Journal of Agribusiness 24,1 (Spring 2006):41–60

Dynamic and Stochastic Structures of U.S. Cotton Exports and Mill Demand

Mohamadou L. Fadiga

This study employs a structural time-series method to model and estimate U.S. cotton exports and mill use. The results show that the stochastic process governing cotton export fluctuations is transitory, while the process pertaining to mill use has transitory, seasonal, and secular origins. The estimated structural relationships after accounting for the unobserved components indicate U.S. cotton exports respond directly to higher international price relative to domestic price of cotton, while mill use responds directly to U.S. textile output price and cotton-to-polyester price ratio. Exchange rate volatility and the U.S. Export Enhancement Program have no significant effect on cotton exports.

Key Words: cotton exports, cotton mill use, Kalman filter, state space, unobserved components

The U.S. textile and apparel industry has encountered multiple difficulties in the last 20 years, due primarily to competition from low-cost textile producing industries in Asia (Gross, 2000). The difficult competitive environment led the U.S. textile industry to move from the production of high-valued end-use products to more production and exports of low-valued products such as yarn, thread, and fabric (Hudson and Ethridge, 2000). New multilateral arrangements such as the Caribbean Basin Initiative also facilitated the rise in exports of yarn, fabric, and thread. Under this agreement, items from materials produced in the United States and assembled in the beneficiary countries are granted duty-free access into the U.S. market. This initiative enables U.S. apparel manufacturers, especially those establishing operations in the assembling countries, to become more price-competitive. It also creates the conditions for U.S. textile mills to increase their yarn, fabric, and thread exports, which may ultimately lead to higher demand for U.S. cotton.

The disengagement of the U.S. textile industry from the production of labor-intensive end-use products such as apparel is affecting the developing world, especially Asia, the Caribbean region, and Mexico. Imports of foreign-produced apparel and home furnishings into the United States have been increasing over the last

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decade, passing from $41 billion to $62.5 billion between 1995 and 2001 for apparel alone (U.S. Department of Commerce, 2004). Textile industries in these regions are experiencing a sustained growth in their operations, leading to higher cotton demand in part from the United States. The shipment of raw cotton from the United States amounted to 11.9 million bales for the 2002/03 marketing year, representing about 38.7% of world cotton exports [U.S. Department of Agriculture/Economic Research Service (USDA/ERS), 2004a].

The evolution of export-to-supply and mill use-to-supply ratios over the last decade illustrates the changes being faced by the U.S. textile industry. The mill use-to-supply ratio averaged about 49.41% between 1990 and 2000, then fell to 29% between 2001 and 2003, while the exports-to-supply ratio rose from 28.28% to 48.57% over these two periods. Most of the U.S. exports go to Mexico, China, Turkey, Pakistan, India, Canada, South Korea, Thailand, Indonesia, and Taiwan, where the United States has a sizable share of the cotton markets (USDA/Foreign Agricultural Service, 2004). Because the United States constitutes a reliable supply source for these countries, the shares are expected to remain high.

Although it is widely accepted that robust industrial activities and a favorable parity between international price and domestic price of cotton have direct effects on exports, empirical evidence of the effects of exchange rate and exchange rate volatility on trade flows is not firmly established. Related studies reached different conclusions despite hypothesizing that exchange rate and exchange rate volatility hinder exports (Bini-Smaghi, 1991; Chowdhury, 1993; Arize, 1995, 1996). The conflicting empirical findings may be due to specification problems. Chowdhury (1993) pointed out procedural flaws in earlier studies stemming from a failure to account for the possible integration and long-run relationship between export volume and most of its determinants, including exchange rate and world price. When two variables establish a long-run relationship, an error correction model or a first-order autoregressive distributed lag model can assess the short- and long-run dynamics between the variables (Davidson and MacKinnon, 1993). However, these methods provide no information about the trend, cyclical, and seasonal components of the series.

For mill use, while cotton-to-polyester price ratio, textile output price, and cotton textile deficit determine the optimal level of cotton consumption at the mill level (Meyer, 1999), U.S. textile mills also operate under the influence of international business cycles and foreign textile manufacturing activities. These events are not under the control of U.S. manufacturers and constitute a major source of uncertainty for the U.S. textile industry that can be accounted for by modeling the unobserved components of mill use.

The objectives of this study are threefold: (*a*) to model and estimate the unobserved components (trend, seasonal, and cycle) of cotton exports and mill use; (*b*) to identify, quantify, and filter out the variability that arises from their underlying stochastic nature; and (*c*) to estimate the structural relationships of cotton exports and mill use with their respective determinants. The structural time-series approach based on the state space model with the Kalman filter is a useful framework for achieving these objectives. Unlike the state space model based on Aoki's (1987) linear system approach, the structural time series proposed in this study uses the diffuse Kalman filtering procedure (de Jong, 1991). It does not require stationary series nor does it make any assumption with respect to the nature of the trend or cycle. The stochastic or deterministic nature of the trend or cycle is solely driven by the data. A deterministic trend or cycle is a limiting case of its stochastic counterparts when the variance of the respective disturbance converges to zero. This framework provides the ability to investigate the long-run and short-run dynamics of cotton exports and mill use by modeling their underlying unobserved and observed components. The decomposition of economic series in terms of their respective components can help in determining how these components relate to the economic phenomena that shape their evolution (Kasa, 1992).

The unobserved components have important policy implications for the U.S. textile industry and cotton export sector. For instance, the amplitude and duration of cotton exports and mill use cycles can be key elements to help managers anticipate booms and slumps in domestic and foreign textile manufacturing activities and adjust their operations accordingly. Moreover, the ability to model simultaneously the explanatory variables, including intervention dummies to account for the effects of U.S. agricultural policies, with the embedded components is an added advantage of the proposed approach in comparison to separate structural econometrics or pure time-series modeling.

Description of the Data and Preliminary Methods

This study used monthly data between 1980:1 and 2003:7 compiled from various sources. Cotton exports, mill use, cotton textile imports, and cotton textile exports (thousand bales) were compiled from the *Cotton and Wool Situation and Outlook Yearbook* published by the U.S. Department of Agriculture (USDA/ERS, 2004a). The real trade-weighted exchange rate index was taken from the USDA/ERS website (2004b). Mill-delivered price of cotton, A-index, and mill-delivered price of polyester (cents per pound) were retrieved from the National Cotton Council of America (2004) website. The textile output price is a price index published by the U.S. Bureau of Labor Statistics (U.S. Department of Labor, 2005). The overall data set was transformed into logarithm format. The price and exchange rate series are in real terms with year 2000 as base.

A stationarity test based on the augmented Dickey-Fuller method indicates that exports (*XP*) and mill use (*MUS*) are integrated of order one. Thus, the trends associated with both series are stochastic. As shown by figure 1, exports fluctuated around a mean throughout most of the sample period (except after January 2000), while mill use was relatively stable between 1980 and 1985, then exhibited a small upward trend until 1996, before entering a period of decline from 1997 onward. Most of the fluctuations in both series appeared to be the effects of the embedded seasonal and cyclical components. Diagnostic tests based on the correlograms and power spectra of exports and mill use revealed the presence of two stochastic cycles

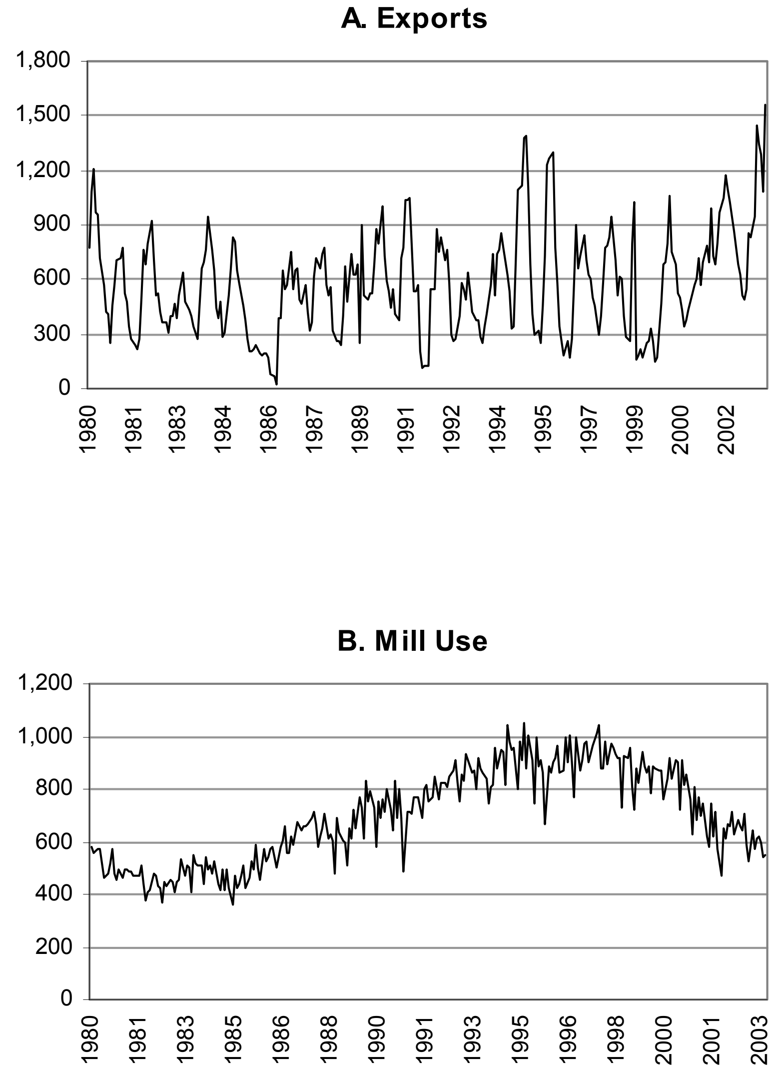


Figure 1 (panels A and B). Monthly U.S. cotton exports and mill use (1,000 bales), 1980:1−2003:7

embedded in both series. Thus, two stochastic cycles and a stochastic season were specified along with a stochastic level with a fixed slope for exports and a fixed level with a stochastic slope for mill use.

The Structural Time-Series Model

Following Harvey (1989, 1990) and Koopman et al. (2000), a structural time series of U.S. cotton exports and mill use was formulated as follows:

$$Y_t = \mu_t + \psi_t + \phi_t + \gamma_t + \mathbf{X}_t\mathbf{B} + \varepsilon_t, \tag{1}$$

$$\mu_t = \mu_{t-1} + \beta_{t-1} + \eta_t, \tag{2}$$

$$\beta_t = \beta_{t-1} + \xi_t, \tag{3}$$

$$\begin{bmatrix} \psi_t \\ \bar{\psi}_t \end{bmatrix} = \rho_1 \begin{bmatrix} \cos\lambda_1 & \sin\lambda_1 \\ -\sin\lambda_1 & \cos\lambda_1 \end{bmatrix} \begin{bmatrix} \psi_{t-1} \\ \bar{\psi}_{t-1} \end{bmatrix} + \begin{bmatrix} \omega_t \\ \bar{\omega}_t \end{bmatrix}, \tag{4}$$

$$\begin{bmatrix} \phi_t \\ \bar{\phi}_t \end{bmatrix} = \rho_2 \begin{bmatrix} \cos\lambda_2 & \sin\lambda_2 \\ -\sin\lambda_2 & \cos\lambda_2 \end{bmatrix} \begin{bmatrix} \phi_{t-1} \\ \bar{\phi}_{t-1} \end{bmatrix} + \begin{bmatrix} \tau_t \\ \bar{\tau}_t \end{bmatrix}, \tag{5}$$

$$\gamma_t = -\sum_{i=1}^{s-1} \gamma_{t-i} + \kappa_t. \tag{6}$$

Equation (1) represents the decomposition of the dependent variable Y_t (U.S. cotton exports or mill use) in terms of its trend (μ_t), cycles (ψ_t and ϕ_t), and seasonal (γ_t) and irregular (ε_t) components. The trend component is further decomposed in equation (2) according to its level (μ_{t-1}), slope (β_{t-1}), and stochastic (η_t) components. The slope component has a stochastic representation governed by ξ_t in equation (3). The specifications used in equations (2) and (3) provide flexibility to the trend and enable the level and the slope to grow slowly over time (Harvey et al., 1986). At the steady-state point, the level represents the actual value of the trend, while the estimated parameter of the slope is interpreted as its rate of growth. The cyclical components in equations (4) and (5) are specified as a succession of sine and cosine waves with the parameters ρ_1 and $\rho_2 \in [0, 1]$ and λ_1 and $\lambda_2 \in [0, \pi]$, referred to as damping factors and frequencies of the cycles, respectively. A damping factor less than one is indicative of a stationary cycle. Equation (6) illustrates the seasonal components specified as a summation of $s - 1$ dummy variables ($s = 12$ for monthly series). The stochastic nature of the cycles is governed by $[\omega_t, \bar{\omega}_t]'$ and $[\tau_t, \bar{\tau}_t]'$, while that of the seasonal component is due to κ_t.

The error components in equations (1)–(6) are assumed to follow a normal distribution with mean zero and variances σ_{g}^{2}, σ_{η}^{2}, σ_{ξ}^{2}, σ_{j}^{2} , σ_{τ}^{2}, and σ_{κ}^{2} for the irregular, trend, slope, cyclical, and seasonal components, respectively. If one of these variances converges to zero, the corresponding unobserved component becomes deterministic. If all variances governing the trend, cycles, and season converge to zero, the stochastic model collapses into a purely deterministic model that can be estimated by ordinary least squares.

The vector $\mathbf{X}_t$ represents the explanatory variables for the structural relationships between U.S. cotton exports or mill use and their respective determinants. For U.S. cotton exports, $\mathbf{X}_t = [XP_{t-1}, ADR_t, XRV_t, INT90_t]$, where XP_{t-1} is the lag of cotton exports, ADR_t is an indicator of competitiveness defined as the ratio of the A-index (i.e., international price of cotton) to domestic price of cotton, and XRV_t is the short-term exchange rate volatility derived as a moving sample standard deviation of the real trade-weighted exchange rate index (Koray and Lastrapes, 1989; Chowdhury, 1993). The variable $INT90_t$ is a dummy intervention that indicates the beginning of the export-marketing assistance for cotton.

For mill use, $\mathbf{X}_t = [MUS_{t-3}, CPR_{t-3}, TDEF_{t-3}, TXPI_{t-3}, INT85_t, INT96_t]$, with MUS_{t-3}, CPR_{t-3}, $TDEF_{t-3}$, and $TXPI_{t-3}$ representing the quarterly lag of cotton mill use, domestic cotton price-to-polyester price ratio, cotton textile trade deficit, and textile output price index, respectively. The variables $INT85_t$ and $INT96_t$ are intervention dummies to measure the impact of the Food Security Act of 1985 and the Federal Agriculture Improvement and Reform (FAIR) Act of 1996 on mill consumption of cotton.

For the exports, the specification of the explanatory variables is based on the assumption that cotton exporters adjust instantaneously (within a month) to the world price-to-domestic price ratio and the exchange rate volatility. This assumption is founded primarily on the rapid flow of information between trading countries and the adoption of policies in the United States to help smooth the effects of unfavorable international market conditions. Together, these two factors facilitate decision making by shippers as to whether to ship, sell in the domestic market, or store until better market conditions emerge. The lag of export is included to account for the remaining adjustments (Chavas and Johnson, 1982).

The mill use specification is based on expectations of textile mill output price, parity of cotton price relative to polyester price, and cotton textile trade deficit. The expectations are assumed to follow a quarterly based adaptive expectation mechanism (Nerlove, 1958). The use of a quarterly window is predicated on the fact that most of the projections on U.S. economic indicators are provided on a quarterly basis. Moreover, the production of various textile blends to meet the attributes of specific end-use products involves decisions made well in advance. Thus, following Monke and Taylor (1985), if all prices and quantities adjust similarly within a quarter, then a three-month lag for mill use, textile mill output price, cotton-to-polyester price ratio, and cotton textile trade deficit fully account for all the anticipated adjustments for a desired level of cotton consumption at the mill level.

Statistical Treatment and Estimation

The structural time-series model defined in equations (1)–(6) is cast in a state space form and estimated by maximum likelihood procedure using the Kalman filtering process (Harvey, 1989, 1990; de Jong, 1991; Koopman et al., 2000). The state space form is comprised of measurement and transition equations, also referred to as signal and state equations, respectively. The measurement and transition equations are specified as follows:

$$Y_t = \mathbf{Z}_t \boldsymbol{\alpha}_t + \mathbf{X}_t \mathbf{B} + \mathbf{G}_t \mathbf{u}_t \tag{7}$$

and

$$\boldsymbol{\alpha}_t = \mathbf{T}_t \boldsymbol{\alpha}_{t-1} + \mathbf{H}_t \mathbf{u}_t , \tag{8}$$

where Y_t is the dependent variable of interest and remains as earlier defined, $\boldsymbol{\alpha}_t = (\mu_t, \beta_t, \psi_t, \overline{\psi}_t, \phi_t, \overline{\phi}_t, \gamma_t, ..., \gamma_{t-10})'$ is the state vector, and $\boldsymbol{\mu}_t = (\varepsilon_t, \eta_t, \xi_t, \varkappa_t, \overline{\varkappa}_t, \tau_t, \tau_t, \kappa_t)'$ is the vector of stochastic components. $\mathbf{Z}_t$ and $\mathbf{T}_t$ are fixed matrices of known and unknown values, while $\mathbf{G}_t$ and $\mathbf{H}_t$ are sparse matrices for which the non-zero values are the standard deviations (also referred to as hyperparameters) of the errors associated with the irregular, trend, slope, cyclical, and seasonal components. The unknown values in the fixed matrices (damping factors and amplitude) and sparse matrices (hyperparameters), along with the state vectors and the parameters of the explanatory variables, are jointly estimated. A detailed specification of the measurement and transition equations is presented in the appendix.

Empirical Results

Stochastic Component Analysis

As shown by the results reported in table 1, in the case of exports, the variances associated with the level, slope, and seasons converge to zero, indicating these components are deterministic. The deterministic nature of these components is illustrated in figure 2, which shows no variability in the trend, slope, and seasonal components. The stochastic characteristics of U.S. cotton exports are governed by two stochastic cycles with standard deviations evaluated at 0.037 and 0.109 and q-ratios (signal-to-noise ratios) evaluated at 0.169 and 0.476, respectively (table 1). Thus, the variability in U.S. cotton exports is primarily characterized by the results of two transitory cyclical innovations.

For mill use, however, two stochastic cycles, a stochastic season, and a stochastic slope govern the underlying fluctuations. The standard deviations of the cyclical components were evaluated at 0.019 and 0.065×10^{-2}, while that of the seasonal component amounted to 0.031. Although the observed variations in U.S. cotton mill use are primarily the results of seasonal and cyclical innovations, there are some variations due to the slope of the trend component. This is illustrated in figure 3, with

Table 1. Estimated Standard Deviations of Disturbances

	Exports		Mill Use	
Components	Std. Deviation	*q*-Ratio [a]	Std. Deviation	*q*-Ratio [a]
Irregular (σ_g)	0.219	1.000	0.019	1.000
Level (σ_η)	0.000	0.000	0.000	0.000
Slope (σ_ξ)	0.000	0.000	0.064 [b]	0.018
Cycle (σ_j)	0.037	0.169	0.019	0.793
Cycle (σ_τ)	0.109	0.476	0.065 [b]	0.191
Season (σ_κ)	0.000	0.000	0.031	0.913

Notes: The parameters of the first cycle are a damping factor ρ_1 estimated at 0.000 (0.743), a period $2\pi/\lambda_1$ evaluated at 8.043 (6.152) months, and a frequency λ_1 estimated at 0.781 (1.021) for the Exports (Mill Use) equation. The parameters of the second cycle are a damping factor ρ_2 estimated at 0.865 (0.982), a period $2\pi/\lambda_2$ evaluated at 16.067 (30.716) months, and a frequency λ_2 estimated at 0.781 (0.204) for the Exports (Mill Use) equation. The likelihood function was evaluated at !616.15 (!1,306.7) for the Exports (Mill Use) equation.

[a] The *q*-ratios indicate the signal-to-noise ratios and express the importance of each disturbance relative to the irregular disturbance.

[b] These estimates are multiplied by 100.

the slope, seasonal, and cyclical components exhibiting some variability as the series evolve through time. The *q*-ratios indicate that seasonal shocks are 37% larger than cyclical shocks originating from the short cycle, 79% larger than shocks from the long cycles, and 98% larger than the permanent shocks. Thus, most of the observed variability in mill use emanates from seasonal and cyclical innovations. The contribution of permanent shocks to the overall variability of mill use is relatively low, corroborating the assertion about the relative importance of transitory events compared to long-term secular events in impacting U.S. textile mill operations.

U.S. cotton exports and mill use follow two distinct paths, as indicated by the estimated parameters of their respective long cycles. The period of the long cycle of exports was estimated at 16 months with a damping factor evaluated at 0.865, and mill use was estimated at 31 months with a damping factor evaluated at 0.982. The damping factors are indicative of stationary cycles for both exports and mill use. The periods of the short cycles are closer, 8 and 6.15 months for exports and mill use, respectively. Thus, the observed values of exports are the combined effects of a deterministic trend and two stochastic cycles, while for mill use, they are the results of interactions between a stochastic trend and two stochastic cycles after accounting for the seasonal effects in both series.

Analysis of State Vector

The estimation of the final state vector indicates that the level and slope of the trend are significant at the 1% level. The results are summarized in table 2 and show a trend level estimated at 4.560 with a slope estimated at 0.159×10^{-2} for U.S. cotton

Table 2. Estimated Coefficients of Final State Vector

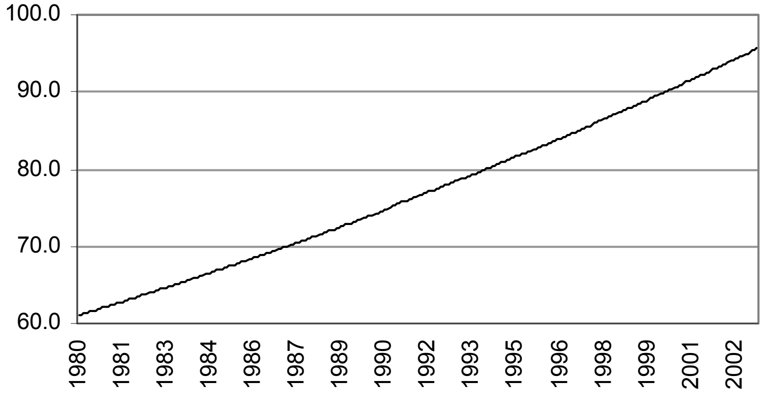
		Exports		Mill Use	
Variable	Parameter	Estimate	Std. Error	Estimate	Std. Error
Level	μ_T	4.560***	0.325	!0.232	1.830
Slope	$\beta_T \times 10^{\&2}$	0.159***	0.053	!0.798***	0.268
First Cycle	ψ_T	0.013	0.036	0.001	0.025
First Cycle	$\overline{\psi}_T$	0.000	0.037	!0.002	0.027
Second Cycle	ϕ_T	0.389	0.139	0.011	0.021
Second Cycle	$\overline{\phi}_T$	!0.035	0.176	!0.045	0.022
January	$\gamma_{T\&1}$	!0.183***	0.057	0.0005	0.031
February	$\gamma_{T\&2}$	!0.047	0.058	!0.049*	0.027
March	$\gamma_{T\&3}$	0.020	0.059	0.064***	0.026
April	$\gamma_{T\&4}$	0.107*	0.061	0.043*	0.026
May	$\gamma_{T\&5}$	0.312***	0.060	0.094***	0.028
June	$\gamma_{T\&6}$	0.179***	0.059	!0.028	0.027
July	$\gamma_{T\&7}$	0.130**	0.060	0.012	0.026
August	$\gamma_{T\&8}$	0.260***	0.058	!0.187***	0.026
September	$\gamma_{T\&9}$	0.171***	0.062	!0.087***	0.026
October	$\gamma_{T\&10}$	!0.271***	0.064	0.107***	0.027
November	$\gamma_{T\&11}$	!0.435***	0.061	0.032	0.026

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 unobserved components and state dependent variables are evaluated. No t-statistic is provided for the parameters of the cycles because the expected value of a cycle is zero (see Koopman et al., 2000).

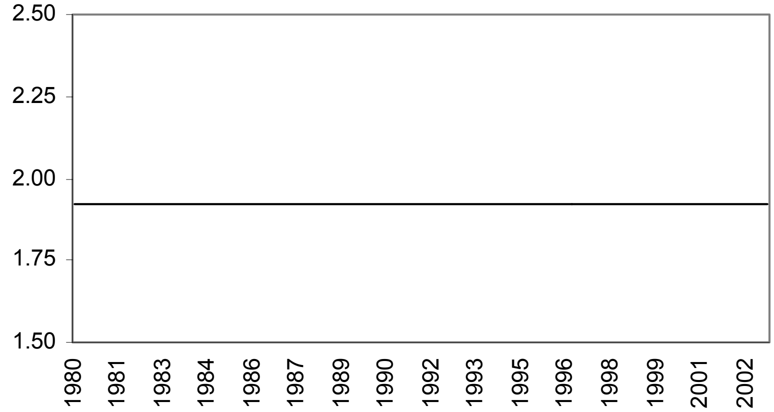
exports and a trend level of !0.232 with a slope estimated at !0.798 × $10^{!2}$ for U.S. mill use. The parameter estimate μ_T represents the level of the trend at the steady-state point (i.e., $t = T$). Taking the exponential of μ_T yields the trend value of exports and mill use. The estimated value of the slope parameter shows that at the steady-state level, U.S. cotton exports increased by 1.92%, while U.S. mill use declined by 9.587%.

Figures 2 and 3 illustrate the path of the slopes (growth rates) of exports and mill use. It is important to note that the trend and slope panels of these two figures are in thousand bales and percent, respectively. The season and cycle panels do not have unit; they are proportionality factors—i.e., the factors by which to multiply the trend to obtain the systematic part of the series (Koopman et al., 2000). The annualized parameter of the slope of the trend is more predictable for exports, which have a deterministic trend illustrated by the horizontal line in figure 2. For mill use, however, the annualized slope parameter changes from one period to the next (figure 3). The variability displayed in its path is the resulting effects of the stochastic nature of the slope despite the relatively small magnitude of its standard deviation.

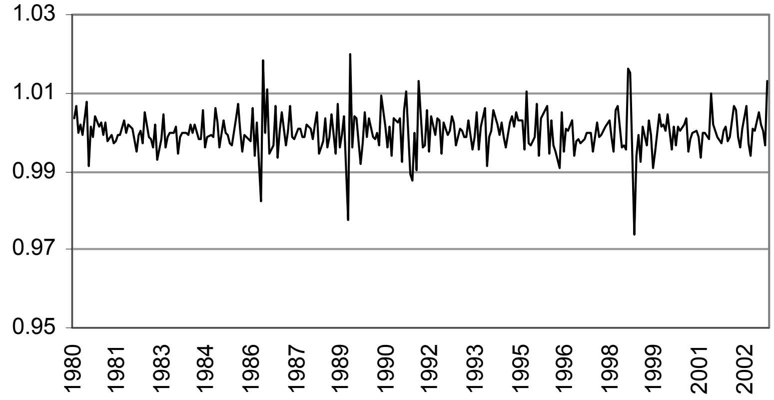
A. Trend

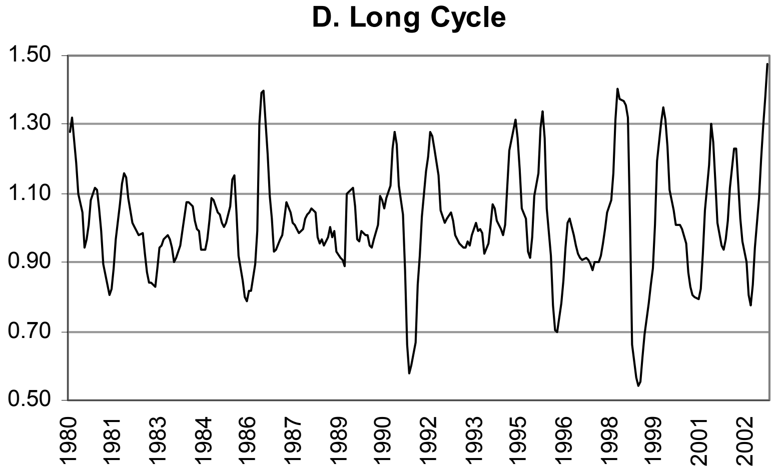


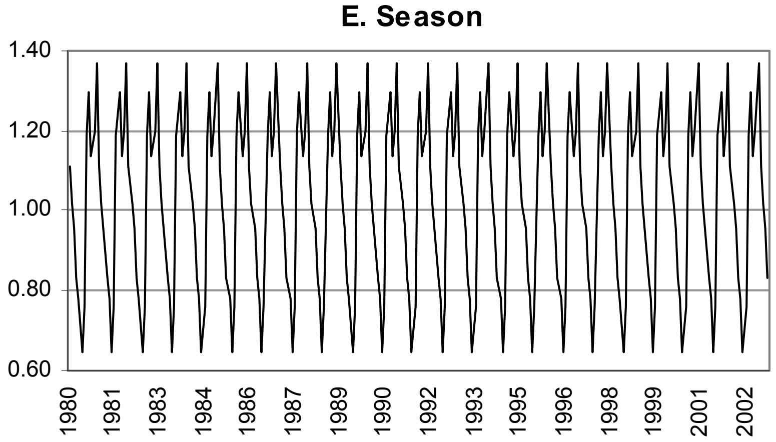
B. Slope



C. Short Cycle

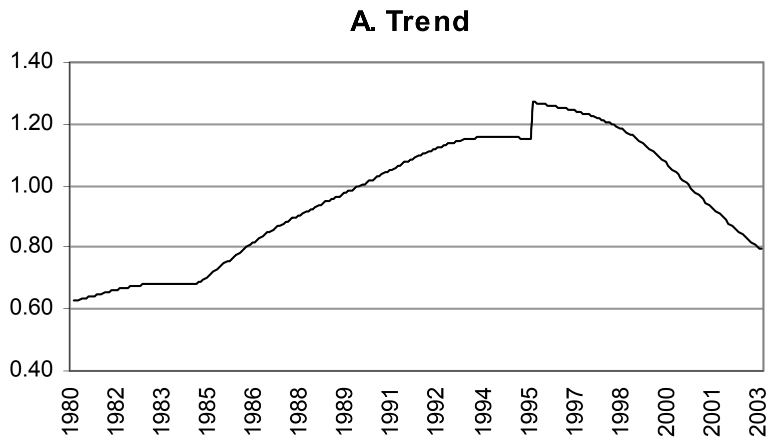


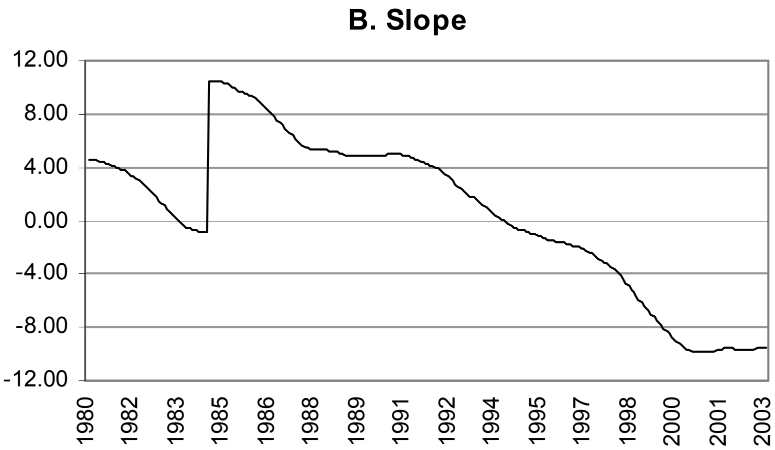


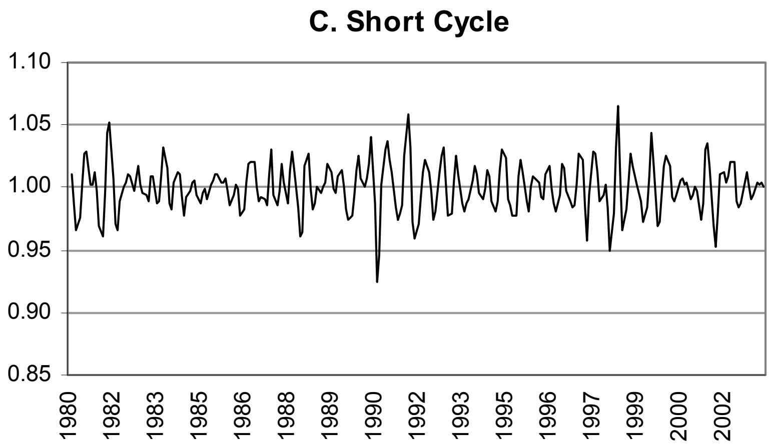


Notes: Panel A (trend) is measured in 000s of bales, and panel B (slope) is measured in percent. Panels C, D, and E (cycles and season panels) are proportionality factors and thus have no unit.

Figure 2 (panels A, B, C, D, and E). Evolution of the trend, slope, cycles, and season associated with U.S. cotton exports, 1980:1−2003:7


A. Trend
1.40
1.20
1.00
0.80
0.60
0.40
1980
1982
1983
1985
1986
1988
1989
1991
1992
1994
1995
1997
1998
2000
2001
2003


B. Slope
12.00
8.00
4.00
0.00
-4.00
-8.00
-12.00
1980
1982
1983
1985
1986
1988
1989
1991
1992
1994
1995
1997
1998
2000
2001
2003


C. Short Cycle
1.10
1.05
1.00
0.95
0.90
0.85
1980
1982
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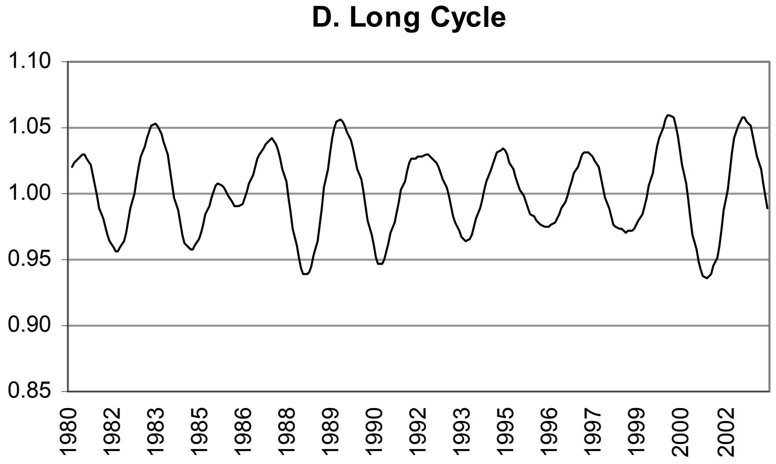
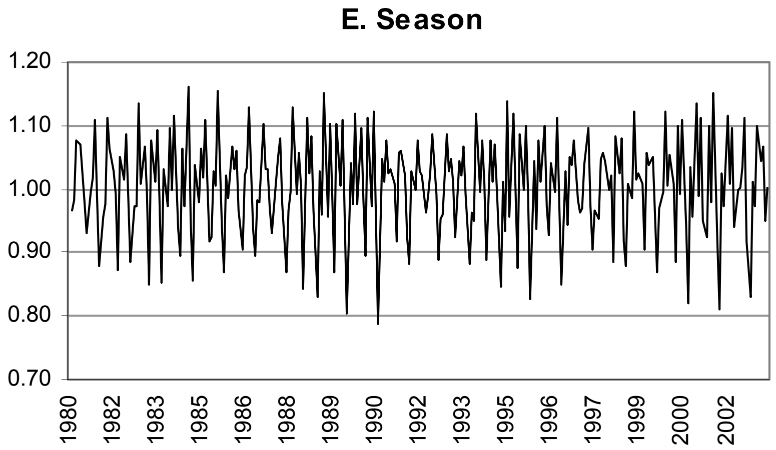

D. Long Cycle


E. Season

Notes: Panel A (trend) is measured in 000s of bales, and panel B (slope) is measured in percent. Panels C, D, and E (cycles and season panels) are proportionality factors and thus have no unit.

Figure 3 (panels A, B, C, D, and E). Evolution of the trend, slope, cycles, and season associated with U.S. cotton mill use, 1980:1−2003:7

The annualized slope parameter exhibits a relatively stable path, around 5%, between 1980 and 1984. A structural shift occurred in 1985, which may be attributed to the adoption of the Food Security Act, to reach a maximum growth rate of about 10% followed by a slow decay to reach !9.587% at the steady-state period. The growth rate of exports and mill use at the steady-state point reveals the U.S. cotton industry is facing a fundamental problem. Specifically, mill use is declining at a faster rate than the growth observed in the export sector. Thus, if the industry does not decelerate the loss in mill use of domestically produced cotton or develop new markets for raw cotton fibers, yarn, fabric, and thread, then more mills are likely to close down.

Table 2 also presents estimation results of the transitory components. Although the estimated parameters of the cycle along with their respective root mean squared errors are provided, significance tests based on the *t*-statistics were not conducted, as the expected value of a cycle is zero (Koopman et al., 2000). The amplitudes of the cycle are calculated from the estimated state parameters ψ_T and $\overline{\psi}_T$ for the first cycle and ϕ_T and $\overline{\phi}_T$ for the second cycle. The amplitude of the long cycle amounts to 3.781% of the trend for mill use and 6.834% for exports. The estimated parameters of the seasonal dummies for exports show no significant difference in export flow between the months of February and March, and December (the month of reference), while for mill use, no significant difference was noted between the months of January, June, and July and the month of December.

Results of further analysis of the effects of seasons on U.S. cotton exports and mill use are provided in table 3. U.S. cotton exports, on average, are above the trend line from November through May, with exports in March and December almost 37% and 30% above the trend line, respectively. Cotton mill use is above the trend line from March through May, July, September, and October, with mill use in March almost 10% above the trend line. Exports are below trend from June through October, with the lowest level in September (more than 35% below the trend line). Mill use is at its lowest level in December (17% below the trend line).

Analysis of Structural Relationships

The estimation of the explanatory variables in the final state vector (table 4) reveals that the coefficient of lag of exports is between 0 and 1 and is significantly different from zero. The magnitude of the parameter quantifies the remaining adjustments. Thus, 69% of all adjustment in the export sectors occurs within a month. The parameter estimate of the ratio of A-index to the U.S. domestic price of cotton is significant and greater than one. Consequently, U.S. cotton exports increase when international price rises above domestic price of cotton. The effects of exchange rate volatility and the Export Enhancement Program were estimated and the parameters had the expected signs, but were not significant. Contrary to what was expected, they did not affect cotton exports.

Statistical significance of the lag of mill use supports the validity of the adaptive expectation model, as the estimated parameter falls between 0 and 1. Thus, mill use

Table 3. Seasonal Analysis at End of Period

	Exports		Mill Use	
Season	Seasonal Factor	Percentage	Seasonal Factor	Percentage
January	1.138	13.850	1.012	1.227
February	1.196	19.684	0.971	−2.826
March	1.367	36.717	1.098	9.888
April	1.113	11.353	1.044	4.410
May	1.020	2.041	1.066	6.613
June	0.954	−4.600	0.951	−4.841
July	0.832	−16.742	1.005	0.053
August	0.782	−21.729	0.999	−0.001
September	0.647	−35.289	1.032	3.285
October	0.762	−23.772	1.113	11.323
November	1.187	18.750	0.915	−8.402
December	1.297	29.727	0.829	−17.118

Notes: Seasonal factor represents a proportionality factor. Percentage is the percentage of the observed seasonal value above or below the trend line.

Table 4. Estimated Coefficients of Explanatory Variables

		Exports		Mill Use	
Variable	Definition	Estimate	Std. Error	Estimate	Std. Error
XP_{T-1}	Lag of exports	0.311***	0.050	—	—
ADR_T	World price-to-domestic price ratio	2.352***	0.249	—	—
XRV_T	Exchange rate volatility	−0.511	0.971	—	—
$INT90_T$	Export Enhancement Program	0.267	0.085	—	—
MUS_{T-3}	Lag of mill use	—	—	0.299***	0.059
DEF_{T-3}	Lag of cotton textile deficit	—	—	−0.013	0.025
$TXPI_{T-3}$	Lag of textile output price index	—	—	1.018***	0.391
CPR_{T-3}	Lag of cotton-to-polyester price ratio	—	—	0.055**	0.025
$INT85_T$	Food Security Act of 1985	—	—	0.009**	0.003
$INT96_T$	FAIR Act of 1996	—	—	0.099***	0.037
$Q_{[12]}$	Autocorrelation	9.919		21.026	
$H_{[86]}$	Heteroskedasticity	1.846		1.199	
R_s^2	Goodness of Fit	0.337		0.579	

Notes: Single, double, and triple asterisks (*) denote statistical significance at the 10%, 5%, and 1% levels, respectively. The relationships between explanatory variables and state dependent variables are evaluated at the steady-state point, $t = T$. The statistic $Q_{[12]}$ is less than $\chi^2_{[12]}$ at the 1% level, which indicates a failure to reject the null of no autocorrelation. The statistic $H_{[86]}$ is less than $F_{[86,86]}$ at the 1% level, which indicates a failure to reject the null of no heteroskedastic residuals. The goodness-of-fit R_s^2 refers to the coefficient of determination based on deviations around the seasonal means.

of cotton fully adjusted to cotton-to-polyester price ratio, textile output price, and trade deficit levels within a quarter. Moreover, the coefficient of textile output price was significant and greater than one, indicating that mill demand for cotton is highly responsive to textile output price in the short run. The coefficient pertaining to the ratio of domestic price to polyester price was significant, though less than one. Higher price of cotton relative to polyester tends to decrease cotton mill use.

The results also showed that cotton textile trade deficit did not affect mill use as hypothesized. Although this finding appears counter-intuitive, it was based on the entire sample period where imports have consistently placed below mill use between 1980 and 1997. Moreover, the two series generally moved together between the two periods and started to diverge only after 1997, when imports continued their upward trend and mill use started declining, reaching historical lows by the end of the sample period. These two dynamics appeared to be balancing each other and might explain the lack of significance of cotton textile deficit despite the correct sign of its parameter estimates. Regardless of this finding, there are clear indications that higher imports were associated with lower mill use in the latter part of the sample period.

Finally, the significance of the coefficient of the intervention variables suggests the Food Security Act of 1985 and the FAIR Act of 1996 have directly affected mill use, though differently. The Food Security Act of 1985 affected the slope of the trend, which shifted from 4% to almost 10% before following a steady decay over the remainder of the sample period. The FAIR Act of 1996, however, affected the trend by shifting its level by 1,105 bales a month compared to the pre-1996 period. This effect was short-lived because U.S. mill use entered a declining phase throughout the remainder of the sample period. Part of the decline may be due to adjustments taking place in the domestic textile industry because of rising imports, manmade fiber effects, or slow foreign demand for U.S. textile mill products.

Conclusions

This study has shown that the stochastic process governing the evolution of U.S. cotton exports and mill use over the period 1980–2003 was predominantly transitory, with cotton mill use experiencing the most volatile cycles and season. Mill use also exhibited some variability associated with the disturbance of its trend component, but it was less important than the variability arising from the disturbances of its transitory components. Consequently, the effects of shocks on exports and mill use tended to dissipate rapidly. This analysis found two distinct paths for mill use and cotton exports, as illustrated by the direction of their respective trend. Cotton mill use has been declining while raw cotton exports have been increasing. However, the export sector, at its current growth rate, cannot accommodate the entire surplus resulting from declining mill use. Thus, exploring new markets for U.S. raw fiber and/or expanding textile-based industries in the Caribbean basin, the Central American region, and Mexico to boost demand for U.S. yarn, fabric, and thread may be necessary to ensure the survival of the U.S. cotton industry.

As for the structural relationships between export volume and its determinants, the study showed that, contrary to expectations, increased level of exchange rate volatility and the Export Enhancement Program adopted under the Food, Agriculture, Conservation, and Trade Act (FACTA) of 1990 did not affect the level of cotton exports. A favorable parity of international cotton price relative to domestic price of cotton directly influenced cotton exports. With respect to mill use, the Food Security Act of 1985 permanently changed the direction of the trend, while the FAIR Act of 1996 shifted mill use to a higher level from its original level. However, this was transitory because U.S. mill use has been declining since 1997, which leads to the increased importance of the export sector to absorb the surplus resulting from loss in mill use.

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Appendix:
Detailed Specification of the State Space Model

This appendix illustrates a detailed derivation of the state space representation [text equations (7) and (8)] of the U.S. cotton exports. The representation of mill use can be derived similarly, with minor adjustments. The measurement equation, $Y_t = \mathbf{Z}_t\boldsymbol{\alpha}_t + \mathbf{X}_t\mathbf{B} + \mathbf{G}_t\mathbf{u}_t$, is derived as follows:

$$\text{(A1)} \qquad XP_t = \begin{bmatrix} 1 & 0 & 1 & 0 & 1 & 0 & 1 & \mathbf{0}_{(1\times 10)} \end{bmatrix} \times \begin{bmatrix} \mu_t \\ \beta_t \\ \psi_t \\ \bar{\psi}_t \\ \phi_t \\ \bar{\phi}_t \\ \gamma_t \\ \gamma_{t-1} \\ \gamma_{t-2} \\ \gamma_{t-3} \\ \gamma_{t-4} \\ \gamma_{t-5} \\ \gamma_{t-6} \\ \gamma_{t-7} \\ \gamma_{t-8} \\ \gamma_{t-9} \\ \gamma_{t-10} \end{bmatrix} + \begin{bmatrix} XP_{t-1} & ADR_t & XRV_t & INT90_t \end{bmatrix}$$

$$\times \begin{bmatrix} B_1 \\ B_2 \\ B_3 \\ B_4 \end{bmatrix} + \begin{bmatrix} \sigma_g & \mathbf{0}_{(1\times 7)} \end{bmatrix} \times \begin{bmatrix} g_t \\ \eta_t \\ \xi_t \\ \varphi_t \\ \bar{\varphi}_t \\ \tau_t \\ \bar{\tau}_t \\ \kappa_t \end{bmatrix}.$$

A detailed representation of the transition equation, $\boldsymbol{\alpha}_t = \mathbf{T}_t\boldsymbol{\alpha}_{t-1} + \mathbf{H}_t\mathbf{u}_t$, is presented in equation (A2), as follows:

$$\begin{bmatrix}\mu_t\\ \beta_t\\ \psi_t\\ \overline{\psi}_t\\ \phi_t\\ \overline{\phi}_t\\ \gamma_t\\ \gamma_{t-1}\\ \gamma_{t-2}\\ \gamma_{t-3}\\ \gamma_{t-4}\\ \gamma_{t-5}\\ \gamma_{t-6}\\ \gamma_{t-7}\\ \gamma_{t-8}\\ \gamma_{t-9}\\ \gamma_{t-10}\end{bmatrix} = \left[\begin{array}{cccccc|ccccc} 1 & 1 & 0 & 0 & 0 & 0 & & & & & \\ 0 & 1 & 0 & 0 & 0 & 0 & & & & & \\ 0 & 0 & \rho_1\cos\lambda_1 & \rho_1\sin\lambda_1 & 0 & 0 & & & \mathbf{0}_{(6\times11)} & & \\ 0 & 0 & \rho_1\sin\lambda_1 & \rho_1\cos\lambda_1 & 0 & 0 & & & & & \\ 0 & 0 & 0 & 0 & \rho_2\cos\lambda_2 & \rho_2\sin\lambda_2 & & & & & \\ 0 & 0 & 0 & 0 & -\rho_2\sin\lambda_2 & \rho_2\cos\lambda_2 & & & & & \\ \hline & & & & & & -1 & \cdots & \cdots & -1 & -1 \\ & & & & & & & & & & 0 \\ & & \mathbf{0}_{(11\times6)} & & & & & & \mathbf{I}_{(10\times10)} & & \vdots \\ & & & & & & & & & & 0 \\ & & & & & & & & & & 0 \end{array}\right] \tag{A2}$$

$$\times \begin{bmatrix}\mu_{t-1}\\ \beta_{t-1}\\ \psi_{t-1}\\ \overline{\psi}_{t-1}\\ \phi_{t-1}\\ \overline{\phi}_{t-1}\\ \gamma_{t-1}\\ \gamma_{t-2}\\ \gamma_{t-3}\\ \gamma_{t-4}\\ \gamma_{t-5}\\ \gamma_{t-6}\\ \gamma_{t-7}\\ \gamma_{t-8}\\ \gamma_{t-9}\\ \gamma_{t-10}\\ \gamma_{t-11}\end{bmatrix} + \left[\begin{array}{cccccccc} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & \sigma_\eta & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & \sigma_\xi & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & \sigma_j & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & \sigma_j & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & \sigma_\tau & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & \sigma_\tau & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & \sigma_\kappa \\ \hline & & & & & & & \\ & & & \mathbf{0}_{(9\times8)} & & & & \\ & & & & & & & \end{array}\right] \times \begin{bmatrix} g_t\\ \eta_t\\ \xi_t\\ j_t\\ \overline{j}_t\\ \tau_t\\ \overline{\tau}_t\\ \kappa_t\end{bmatrix},$$

where **I** is a 10 × 10 identity matrix.