Jeans	1.92	$1.73

Sources: Cotlook, Cotton Incorporated, USDA

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 100 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, notably 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.

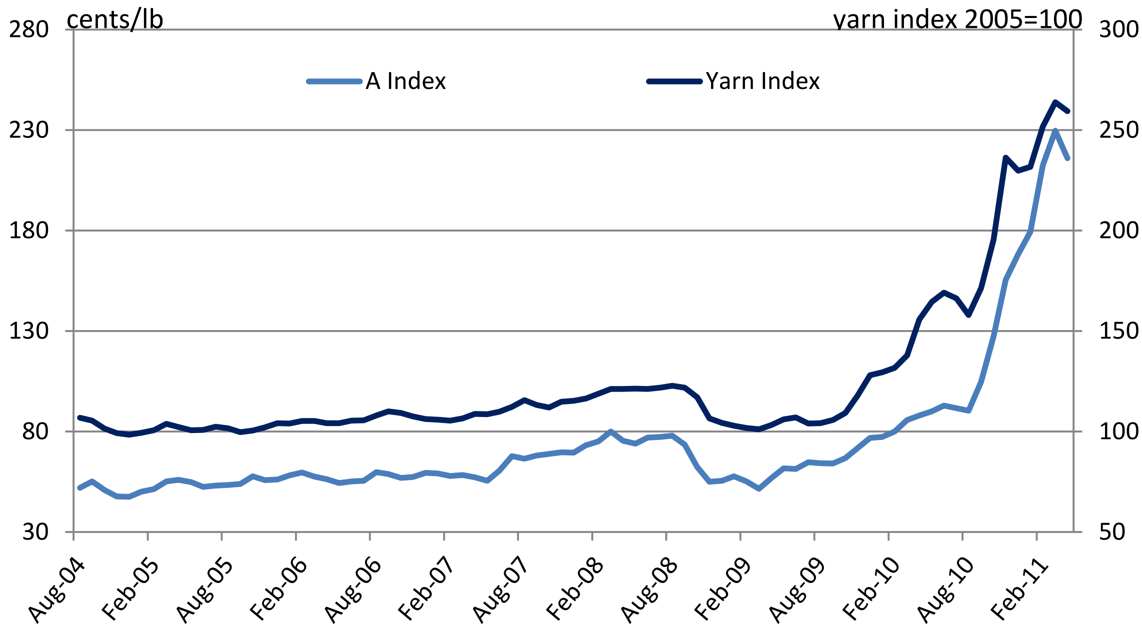
Descriptive Statistics

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. Between August and March, the A Index nearly tripled from values near 85 cents/lb to values over 240 cents/lb. Fiber prices have since retreated, but remain about 90 cents/lb higher crop-year-to-date (August through April) than they were in 2009/10 (Figure 2). Between August and April, Cotlook's yarn index increased 64%.

Figure 2. Fiber and Yarn Prices

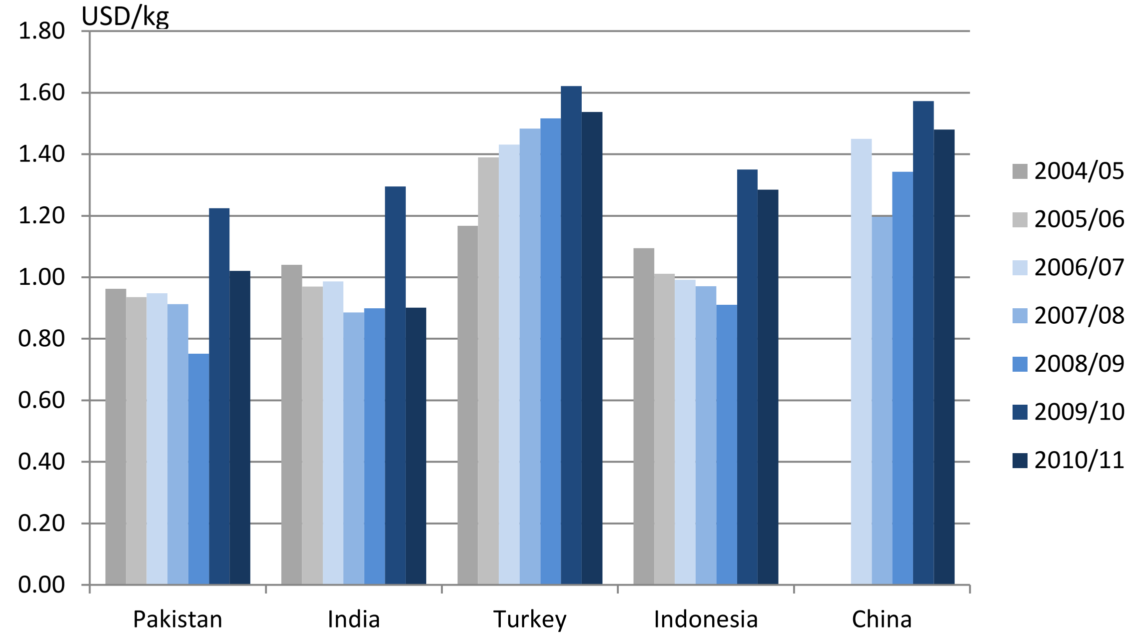


Source: Cotlook

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.

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 in August 2010. The widening of the yarn-fiber difference suggests that the increases in fiber prices have been passed through the yarn stage. Also during this time 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.

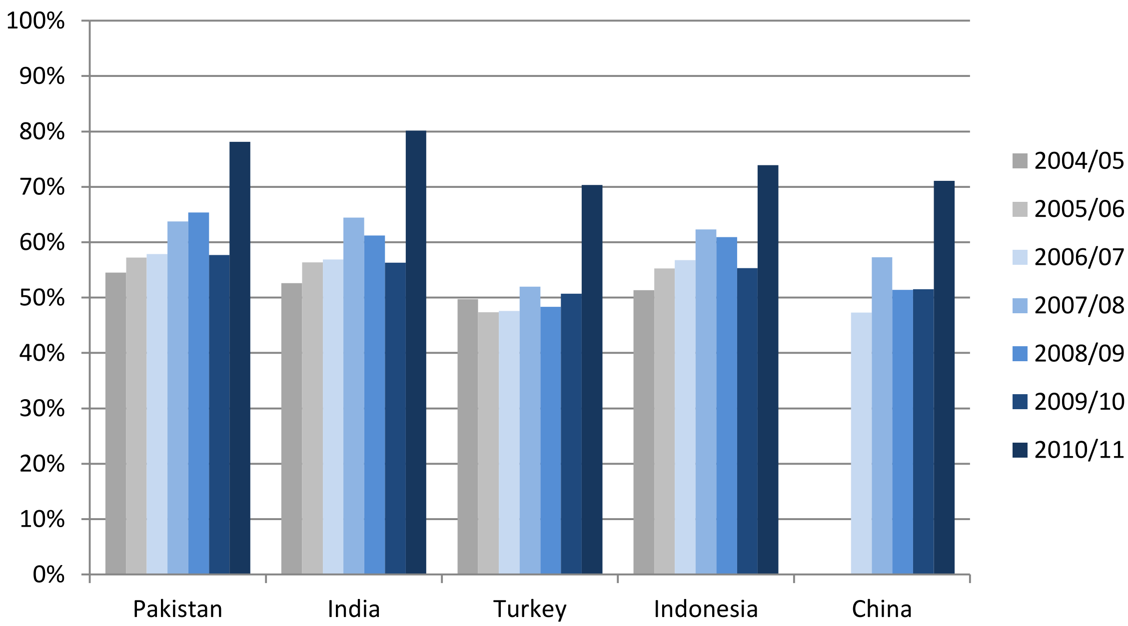
Figure 3. Yarn Prices less Fiber Prices



Source: Cotlook, Chinese yarn prices not published until 2006/07.

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 has been about twenty percent higher in 2010/11 than it was in 2008/09 and 2009/10. The fact that cotton prices compose such a high proportion of yarn prices suggests that spinners are more vulnerable to volatility in cotton prices than they have in the past.

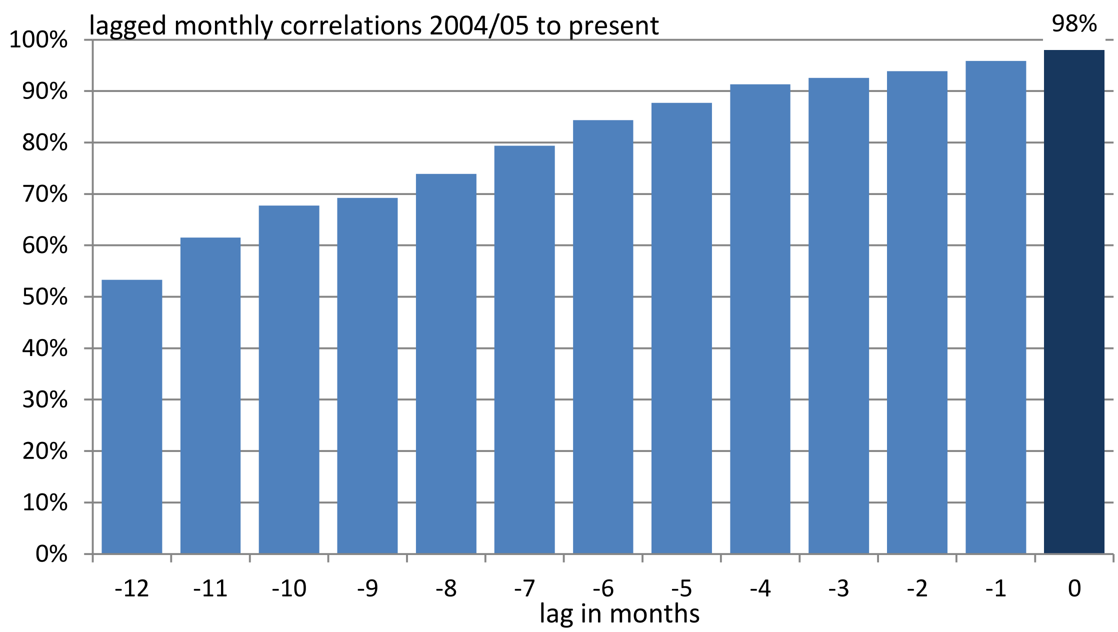
Figure 4. Fiber Prices as a Percentage of Yarn Prices



Source: Cotlook, Chinese yarn prices not published until 2006/07.

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).

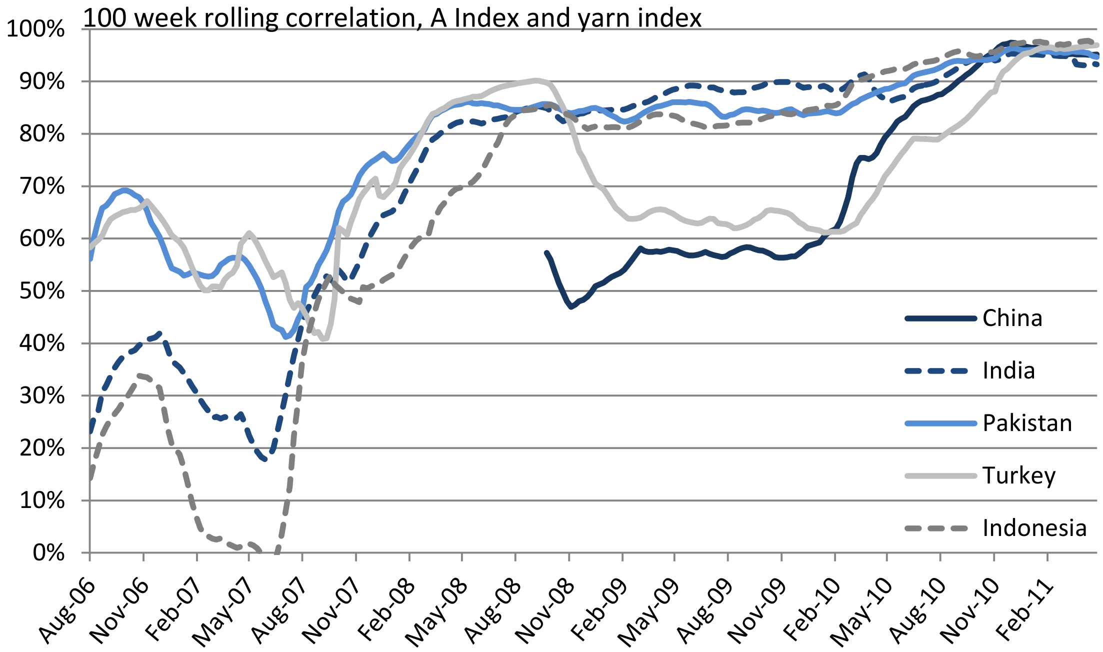
Figure 5. Lagged Correlations between Fiber and Yarn Prices



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 months. Along with the evidence in Figure 3, the strengthening of the correlations is indicative of the pass-through cotton prices through the yarn. In combination, it could be inferred that the recent increases in fiber prices are not only being passed-through on a currency/weight basis, but that they are being passed-through almost immediately.

Figure 6. Rolling Correlations between Fiber and Yarn Prices



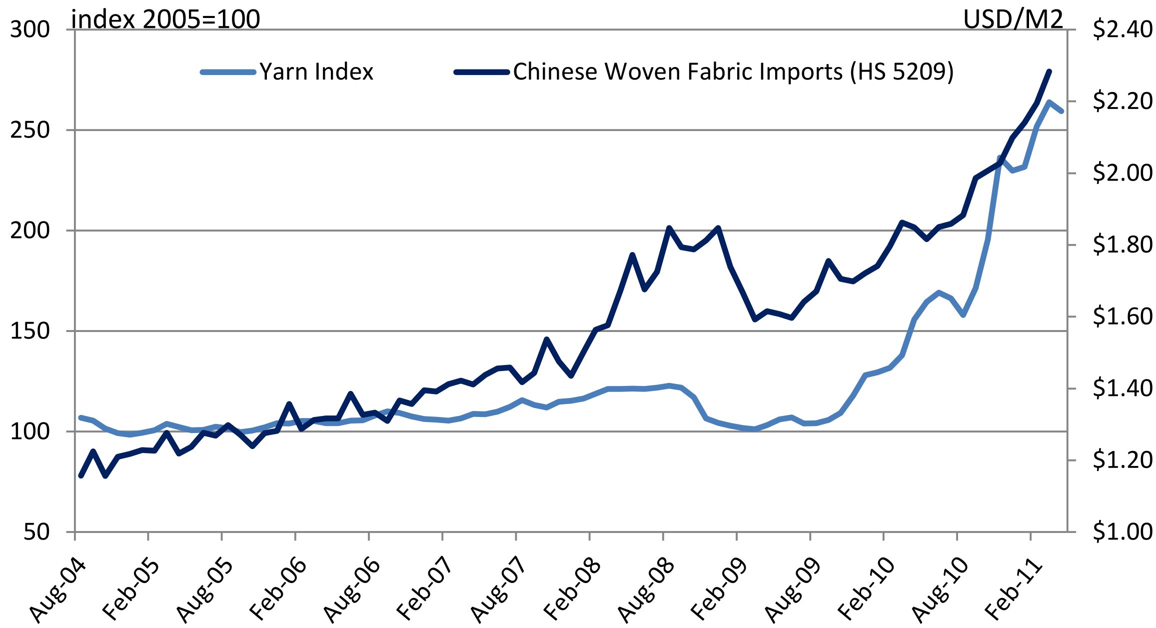
Source: Cotlook. Weekly data. Chinese yarn prices not published until 2006/07.

<u>Yarn-to-fabric</u>

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 March.

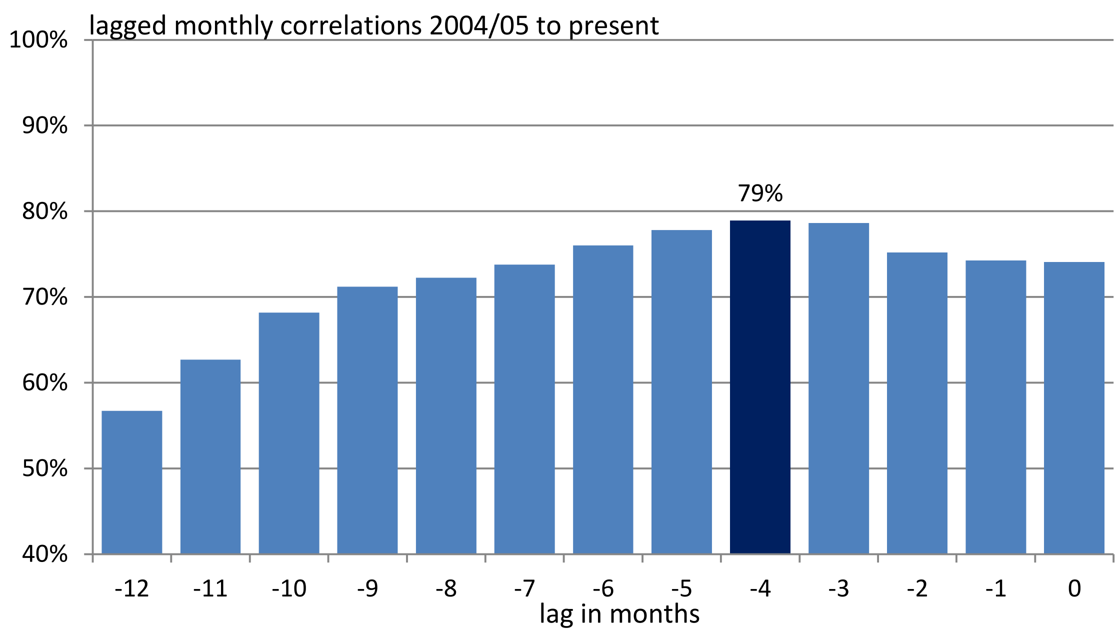
In March, the woven fabric prices were 21% higher than they were in August (Figure 7), when the sharp increase in fiber prices began. Considering that fabric prices are derived from trade data, the full effect of the increase in fiber prices may have yet to surface. Due to the time necessary for manufacture, 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 50% have yet to surface in trade figures for fabric prices. The temporal correlation structure in Figure 8, where correlations of about 80% 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



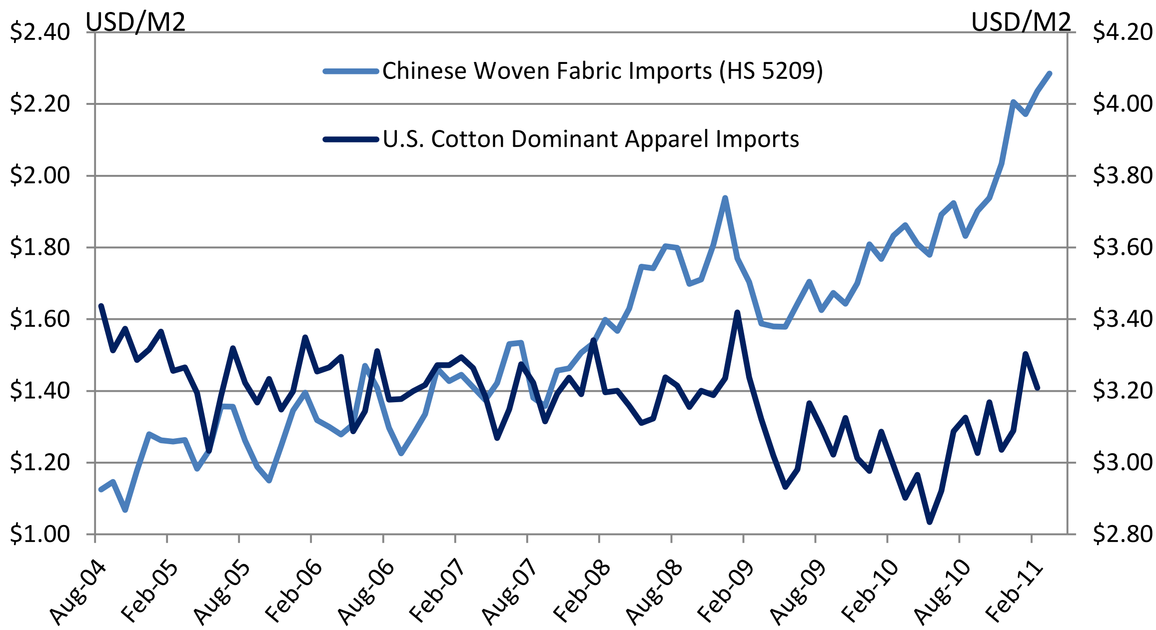
Sources: Cotlook, Global Trade Atlas

Fabric-to-garment

Significant value is added at the garment manufacturing stage of the cotton supply chain. 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.

Price data indicate that 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 could be reflective of 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.

Figure 9. Fabric and Garment Prices

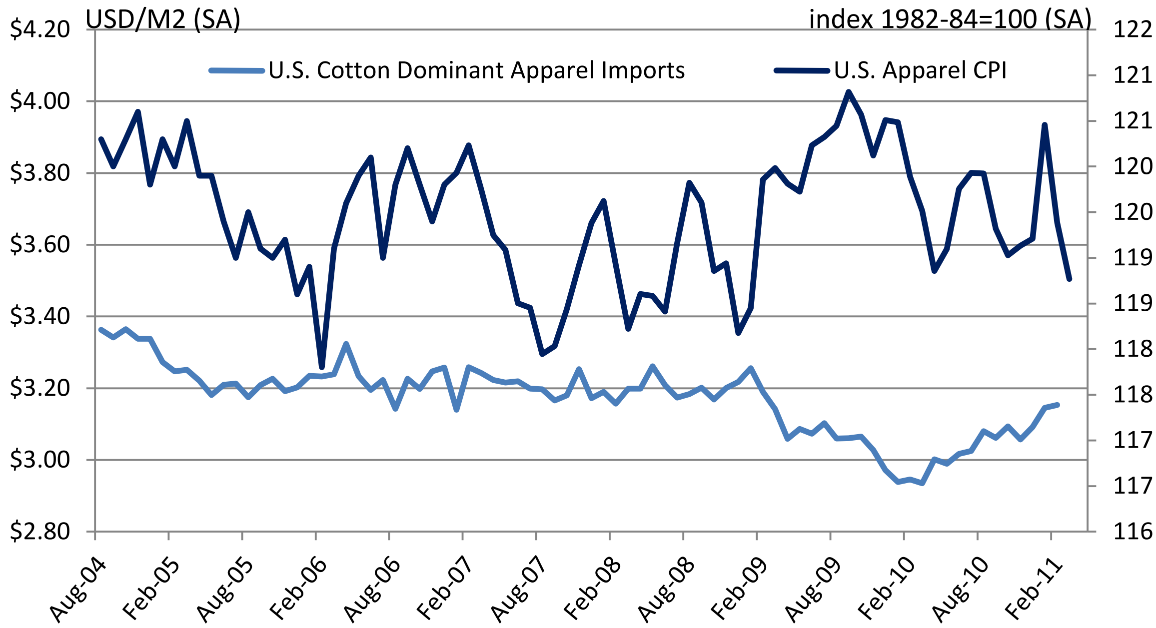


Sources: Global Trade Atlas, OTEXA

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 time period under investigation, with movement of only one to two percent. 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

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. 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 which would weaken. It should be emphasized, however, that the average retail prices presented are 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(π_0). If r(π_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≤r(π_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(π_0).

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

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

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:

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

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):

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

where $ln\left|\Sigma_r\right|$ is the natural logarithm of the determinant of the variance-covariance matrix of the residuals of the restricted model, $ln\left|\Sigma_u\right|$ 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:

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

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

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

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-fabric stages. The monthly average value of heavy-weight woven cotton fabric imported into China (HS 5209) is used to approximate the international price of cotton fabric.

The A Index and the Yarn Index are *I(1)*, while the Fabric Price can be modeled as trend stationary in levels or as an *I(1)* series (Table 2). Using 24 lags for a VAR in levels for each pair of series, the optimal lag length for the cointegration analysis between the A Index and the Yarn Index is 15, while the optimal lag length for the cointegration analysis between the Yarn Index and Fabric Prices is 16 (Table 3). The Trace Test indicates one possible cointegrating relation between the A Index and the Yarn Index in a model with a linear trend in the data, and both an intercept and a trend in the cointegrating equation. However, the Max Eigenvalue test rejects the hypothesis of cointegration in all its variants. The Trace Test and the Max Eigenvalue test suggest that the two variables are stationary (by definition not cointegrated) if a quadratic trend is included in the model. Both the Trace Test and the Max Eigenvalue tests suggest that one cointegrating relationship exists between the Yarn Index and the Fabric Price in a model with no deterministic trend in the data, and no intercept or trend in the cointegrating equation. Both tests also indicate that in a model with no deterministic trend in the data, and an intercept but no trend in the cointegrating equation the two variables are stationary. Therefore, the relationships between the series by pairs are analyzed both as ECMs and as VARs.

Table 2. One-sided p-values for H_0: The series has a unit root over the 2004/05-2010/11 period.*

Series	Augmented Dickey-Fuller Test				Phillips-Perron Test			
	Levels		Differences		Levels		Differences	
	Constant	Constant + Trend	Constant	Constant + Trend	Constant	Constant + Trend	Constant	Constant + Trend
Ln(A Index)	1.000	0.997	<0.001	<0.001	1.000	1.000	<0.001	<0.001
Ln(Yarn Index)	1.000	1.000	<0.001	<0.001	1.000	1.000	<0.001	<0.001
Ln(Fabric Price)	0.952	0.002	<0.001	<0.001	0.929	0.051	<0.001	<0.001

* April 2004 to March 2011 for the A Index and the Yarn Index; April 2004 to February 2011 for the Fabric Price

Table 3. Number of cointegrating relations between the series, 2004/05-2010/11.

Series	Lags	Trace Test Specifications (significance at 5% level)					Max-Eigenvalue Specifications (significance at 5% level)				
	(p-1)	(a)	(b)	(c)	(d)	(e)	(a)	(b)	(c)	(d)	(e)
Ln(A Index) & Ln(Yarn Index)	15	0	0	0	1	2	0	0	0	0	2
Ln(Yarn Index) & Ln(Fabric Price)	16	1	2	na	na	na	1	2	na	na	na

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.

NA: not available, because Ln(Fabric Price) is trend-stationary.

The A Index and the Yarn Index

An ECM with 15 lags of the differenced variables is estimated. The model explains 76% of the variability in the percentage changes of the Yarn Index, and 83% of the variability of the A Index (i.e., R^2(Yarn Index)=0.76 and R^2(A Index)=0.83). However, several roots of the characteristic polynomial of the ECM lie outside the unit circle, indicating that the system is unstable and rendering it unfit for our goals. The longest lags of the differenced variables for which the ECM is stable is 7, with R^2(Yarn Index)=0.52 and R^2(A Index)=0.45. The block exogeneity test fails to reject the hypothesis that the Yarn Index does not Granger-cause the A Index ($Chi^2(7)=3.69$), while it rejects the hypothesis that the A Index does not Granger-cause the Yarn Index ($Chi^2(7)=14.48$).

The following step was to drop the equation for the A Index from the ECM while maintaining the residuals from the cointegrating equation as an explanatory variable in the equation for the Yarn Index, along with lagged differenced values of both the Yarn Index and the A Index. In the final one-equation ECM, selected after running a battery of exclusion/inclusion tests, the cointegration term is not significant (Table 4), and the $R^2=0.60$. The residuals from this final model show no autocorrelation and no heteroskedastic pattern, and the Quandt-Andrews test fails to reject the hypothesis of no structural breaks at the 10% level of significance over the 2005m06-2009m02 period (p-value=0.71).[1] According to this model, a 10% increase in the A Index in one month results in a 4% increase in the Yarn Index in the following month.

[1] The CUSUM test suggests no structural break over the entire period 2004/05-2010/11.

Table 4. Error Correction Model of Yarn Index and A Index

Dependent Variable: DLn(Yarn Index)

Method: Least Squares

Sample (adjusted): 2005M11 2011M03

Included observations: 65 after adjustments

	Coefficient	Std. Error	t-Statistic	Prob.
Cointegrating Term(-1)	-0.000178	0.078670	-0.002262	0.9982
DLn(Yarn Index)(-1)	-0.065044	0.137788	-0.472059	0.6387
DLn(Yarn Index)(-5)	0.397324	0.105173	3.777799	0.0004
DLn(Yarn Index)(-7)	0.670580	0.151892	4.414841	0.0000
DLn(Yarn Index)(-8)	-0.418757	0.159890	-2.619037	0.0113
DLn(A Index)(-1)	0.413132	0.085994	4.804225	0.0000
DLn(A Index)(-12)	-0.172730	0.078033	-2.213548	0.0309
DLn(A Index)(-14)	-0.171569	0.078807	-2.177083	0.0336

R-squared	0.598136	Mean dependent var	0.014864
Adjusted R-squared	0.548784	S.D. dependent var	0.042151
S.E. of regression	0.028314	Akaike info criterion	-4.176088
Sum squared resid	0.045697	Schwarz criterion	-3.908471
Log likelihood	143.7229	Hannan-Quinn criter.	-4.070496
Durbin-Watson stat	1.850469		

Alternatively, a VAR with 24 lags in the differenced variables is estimated. Although the explanatory power of the model is high (R^2(Dln(Yarn Index)=0.92, R^2(Dln(A Index)=0.87), the VAR is unstable. After applying a battery of lag length tests and stability tests to alternative VAR specifications, the best possible stable VAR model is one with only 1 lag of the differenced variables (Table 5). The residuals from this model are not autocorrelated but are heteroskedastic. Block exogeneity tests reject the hypothesis that the A Index does not Granger-cause the Yarn Index, but fail to reject the hypothesis that the Yarn Index does not Granger-cause the A Index. Therefore, a single-equation model in first differences is further estimated with Newey-West HAC standard errors and covariance to analyze the effects of the A Index on the Yarn Index (Table 6). The explanatory power of the model is low, R2=0.32, but the residuals show no autocorrelation and the standard errors are corrected for heteroskedasticity, and the model is stable over the 2004m12-2010m09 period (p-value of Quandt-Andrews=0.83).[2] The A Index has a positive and significant effect on the Yarn Index, although past values of the Yarn Index are not significant.

[2] The CUSUM test suggests no structural break over the entire period 2004/05-2010/11.

Table 5. VAR Model of Yarn Index and A Index

Vector Autoregression Estimates
Sample (adjusted): 2004M10 2011M03
Included observations: 78 after adjustments
Standard errors in ( ) & t-statistics in [ ]

	DLn(A Index)	DLn(Yarn Index)
DLn(A Index)(-1)	0.453477	0.288564
	(0.14004)	(0.08513)
	[3.23812]	[3.38980]
DLn(Yarn Index)(-1)	0.061727	0.156643
	(0.21676)	(0.13176)
	[0.28478]	[1.18886]
C	0.009414	0.004839
	(0.00649)	(0.00395)
	[1.44970]	[1.22576]
R-squared	0.230709	0.318585
Adj. R-squared	0.210195	0.300414
Sum sq. resids	0.224613	0.082994
S.E. equation	0.054725	0.033265
F-statistic	11.24620	17.53254
Log likelihood	117.4761	156.3050
Akaike AIC	-2.935284	-3.930898
Schwarz SC	-2.844641	-3.840255
Mean dependent	0.018280	0.011770
S.D. dependent	0.061578	0.039771
Determinant resid covariance (dof adj.)		2.13E-06
Determinant resid covariance		1.97E-06
Log likelihood		291.0366
Akaike information criterion		-7.308631
Schwarz criterion		-7.127345

Table 6. Single-Equation Model of Yarn Index

Dependent Variable: DLn(Yarn Index)
Method: Least Squares
Sample (adjusted): 2004M10 2011M03
Included observations: 78 after adjustments
Newey-West HAC Standard Errors & Covariance (lag truncation=3)

	Coefficient	Std. Error	t-Statistic	Prob.
C	0.004839	0.002980	1.623532	0.1087
DLn(A Index)(-1)	0.288564	0.111130	2.596630	0.0113
DLn(Yarn Index)(-1)	0.156643	0.186136	0.841553	0.4027

R-squared	0.318585	Mean dependent var	0.011770
Adjusted R-squared	0.300414	S.D. dependent var	0.039771
S.E. of regression	0.033265	Akaike info criterion	-3.930898
Sum squared resid	0.082994	Schwarz criterion	-3.840255
Log likelihood	156.3050	Hannan-Quinn criter.	-3.894612
F-statistic	17.53254	Durbin-Watson stat	1.793687
Prob(F-statistic)	0.000001		

From this subsection, it can be concluded that: (a) the A Index and the Yarn Index do not move in tandem; (b) the A Index has a significant effect on the Yarn Index, but the Yarn Index does not have a significant effect on the A Index; (c) nor past values of the A Index nor past values of the Yarn Index are good predictors of current and future values of the Yarn Index..

<u>The Yarn Index and the Fabric Price</u>

An ECM with no deterministic trend in the data, and no intercept or trend in the cointegrating equation, and with16 lags of the differenced variables is estimated. The model explains 79% of the variability in the percentage changes of the Yarn Index, and 74% of the variability of Fabric Prices. However, the system is unstable. All ECMs with similar data structure but with fewer lags are unstable. Therefore, it is concluded that the Yarn Index and Fabric Prices are not cointegrated.

Since the Yarn Index is *I(1)* and Fabric Prices are trend-stationary, a single-equation model of Fabric Prices in levels with a trend, past values of Fabric Prices in levels and first differences of the Yarn Index is estimated. Starting from a general model with 24 lags of both Fabric Prices and the first differences of the Yarn Index, and after applying inclusion/exclusion tests, the final model includes lags 1, 3, 6, and 12 of the differenced Yarn Index, and lags 1, 8, and 8 of Fabric Prices (Table 7). The R2=0.96, and the residuals show no autocorrelation, and no heteroskedasticity. The Jarque-Bera test fails to reject the hypothesis of normality of the residuals (p-value=0.50). The Quandt-Andrews test fails to reject the hypothesis of no structural break over the 2005m06-2009m03 period (p-value=1).[3] This model indicates that the level of Fabric Prices in a particular month is mainly determined by the level of Fabric Prices in the previous month, along with the constant and a time trend. The model also suggest that a 10% increase in the Yarn Index in one month produces a 3% decline in Fabric Prices the following month, probably due to a decline in demand for yarn in China. However, that effect disappears after 3 months, and 33% of the increase in the Yarn

[3] The CUSUM test suggests no structural break over the entire period 2004/05-2010/11.

Index is transmitted to Fabric Prices after 6 months, and full transmission occurs after 12 months. However, the explanatory power of the model as measured by the adjusted-R^2 only falls from 0.954942 to 0.941879 if all variables related to the Yarn Index are deleted from the final model. And the general properties of the restricted model remain similar to those of the final model.

From this subsection, it can be concluded that: (a) Fabric Prices (heavy weight woven cotton fabrics imported to China) and the Yarn Index bear little correlation; (b) at most, it can be said that yarn prices have a slight effect on fabric prices, with a lag of 6 to 12 months. Similar analysis of the relationship between the Yarn Index and other fabric prices should be explored to reach stronger conclusions.

Table 7. Single-Equation Model of Fabric Prices

Dependent Variable: Ln(Fabric Prices)

Method: Least Squares

Sample (adjusted): 2005M09 2011M02

Included observations: 66 after adjustments

	Coefficient	Std. Error	t-Statistic	Prob.
C	0.061436	0.018286	3.359736	0.0014
TREND	0.002306	0.001173	1.965372	0.0543
Ln(Fabric Prices)(-1)	0.676002	0.078952	8.562146	0.0000
Ln(Fabric Prices)(-8)	-0.364920	0.079625	-4.582975	0.0000
Ln(Fabric Prices)(-11)	0.343811	0.080721	4.259264	0.0001
DLn(Yarn Index)(-1)	-0.299650	0.127010	-2.359262	0.0218
DLn(Yarn Index)(-3)	0.272441	0.124699	2.184800	0.0330
DLn(Yarn Index)(-6)	0.334226	0.170769	1.957188	0.0552
DLn(Yarn Index)(-12)	0.901757	0.207413	4.347646	0.0001

R-squared	0.960488	Mean dependent var	0.462807
Adjusted R-squared	0.954942	S.D. dependent var	0.156069
S.E. of regression	0.033129	Akaike info criterion	-3.850722
Sum squared resid	0.062557	Schwarz criterion	-3.552132
Log likelihood	136.0738	Hannan-Quinn criter.	-3.732735
F-statistic	173.1995	Durbin-Watson stat	1.948196
Prob(F-statistic)	0.000000		

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 resulted in prices in March 2011 that were nearly triple those in August 2010. Due to the magnitude of price the increases in cotton fiber prices, it is anticipated that there will be consequences for prices throughout the entire 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, at the time of publication, there is little evidence that has surfaced regarding the extent of the effect on garment prices, represented by the landed value of cotton textile imports into the U.S., or U.S. retail apparel prices, represented by the apparel CPI. Such results could be 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 likely not completely surfaced in prices at latter stages of the cotton 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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