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Common Trends, Common Cycles, and Price Relationships in the International Fiber Market

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A multivariate unobserved component model was applied to identify common movements among cotton, wool, rayon, and polyester world prices. Two common stochastic trends and cycles govern the stochastic behaviors of price fluctuations in the world fiber market. These unobserved components have important implications as they can help in the design of more efficient commodity programs to smooth terms of trade shocks, especially in developing countries. The study found the effect of inventory adjustments on world cotton price is diminishing, which indicates that speculative behaviors in the world fiber market are less prevalent than previously thought.

Key words: common factors, fiber prices, Kalman filter, state-space, unobserved components

Introduction

Commodity price behavior has been the subject of numerous studies over the years. These investigations have focused mainly on the question of price instability and their effects in both developed and developing economies. Studies on speculation-induced instability, commodity export instability, and commodity stabilization programs have widely addressed the question of price instability (Labys, Badillo, and Lesourd, 1998). However, the level of uncertainty in the world fiber market has increased due to the effects of events such as China's admission into the World Trade Organization, the expiration of the Agreement on Textiles and Clothing, the elimination of the Multifiber Arrangement, and the spillover effects of domestic policies in major cotton exporting and importing countries. These developments have generated a renewed interest on the topic.

For cotton exporters such as the United States and the Sub-Saharan African (SSA) countries, a higher production and a contraction of the domestic textile industry have increased the level of raw fiber exports. With regard to the SSA countries, raw fiber exports as a share of total production increased from 60% in 1980/82 to 85% in 2000/02, and as a share of world cotton trade from 6.9% to 17.3% (International Cotton Advisory Committee, 2003). For the United States, exports of raw cotton fiber account for 38.7% of world cotton exports (U.S. Department of Agriculture/Economic Research Service, 2006). Cotton export earnings for these countries depend on robust international cotton prices.

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Although there are policy alternatives in place to help cope with depressed cotton prices, the instability of the world cotton price remains detrimental to most producers and exporters, especially those in developing countries where financial resources to sustain such programs are rare. This is particularly important for the SSA countries, which have undertaken major steps to liberalize their domestic textile sectors, privatize their ginning industries, and cease most forms of subsidies they were allocating to their agricultural sector (Lele, 1990). This new paradigm has increased the vulnerability of producers in these countries to downturns in international cotton prices. The increased level of uncertainty in the international cotton market can have detrimental macroeconomic effects because it renders economic planning more difficult. Moreover, for most of these countries, cotton contributes between 5% and 10% of the GDP and between 20% and 40% of total export earnings (Baffes, 2005). Hence, any shortfalls in export earnings generally result in current account deficits that cause further economic damages.

While cotton and polyester are the dominant fibers in most import mixes, it is important to consider wool and rayon because their behaviors are generally linked to the dominant fibers' price dynamics. For instance, at the mill level, the degree of inter-fiber combination in the production of various textile blends is dictated by the attributes sought in specific end-use products and by the relative prices of fibers. However, studies in that regard have focused primarily on cotton and polyester interactions and have generally ignored similar adjustments with respect to wool and rayon.

Clearly, a firm understanding of the behavior of fiber prices and their inter-relationships is important for importing and exporting countries. For importing countries, it facilitates a more efficient planning at the mill level and reduces uncertainty in textile manufacturing activities. For exporting countries, it facilitates coping with price risks in the international market, thereby limiting government intervention at the domestic level that may have undesirable spillover effects, especially into vulnerable countries. However, focusing on the fibers individually cannot fully explain the dynamics of fiber prices in the international fiber market. A flexible approach is needed to accommodate all the adjustments between competing fibers. This study therefore utilizes a system of seemingly unrelated time-series equations to analyze the behaviors of fiber prices in the international market.

Structural Time Series and Agricultural Markets

State-space and the Kalman filter have been utilized to analyze agricultural markets. Walburger and Foster (1997) used Aoki's (1987) linear system to identify common trends in U.S. regional cattle prices. They further derived the stochastic deviations of these prices with respect to the underlying common trends and estimated structural relationships between the derived stochastic deviations and market factors such as slaughter and sale volumes, forward contract deliveries, and distance to the nearest markets. The overall goal was to determine which of these factors caused prices to deviate from their underlying trend. Vukina and Anderson (1993) also used Aoki's linear system to analyze risk and cross-hedging strategies using soybean meal futures and fishmeal spot prices to derive static and dynamic hedging models. Ardeni and Wright (1992) employed a similar framework to analyze the long-run deterioration in the net barter terms of trade. Their study found a downward-sloping linear deterministic trend of the net barter terms of trade and confirmed the Prebish-Singer hypothesis. Kapombe and Colyer (1998) analyzed the U.S. broiler supply response and found a prevalence of stochastic trends and a diminishing importance of seasonality in broiler production. All of these analyses were based on univariate state-space models.

This study proposes a multivariate state-space model based on the de Jong (1991) diffuse Kalman procedure to model jointly the unobserved components (trend and cycle) and the structural relationships between the fiber prices and their determinants. The diffuse Kalman approach is similar to the Harvey (1990) technique with a slight difference as to how the two approaches handle initial conditions and regression effects. Under this framework, it is not necessary to ensure stationarity to make valid inferences because the stochastic trends and cycles nest their deterministic counterparts. As the evolution of these components is shaped by economic factors (Kasa, 1992), they have important policy implications that can be useful to both developing and developed countries. For instance, the amplitude and duration of fiber price cycles can assist in the design of more effective commodity stabilization programs in both developed and developing countries to help producers face the adverse effects of price fluctuations (Cashin and McDermott, 2002; Deaton, 1999; Deaton and Miller, 1996). They also can provide an analytical means for assessing the resulting macroeconomic effects of cotton prices in low-income cotton exporting countries. This is particularly important at a time when marketing tools such as warehouse receipt systems designed specifically for cotton are being tested in select African countries.

Preliminary Methods and Analysis

Data Consideration

This study used annual international prices of cotton (A-index), wool, rayon, and polyester (in U.S. dollars per kilogram) between 1960 and 2004, cotton stocks (in thousand metric tons), and West Texas Intermediate (WTI) crude oil prices (in U.S. dollars per barrel). The fiber prices were derived primarily from the World Bank and the International Cotton Advisory Committee (as summarized in Baffes, 2004). Additional price data were collected from the U.S. Department of Agriculture/Economic Research Service website (2006). Cotton stocks were gathered from the Production Supply and Distribution database administered by the U.S. Department of Agriculture/Foreign Agricultural Service (2006). The WTI crude oil prices were retrieved from the Economagic website (2005).

As the principal input in polyester production, oil price determines polyester price and production capacity utilization. The WTI was used as a proxy of world oil price because the oil market is integrated and follows the law of one price (Ewing and Harter, 2000; Serletis and Rangel-Ruiz, 2004). Nominal prices were transformed into real prices using the World Bank manufacture import unit value index (1990 = 1.0). While the secular and cyclical properties of the deflator could contaminate the estimation results (Labys, Badillo, and Lesourd, 1998), real prices were used for consistency with previous studies. Except where noted, all prices were transformed in logarithm format prior to their use.

Instability in the International Fiber Market

Table 1 summarizes the descriptive statistics based on price levels. On average, wool prices were higher, followed by polyester, rayon, and cotton prices. Polyester and wool

Table 1. Summary Statistics of World Fiber Prices ($U.S./kilogram)

Description	Cotton	Wool	Rayon	Polyester
Mean	2.115	4.115	2.284	3.270
Standard Deviation	0.648	1.238	0.203	2.987
Skewness	0.092	0.980	0.014	1.839
Kurtosis	2.151	3.911	2.009	4.982
Instability Index:[a]				
1960–2004	30.65%	30.08%	8.87%	91.35%
1960–1975	12.87%	25.95%	9.90%	59.79%
1975–1990	23.85%	18.03%	9.84%	12.26%
1990–2004	18.06%	18.34%	7.31%	11.11%

[a] Instability index refers to the coefficient of variation (in %); it is calculated using fiber prices at their respective levels.

prices were more skewed and kurtotic than cotton and rayon prices. The positive skewness of wool and polyester prices signifies a predominance of upward spikes for both of these fibers throughout the sample period. The high kurtosis observed in wool and polyester prices is indicative of large price movements (Cashin and McDermott, 2002).

The instability index, although declining over the years, indicates some degree of instability over the sample period for cotton, wool, and polyester prices. For instance, polyester price instability was evaluated at 59.79% for the 1960–1975 period, 12.26% for the 1975–1990 period, and 11.11% for the 1990–2004 period. Clearly, the degree of instability as presented depends on the chosen sample. In the case of cotton, the results show an increased level of instability from 12.87% to 23.85% for the 1960–1975 and the 1975–1990 periods, respectively.

The instability index as a measure of uncertainty in the commodity market presents serious shortcomings because it is descriptive, while the process at the basis of price movements is stochastic in nature, embedded in their permanent and transitory components (Dehn, 2000). Although Dehn recognized the importance of filtering out prices of their permanent components to generate meaningful structural relationships, he used a generalized autoregressive conditional heteroskedasticity (GARCH) model. The conditional mean equation (first difference of the series) was specified as a function of a quadratic deterministic trend, lags of the dependent variable, seasonal dummies, and a constant term. This approach, however, does not account for the transitory component variance or the asymmetric nature of the error term. Normal GARCH models are less accurate than asymmetric-error GARCH or student *t*-GARCH because of their sensitivity to the underlying distribution of the error term, which is generally nonnormal for prices (Ramírez and Fadiga, 2003). The state-space model with the Kalman filtering algorithm generates filtered series through a recursive process that holds true regardless of the distribution of the error term (Koopman, 1993).

Model Specification and Statistical Treatment

Our model of price dynamics follows a generalized multivariate Ornstein-Uhlenbeck process (Lo and Wang, 1995). In discrete time, this process evolves as a multivariate autoregressive of order one of observable and unobservable components (Lo and Wang;

Pindyck, 1999). The observable components are the prices of competing fibers and oil, while the unobservable components pertain to the stochastic trends and cycles. Graphical representations (available from the authors on request) show that while each of the four fiber prices fluctuates around a mean, all except rayon price between 1973 and 2004 exhibit a downward path over the sample period. Thus, each trend was specified as a stochastic level with a fixed slope. Such a specification is also referred to as a random walk with drift (Koopman et al., 2000). Following Koopman et al., a state-space representation of a multivariate random walk with drift was specified as follows:

$$\text{(1)} \qquad \mathbf{Y}_t = (\mathbf{I} \;\; \mathbf{0} \;\; \mathbf{I} \;\; \mathbf{0})\boldsymbol{\alpha}_t + \mathbf{X}_t\mathbf{B}\otimes\mathbf{I} + (\boldsymbol{\Gamma}_\varepsilon \;\; \mathbf{0} \;\; \mathbf{0} \;\; \mathbf{0} \;\; \mathbf{0})\mathbf{u}_t,$$

$$\text{(2)} \qquad \boldsymbol{\alpha}_t = \begin{pmatrix} \mathbf{I} & \mathbf{I} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{I} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \rho\cos\lambda_c\mathbf{I} & \rho\sin\lambda_c\mathbf{I} \\ \mathbf{0} & \mathbf{0} & -\rho\sin\lambda_c\mathbf{I} & \rho\cos\lambda_c\mathbf{I} \end{pmatrix} \boldsymbol{\alpha}_{t-1} + \begin{pmatrix} \mathbf{0} & \boldsymbol{\Gamma}_\eta & \mathbf{0} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{0} & \boldsymbol{\Gamma}_\omega & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \boldsymbol{\Gamma}_{\bar{\omega}} \end{pmatrix} \mathbf{u}_t,$$

where $\mathbf{Y}_t$ is an $n \times 1$ vector of fiber prices, $\mathbf{I}$ an $n \times n$ identity matrix, $\mathbf{0}$ an $n \times n$ matrix of zeros; $\boldsymbol{\alpha}_t = (\boldsymbol{\mu}_t, \boldsymbol{\beta}_t, \boldsymbol{\psi}_t, \bar{\boldsymbol{\psi}}_t)'$ is the state vector with an $n \times 1$ vector of stochastic levels ($\boldsymbol{\mu}_t$), an $n \times 1$ vector of slopes ($\boldsymbol{\beta}_t$), and an $n \times 1$ vector of stochastic cyclical components ($\boldsymbol{\psi}_t$). The vector $\bar{\boldsymbol{\psi}}_t$ is included in the model by construction. Moreover, $\mathbf{u}_t = (\boldsymbol{\varepsilon}_t, \boldsymbol{\eta}_t, \boldsymbol{\xi}_t, \boldsymbol{\omega}_t, \bar{\boldsymbol{\omega}}_t)'$ is a vector of error process where $\boldsymbol{\varepsilon}_t$, $\boldsymbol{\eta}_t$, $\boldsymbol{\xi}_t$, and $\boldsymbol{\omega}_t$ are $n \times 1$ vectors of stochastic errors which drive the stochastic properties of the irregular, level, slope, and cyclical components.

The level and slope jointly form the trend component. However, in the case of a multivariate random walk with drift, the stochastic property of the trend is solely driven by the level. Thus, trend and level are used interchangeably throughout this study. The disturbances are assumed normally distributed with mean $\mathbf{0}$ and variance $\boldsymbol{\Sigma}_\varepsilon$, $\boldsymbol{\Sigma}_\eta$, $\boldsymbol{\Sigma}_\xi$, and $\boldsymbol{\Sigma}_\omega$. The parameters $\boldsymbol{\Gamma}_\varepsilon$, $\boldsymbol{\Gamma}_\eta$, and $\boldsymbol{\Gamma}_\omega$, such that $\boldsymbol{\Sigma}_\varepsilon = \boldsymbol{\Gamma}_\varepsilon\boldsymbol{\Gamma}_\varepsilon'$, $\boldsymbol{\Sigma}_\eta = \boldsymbol{\Gamma}_\eta\boldsymbol{\Gamma}_\eta'$, and $\boldsymbol{\Sigma}_\omega = \boldsymbol{\Gamma}_\omega\boldsymbol{\Gamma}_\omega'$, respectively, are the lower triangles of the variance-covariance matrix of the irregular, secular, and cyclical components. The remaining parameters are a damping factor $\rho \in [0, 1]$ and a frequency $\lambda_c \in [0, \pi]$ common to the four prices. Finally, $\mathbf{X}_t$ is the vector of explanatory variables described in table 2 and $\mathbf{B}$ is the vector of their respective coefficients.

If the variance matrices of the trend and/or cycle innovations are less than full ranks, the price series share trends and/or cycles. The following adjustments are carried out in the specification to account for the presence of linear combinations $\boldsymbol{\mu}_t = \boldsymbol{\Theta}_\mu\tilde{\boldsymbol{\mu}}_t + \tilde{\boldsymbol{\mu}}_\theta$ and $\boldsymbol{\psi}_t = \boldsymbol{\Theta}_\psi\tilde{\boldsymbol{\psi}}_t$, $\boldsymbol{\Sigma}_\eta = \boldsymbol{\Theta}_\mu\mathbf{D}\boldsymbol{\Theta}_\mu'$, $\boldsymbol{\Sigma}_\omega = \boldsymbol{\Theta}_\psi\mathbf{D}\boldsymbol{\Theta}_\psi'$, $\boldsymbol{\Gamma}_\eta = \boldsymbol{\Theta}_\mu\mathbf{D}_\eta^{1/2}$, and $\boldsymbol{\Gamma}_\omega = \boldsymbol{\Theta}_\psi\mathbf{D}_\omega^{1/2}$, with $\mathbf{D}_\eta$ and $\mathbf{D}_\omega$ the diagonal matrices with diagonal elements corresponding to the eigenvalues of the trend and cycle innovations' variance matrices. The coefficient matrices $\boldsymbol{\Theta}_\mu$ and $\boldsymbol{\Theta}_\psi$ are, respectively, $n \times k$ and $n \times s$ factor loading matrices with the elements θ_{ij} constrained to zero for $i > j$ to ensure that the system is identified, $\tilde{\boldsymbol{\mu}}_t$ is an $n - k \times 1$ vector of common levels, $\tilde{\boldsymbol{\mu}}_\theta$ an $n \times 1$ vector of constant terms with the first k elements equal to zero, and $\tilde{\boldsymbol{\psi}}_t$ an $n - s \times 1$ vector of common cycles. The factor loading matrices measure the relationship between the observed prices and the k common trends and s common cycles.

Reduced ranks are tested using the multivariate unobserved component approach (Harvey, Ruiz, and Shephard, 1994). The test looks at the number of nonzero elements in $\mathbf{D}$, which equals the number of nonzero columns in the variance matrices. This

Table 2. Description and Specification of Variables

Explanatory Variable	Label	Dependent Variable (price)			
		Cotton	Wool	Rayon	Polyester
$CSTK_T \times 10^{-4}$	Change in Stock	✓			
$LCOT_{T-1}$	Lag Cotton Price	✓	✓	✓	
$LWOL_{T-1}$	Lag Wool Price		✓	✓	
$LRAY_{T-1}$	Lag Rayon Price			✓	
$LPOL_{T-1}$	Lag Polyester Price		✓		✓
$LWTI_{T-1}$	Lag Oil Price				✓

Notes: A checkmark (✓) indicates that the explanatory variables were specified with the corresponding dependent variable in the structural relationship part of the model. Only the change-in-stock variable is computed at its level. All remaining variables are log-transformed.

approach is based on factor analysis and is more reliable than methods based on autoregressive approximations (Harvey, Ruiz, and Shephard, 1994; Luginbuhl and Koopman, 2004). The unobserved state vector and variance parameters, along with the factor loading matrices, the damping factor, the frequency of the cycle, and the parameters of explanatory variables, are jointly estimated by maximum-likelihood procedure using the Kalman filtering technique.

Empirical Results

Common Factor Analysis

The unrestricted multivariate random walk with drift initially fitted has four stochastic trends with fixed slopes and four stochastic cycles. The estimated eigenvalues of the trend, cycle, and irregular components' variance matrices are presented in table 3. It follows from the estimated eigenvalues that $Rank(\mathbf{\Sigma}_\eta) = 3$ and $Rank(\mathbf{\Sigma}_\omega) = 2$. However, the estimation of the system with these rank restrictions yields one more zero diagonal element for the eigenvalues matrix, indicating the presence of an additional common factor for the trend. This is not unexpected because under the unrestricted model, cotton and polyester prices contribute up to 87% of the total variance pertaining to the trend while cotton and wool contribute 100% of the total cycle's variance (table 3). Thus, two common trends and two common cycles adequately describe the long-run and short-run dynamics of international fiber prices.

This finding was further confirmed by a likelihood-ratio (LR) test, which was evaluated using the log-likelihood values under the unrestricted model evaluated at 330.157 (table 3), and under the restricted model evaluated at 329.420 (table 4). The calculated LR ($LR = -2 \times [329.420 - 330.157] = 1.473$) is less than $\chi^2_{[4]}$ at the 5% significance level, indicating that the two common trends and two common trends cycles' restrictions are binding.

From this point forward, the results presented are based on a multivariate random walk with drift restricted to two common trends and two common cycles. The estimated standardized factor loading matrices in tables 4 and 5 led to the following relationships between fiber prices and the common trends and cycles:

Table 3. Eigenvalues of the Diagonal Matrices Under the Unrestricted Model

	Fibers			
Description	Cotton	Wool	Rayon	Polyester
Irregular ($\mathbf{D}_\varepsilon$)	0.104	0.064	0.035	0.001
Percentage (%)	(50.98)	(31.37)	(17.16)	(0.49)
Trend ($\mathbf{D}_\eta$)	0.058	0.000	0.020	0.079
Percentage (%)	(36.82)	(0.00)	(12.76)	(50.41)
Cycle ($\mathbf{D}_\omega$)	0.022	0.023	0.000	0.000
Percentage (%)	(48.89)	(51.11)	(0.00)	(0.00)

Notes: The estimates correspond to the eigenvalues of the variance matrices of the irregular, trend, and cycle components. The number of nonzero eigenvalues is the rank of the corresponding matrix. The unrestricted log-likelihood value (LogL) was evaluated at 330.157 ($-2 \times$ LogL = -660.314).

Table 4. Estimated Factor Loadings (Θ_μ) and Communality Scores of the Trends

	Factor Loadings						
	Standardized		Unstandardized		Rotated		
Fibers	$\tilde{\mu}_{1t}$	$\tilde{\mu}_{2t}$	$\tilde{\mu}_{1t}$	$\tilde{\mu}_{2t}$	$\tilde{\mu}_{1t}$	$\tilde{\mu}_{2t}$	Communality
Cotton	1.000	0.000	0.231	0.000	0.438	0.269	0.264
Wool	-1.984	1.000	-0.459	0.173	-0.869	-0.076	0.761
Rayon	-0.310	0.270	-0.071	0.046	-0.136	0.040	0.020
Polyester	-0.425	2.348	-0.098	0.406	-0.186	0.959	0.955

Notes: The matrix Θ_μ measures the contribution of each common trend to the variance of each fiber price, $\tilde{\mu}_{1t}$ and $\tilde{\mu}_{2t}$, such that $\tilde{\boldsymbol{\mu}}_t = (\tilde{\mu}_{1t}, \tilde{\mu}_{2t})'$ indicates the first and second common trends, and communality is the contribution of the two common trends to the variance of each price, and $\tilde{\boldsymbol{\mu}}_\theta = (0, 0, 0.125, -3.658)'$ is the estimated vector of constant terms pertaining to the trend. The restricted log-likelihood value was evaluated at 329.420 ($-2 \times$ LogL = -658.841).

Table 5. Estimated Factor Loadings (Θ_ψ) and Communality Scores of the Cycles

	Factor Loadings						
	Standardized		Unstandardized		Rotated		
Fibers	ψ_{1t}	ψ_{2t}	ψ_{1t}	ψ_{2t}	ψ_{1t}	ψ_{2t}	Communality
Cotton	1.000	0.000	0.148	0.000	0.464	-0.530	0.497
Wool	1.687	1.000	0.251	0.157	0.784	0.597	0.971
Rayon	0.593	-0.165	0.088	-0.025	0.275	-0.561	0.390
Polyester	0.662	0.089	0.098	0.014	0.308	-0.218	0.142

Notes: The matrix Θ_ψ measures the contribution of each common trend to the variance of each fiber price, ψ_{1t} and ψ_{2t}, such that $\boldsymbol{\psi} = (\psi_{1t}, \psi_{2t})'$ indicates the first and second common cycles, and communality is the contribution of the two common cycles to the variance of each price.

$$\begin{bmatrix} y_{1t} \\ y_{2t} \\ y_{3t} \\ y_{4t} \end{bmatrix} = \begin{bmatrix} 1.000 & 0.000 \\ -1.984 & 1.000 \\ -0.310 & 0.270 \\ -0.425 & 2.348 \end{bmatrix} \begin{bmatrix} \tilde{\mu}_{1t} \\ \tilde{\mu}_{2t} \end{bmatrix} + \begin{bmatrix} 0.000 \\ 0.000 \\ 0.125 \\ -3.658 \end{bmatrix} + \begin{bmatrix} 1.000 & 0.000 \\ 1.647 & 1.000 \\ 0.593 & -0.165 \\ 0.662 & 0.089 \end{bmatrix} \begin{bmatrix} \psi_{1t} \\ \psi_{2t} \end{bmatrix},$$

where y_{1t}, y_{2t}, y_{3t}, and y_{4t} are, respectively, cotton, wool, rayon, and polyester prices; $\tilde{\mu}_{1t}$ and $\tilde{\mu}_{2t}$ are the common trends; and ψ_{1t} and ψ_{2t} their common cycles. For more insights about the relationships between common trends, common cycles, and fiber prices, we used the rotated factor loading matrices as suggested in Harvey, Ruiz, and Shephard (1994). The rotated factor loading matrices are the orthogonal transformations of the unstandardized factor loading matrices. As table 4 shows, cotton price loads on the first and second common trends, while polyester price loads almost exclusively on the second common trend. Moreover, the calculated communality scores (the sum of the squared rotated factors) indicate that the two common trends contribute up to 26% of variability of cotton price, 76% of that of wool price, and 96% of that of polyester price. Only 2% of the variability of rayon price can be attributed to the two common trends. As for the cycles, the four fiber prices load on the first common cycle while only wool price loads heavily on the second common cycle. The two common cycles account for 50% and 97%, respectively, of the cyclical variability of cotton and wool prices and only 39% and 14% of the cyclical variability of rayon and polyester prices, respectively (table 5).

Stochastic Component Analysis

The results reported in table 6 indicate that the stochastic nature of cotton, wool, rayon, and polyester prices are embedded in their irregular, trend, and cyclical components. The trend and cycle decompositions reveal that wool price exhibits the highest variance for both components' innovations. The calculated ratios of the trend to the cycle innovations' variances indicate that permanent innovations dominate transitory innovations for all fiber prices, and permanent shocks last longer for polyester price, followed by wool and cotton prices. The common cycles have a period of 7.35 years with a frequency of 0.855 and a damping factor of 0.937, which is indicative of a stationary cycle. Thus, in the long run, the cyclical component dissipates and the forecast of each price series converges toward its trend values. The unobserved components have some policy implications for fiber exporters, especially in the developing countries. Knowledge about the cycle duration and the size of the permanent innovations relative to the transitory innovations could be useful when designing policies to smooth export earning shocks. The Australian wool stabilization program faltered and was subsequently phased out in 1992 because it was too costly and unsustainable (Cashin, Liang, and McDermott, 2000). The prohibitive cost of the program was associated with the duration of shocks.

The estimated correlation matrices $\mathbf{\Omega}$ between cotton, wool, rayon, and polyester price trends' and cycles' disturbances are:

$$\mathbf{\Omega}(\boldsymbol{\eta}_t) = \begin{bmatrix} 1.000 & & & \\ -0.962 & 1.000 & & \\ -0.899 & 0.984 & 1.000 & \\ -0.308 & 0.554 & 0.693 & 1.000 \end{bmatrix} \text{ and } \mathbf{\Omega}(\omega_t) = \begin{bmatrix} 1.000 & & & \\ 0.834 & 1.000 & & \\ 0.969 & 0.675 & 1.000 & \\ 0.981 & 0.924 & 0.905 & 1.000 \end{bmatrix}.$$

Table 6. Estimated Standard Deviations of the Irregular, Trend, and Cyclical Disturbances

	Disturbances		
Fibers	Irregular	Trend	Cycle
Cotton	0.104	0.053	0.022
Wool	0.141	0.110	0.045
Rayon	0.053	0.018	0.013
Polyester	0.047	0.074	0.015

Notes: The additional parameters associated with the cycle are a damping factor ρ estimated at 0.937, a cycle period of $2\pi/\lambda_c$ evaluated at 7.35 years, and frequency λ_c estimated at 0.855.

The results confirm common trends are shared by cotton and wool prices on one hand, and wool and rayon prices on the other hand. The estimated correlation between cotton and polyester prices' disturbances is −0.308, suggesting no long-run relationship between cotton and polyester prices. Moreover, the correlation between cotton and polyester prices' cycle disturbances was evaluated at 0.981, and the correlation between cotton and rayon prices' cycle disturbances at 0.969. Thus, cotton and polyester prices on one hand and cotton and rayon prices on the other hand have synchronous cycles. Figures 1 and 2 illustrate the paths of the specific and common trends and cycles of cotton, wool, rayon, and polyester prices between 1960 and 2004.

While these results appear intriguing, the extent to which cotton and polyester prices establish a long-run relationship is only plausible from 1980 onward when the cotton-to-polyester price ratio started fluctuating around one. Baffes (2005) noted the presence of structural breaks in real cotton prices in 1980, which can be attributed to the world-wide shift in fiber consumption patterns. In the 1960s, cotton accounted for 68% of total fiber demand because of favorable price relationships (Baffes, 2005). Shifting consumer tastes in the 1970s, in combination with technological innovations, considerably improved the popularity of polyester and its competitive position relative to cotton (Meyer, 1999; Fadiga, Chaudhary, and Mohanty, 2003). As a result, cotton share of total fiber consumption fell to less than 50% in 1980. Since 1980, cotton and polyester prices continuously adjust to each other, and their relative price determines the optimal consumption of each fiber at the mill level.

Final State Vector and Structural Relationships

The maximum-likelihood estimates of the final state vector and the explanatory variables are presented in table 7. The parameter estimate μ_T is the level of the trend and β_T its growth rate at the steady-state point (i.e., $t = T$). The exponential of μ_T is the trend value of cotton, wool, rayon, and polyester prices. Thus, the trend value at the end of the period is 1.121 for cotton, 3.589 for wool, 1.642 for rayon, and 0.841 for polyester. The estimated value of the slope parameter indicates, at the steady-state point, cotton price declined by 1.6% a year in real terms, wool price by 2.9%, and polyester price by 3.5%. Price of rayon remained relatively the same over the sample period. With regard to the cycle, the estimated state parameters ψ_T and $\overline{\psi}_T$ determine the amplitude. The results indicate that the amplitude of the cycle as a percentage of the trend is 2.839% for cotton price, 11.014% for wool price, 1.287% for rayon price, and 2.509% for polyester price.

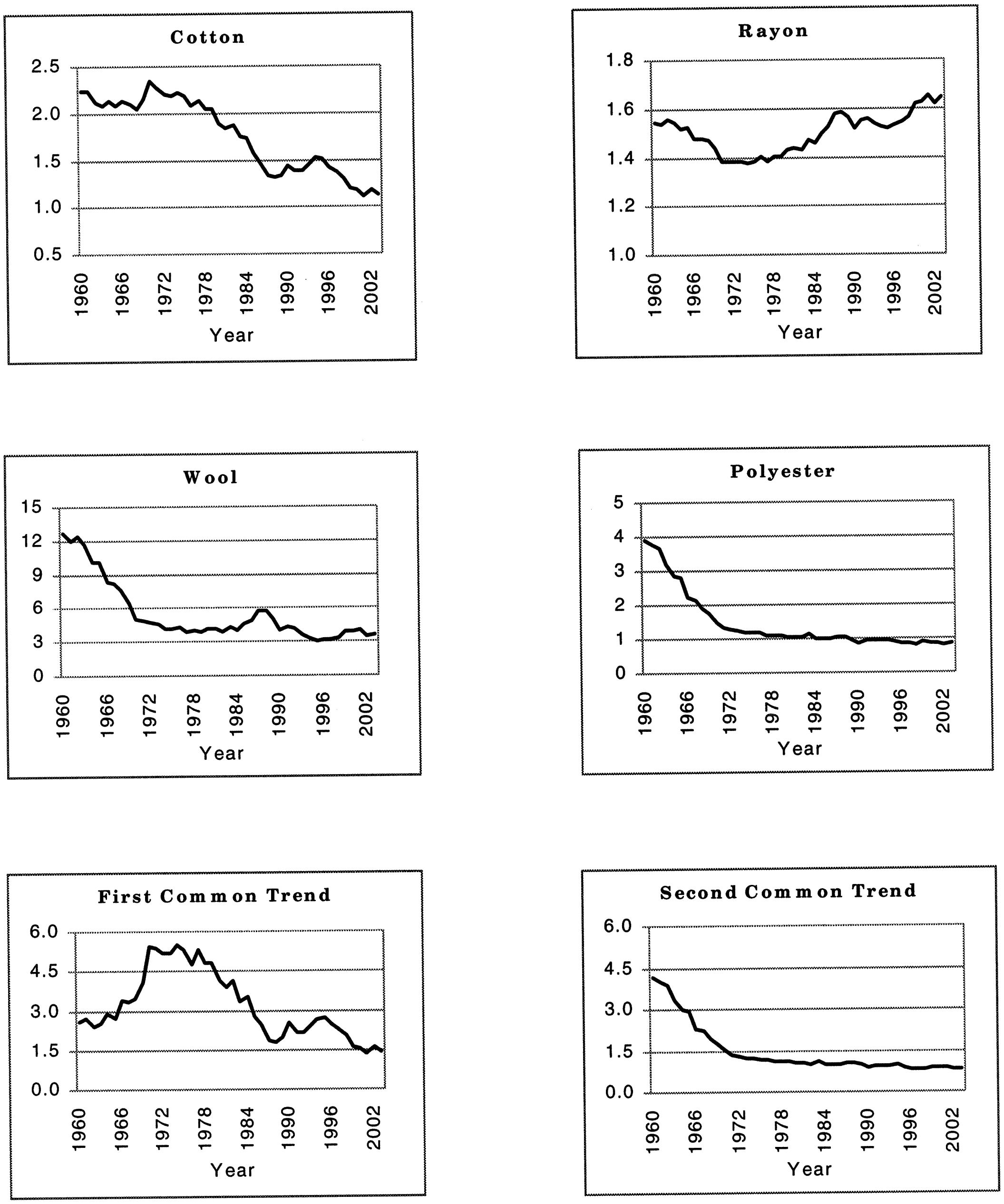

Figure 1. Individual and common trends of cotton, wool, rayon, and polyester prices, 1960–2004

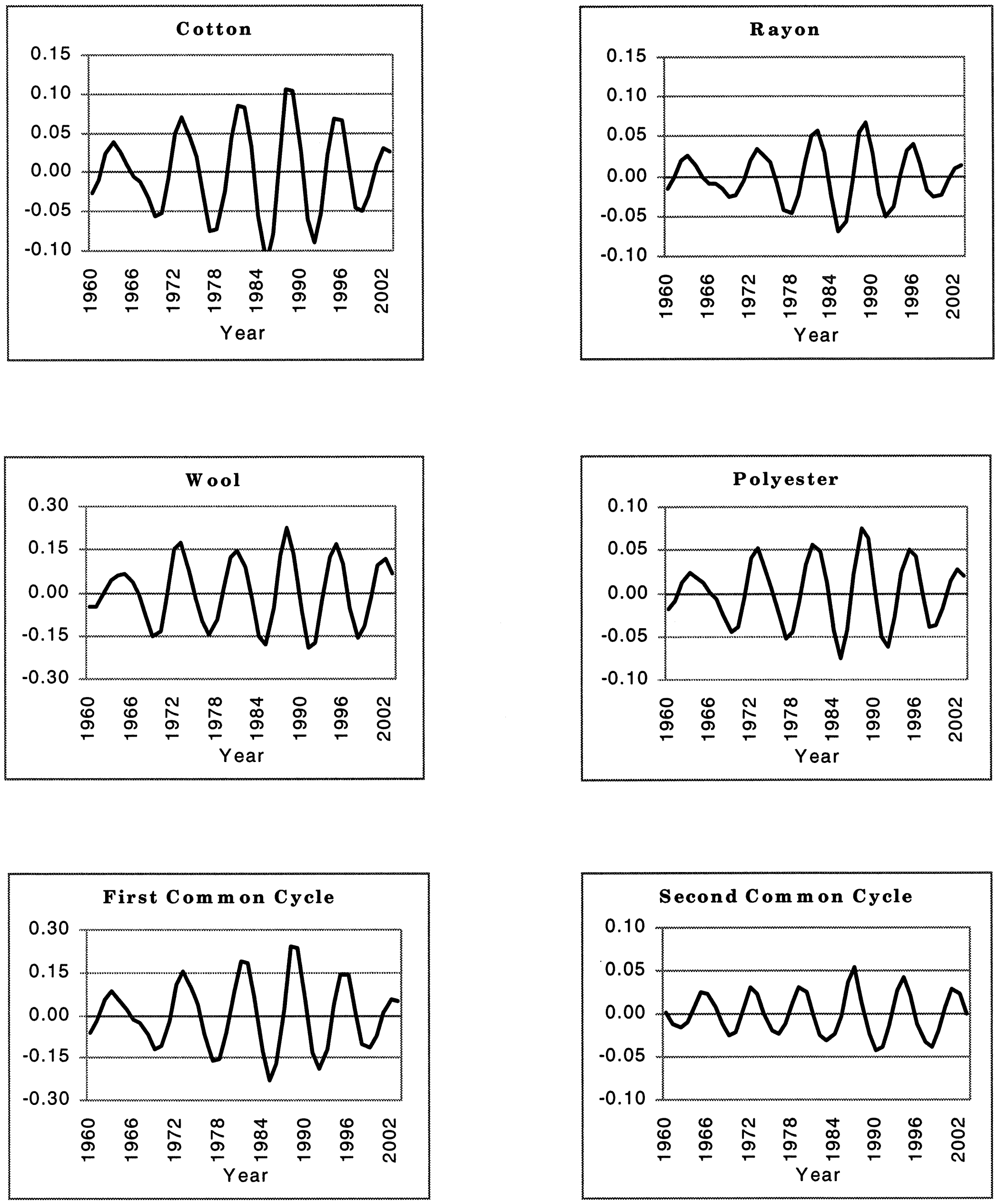

Figure 2. Individual and common cycles of cotton, wool, rayon, and polyester prices, 1960–2004

Table 7. Maximum-Likelihood Estimates of the Final State Vector and Coefficients of Explanatory Variables

		Cotton		Wool		Rayon		Polyester	
Description	Label	Estimate	Std. Error	Estimate	Std. Error	Estimate	Std. Error	Estimate	Std. Error
Parameters:		<--------	--------	--------	STATE VECTOR	ESTIMATION --------	--------	--------	-------->
μ_T	Level	0.114**	0.057	1.278***	0.160	0.496***	0.101	-0.173	0.194
β_T	Slope	-0.016*	0.008	-0.029	0.019	0.001	0.004	-0.035***	0.013
ψ_T	Cycle	0.025	0.032	0.063	0.086	0.012	0.024	0.019	0.026
$\overline{\psi}_T$	Cycle	-0.011	0.035	-0.090	0.092	-0.002	0.027	-0.016	0.029
Variables:		<--------	--------	STRUCTURAL	RELATIONSHIPS	ESTIMATION --------	--------	--------	-------->
$CSTK_T \times 10^{-4}$	Change in Stock	-0.645***	0.154	—	—	—	—	—	—
$LCOT_{T-1}$	Lag Cotton Price	0.216*	0.129	0.472***	0.185	0.191***	0.051	—	—
$LWOL_{T-1}$	Lag Wool Price	—	—	-0.149*	0.140	—	—	—	—
$LRAY_{T-1}$	Lag Rayon Price	—	—	—	—	0.388***	0.119	—	—
$LPOL_{T-1}$	Lag Polyester Price	—	—	-0.405**	0.174	-0.043***	0.044	0.299**	0.127
$LWTI_{T-1}$	Lag Oil Price	—	—	—	—	—	—	0.120**	0.052
Model Diagnostics:									
Rd^2	Goodness of Fit	0.579		0.401		0.505		0.271	
$Q(10)$	Autocorrelation	4.037		6.013		8.156		8.760	
$H(14)$	Heteroskedasticity	0.908		0.489		0.452		0.469	

Notes: Single, double, and triple asterisks (*) denote statistical significance at the 10%, 5%, and 1% levels, respectively. The steady-state level, $t = T$, represents the point at which the relationships between component/explanatory variables and state dependent variables are evaluated. The parameters μ_T, β_T, ψ_T, and $\overline{\psi}_T$ are the individual elements of the parameter vectors $\boldsymbol{\mu}_t$, $\boldsymbol{\beta}_t$, $\boldsymbol{\psi}_t$, and $\overline{\boldsymbol{\psi}}_t$. No t-statistic is provided for ψ_T and $\overline{\psi}_T$ because of the transitory nature of the cycle component, making such statistics inappropriate (Koopman et al., 2000). The values of $Q(10)$ that are less than $\chi^2_{[10]}$ at the 5% level = 18.31 indicate no autocorrelation, while the values of $H(14)$ that are less than $F_{[14,14]0.05}$ = 2.46 indicate no heteroskedasticity. Rd^2 represents the goodness-of-fit coefficient, which accounts for the presence of trend movements in the series. The log of likelihood value is provided in table 4.

The relationships between each fiber price and a set of independent variables were estimated to gauge the conditional adjustments taking place in the international fiber market. As previously noted, the dynamics in the international fiber market are driven by the interactions of complex phenomena that determine market-clearing conditions and price level in each sector. In this paradigm, the effects of shocks from various sources—including climatic, technological, and economic effects—are transmitted between various sectors of the fiber market and are manifested through continuous price realignments. Consequently, these shocks affect demand, price, and supply levels in the world market. From this viewpoint, the structural parameters measure the conditional effects between price levels. The results show cotton price in the international market responds directly to past cotton price and inversely to change in stocks. There is a direct conditional effect of cotton price on wool price and an indirect conditional effect of polyester price on wool price. Price of rayon responds directly to cotton price and indirectly to polyester price given its past price. Finally, polyester price responds directly to past polyester and oil prices.

The results of structural relationships provided insights about the conditional dynamics and adjustments in the international fiber market. Significant interactions were found between fiber prices, change in inventory level, and oil price. The positive relationship between current and past cotton prices is consistent with previous findings by Monke and Taylor (1985) that cotton price adjusts slowly to its past level through a slow change illustrated by a relatively low coefficient estimate. Similar results were obtained with rayon price; however, Monke and Taylor did not include rayon price in their model. The negative impact of change in stocks on current cotton price indicates that current price adjusts to the level of inventory in the world market, as reported by Monke and Taylor. The responsiveness of price to changes in inventory level was calculated in the short run and long run. The average change in stock was evaluated at 154,000 metric tons, at which level the short-run inventory elasticity (parameter estimate times the average change in stock) was evaluated at -0.099, while the long-run elasticity was estimated at -0.013. The magnitudes of the short-run and long-run elasticities suggest inventory levels are no longer a determining factor in shaping world cotton price. The reduced role of inventory adjustment on price indicates less speculative behavior in the world market influenced by factors such as declining Chinese and U.S. held stocks, favorable oil market for polyester production, and widespread use of forward contracting by manufacturers.

Our results suggest oil price is a main determinant of short-run price relationships in the international fiber market because of its positive effect on polyester price through which it affects cotton price in the short run. As the primary input in polyester production, a rise in oil price leads to a contraction in polyester production or a higher price of polyester. Consequently, demand for cotton increases, leading to a higher price of cotton.

Conclusion

This study proposed a state-space model to decompose international cotton, wool, rayon, and polyester prices into their trend and cyclical components. The decomposition provided useful insights about the short-run and long-run behaviors of prices, and has important policy implications as well. The study showed that the stochastic behaviors of world fiber prices are transitory and permanent, and the predominance of either one determines whether shocks are lasting or short-lived. In relative terms, the permanent component was more important for wool, polyester, and cotton, while for rayon it was the transitory component. Thus, shocks for polyester, wool, and cotton prices last longer than shocks for rayon prices.

The conditional dynamics show the importance of oil price and the diminished role of inventory adjustments in the determination of current fiber prices in the world market. More importantly, the absence of a direct relationship between cotton and polyester prices indicates the possibility for manipulation of the fiber market to alter the cotton-to-polyester price ratio in order to boost cotton demand. The extent to which this strategy could be successful can be explored, provided availability of data.

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