Production Costs, Scale Economies and Technical Change In U.S. Textile and Apparel Industries*

Anusua Datta[1]

and

Susan Christoffersen[2]

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Abstract

The production-cost structure of the U.S. textile industry is examined using a dual cost framework. A translog cost function is used to measure substitution elasticities between inputs, scale economies and the nature of technical change. The scope for factor substitution in textiles remains limited with all substitution elasticities being less than unity. Labor and materials are complements in apparel production, but there is evidence of substitution between capital and labor. The rate of technical change is higher in textiles than in apparel. Given the intense import competition from low wage countries, in both industries technical progress is labor saving. Overall economies of scale are larger in apparel, however, scale economies have continued to increase in textiles.

Keywords: industry studies, translog cost, factor substitution, productivity, scale economies

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* This research was supported by a grant from the National Textile Center.
[1] Corresponding author: School of Business Administration, Philadelphia University, Philadelphia, PA 19144. Ph: 215-951-2916; Fax: 215-951-2652; Email: dattaa@philau.edu.
[2] School of Business Administration, Philadelphia University, Philadelphia, PA 19144. Ph: 215-951-2810; Email: christoffersens@philau.edu.

1. Introduction

The textile and apparel industries have historically been important to the U.S. economy, accounting for a significant percentage of manufacturing output and employment. However, these sectors have faced difficult times over the past three decades. Their combined share of manufacturing employment, which stood at 12.1% in the 1970s, declined to 8.1% by the 1990s [Francisco, 2000]. In 2001 alone, the number of plant closings in textiles was as high as 100 and the industry lost about 60,000 workers, about 10% of U.S. textile workforce [ATMI, 2001]. With the gradual phasing out of protective barriers such as the Multi-Fiber Arrangements (MFA) this sector faces increasingly intense import competition from low wage developing countries in apparel and both developed and developing countries in textiles [Cline, 1990]. A key to improving competitiveness may lie in the ability of domestic U.S. firms to find least-cost methods of producing output.

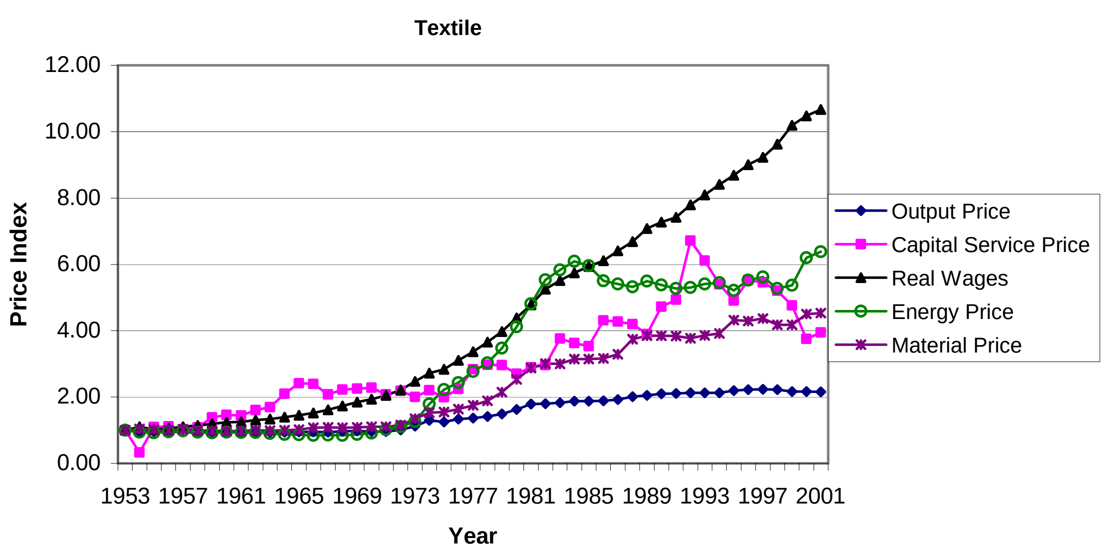
While the two industries are closely related, there are striking differences in their production structures. The apparel production process is largely low-tech and labor-intensive. Moreover, lower entry barriers make this industry especially susceptible to low-wage competition. The textile industry on the other hand is much more capital intensive, which effectively raises the barriers to entry. Chmura [1985] and Levinsohn and Petropolous [2001] note that, relative to the apparel industry, the textile industry has made significant improvements in technology, which resulted in higher productivity and lower employment in the latter.

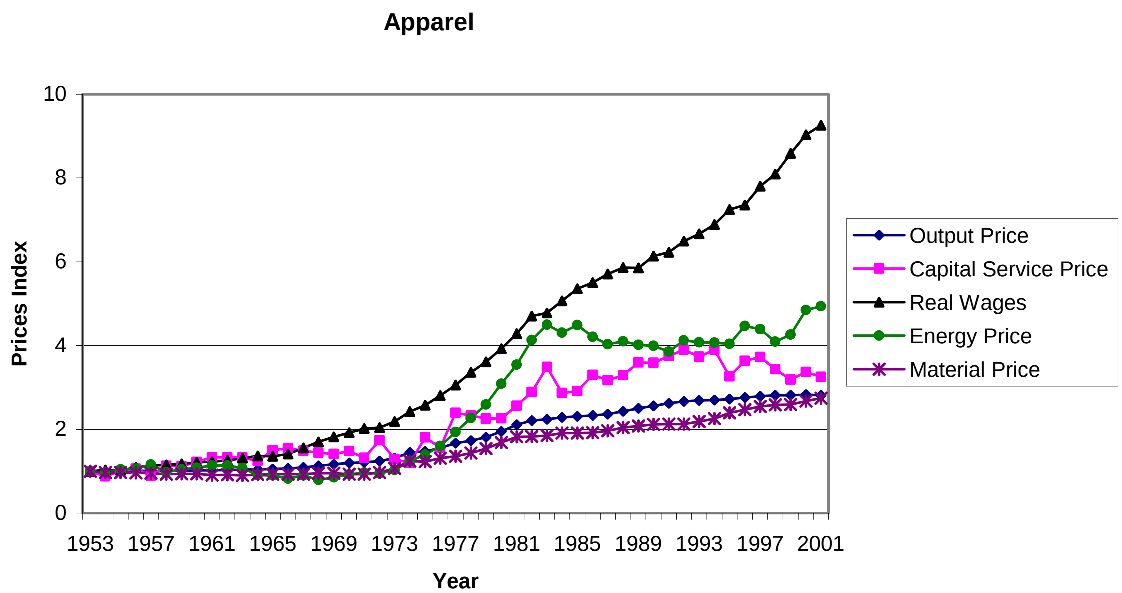
The crisis facing the domestic textile and apparel industries requires a broad based analysis of the factors that impact the competitiveness of the sector. The production-cost structure of the U.S. textile and apparel industries is examined using a dual cost framework. A translog cost function is used to measure substitution elasticities between inputs (capital and labor, energy and non-energy) and economies of scale, to determine whether large-scale or small-scale operations are optimal for improving competitive strength. The nature of technical change is examined, to determine the rate and biases in technical progress. Finally, we examine the rate and sources of productivity growth in the two sectors.

2. Trends in Factor Prices and Factor Shares

Over the past 50 years prices of textile products have increased very modestly. As Figure 1 indicates, output prices rose by about 54%. In comparison input prices rose at a much faster pace. The fastest growing component of cost is labor wages. Real wage rates between 1949 and 1999 increased by as much as ten folds. The price of energy, raw material, and capital rental prices increased between three to five folds. Output prices have remained low, due largely to competition from low cost imports.

Figure 1: Trends in Output and Input Prices in Textiles and Apparel Industries



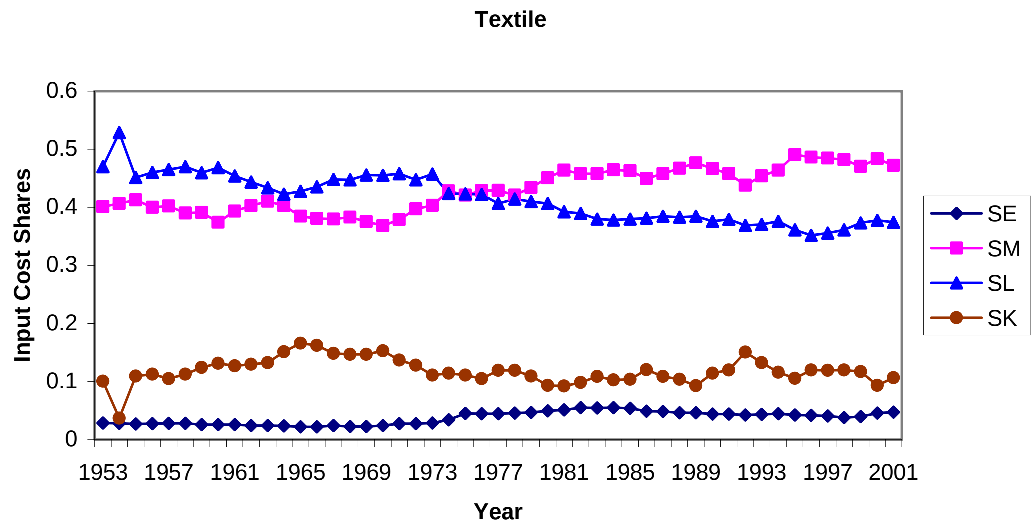


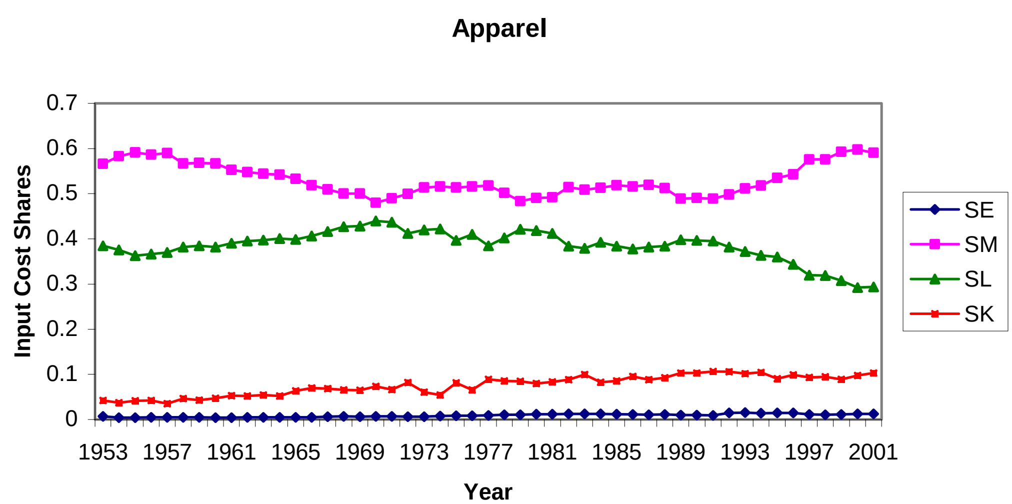
The apparel industry shows similar trends. In apparel labor wages increased by a factor of eight, while output prices merely doubled between 1953 and 2001. The growth in the price of capital, energy and materials in apparel ranged between 1.7 to 3 folds.

Cost shares of the factors of production are illustrated in Figure 2. Labor accounted for the biggest share of textile production costs before 1975. The share of labor, which was nearly one-half of total costs in the early 1950s, gradually declined to about one-third by the end of the 1990s, a period during which the price of labor increased sharply. This is perhaps is indicative of displacement of labor by other inputs in textiles. The share of materials increased from about 30% to a little more than 40%. The share of capital in total costs fluctuated between 10-15%, while energy accounted for less than 7% of total cost. The production structure of the U.S. textile industry indicates that it is still fairly labor intensive.

As expected, apparel production is highly labor and material intensive. Raw materials account for 50% -60% of total cost, while the share of labor is between 30% and 43%.

Figure 2: Input Costs as a Share of Total Cost in Textiles and Apparel





Labor share declined from a high of 44% in 1970 to below 30% in 2001. The share of capital on the other hand, which was below 5% at the beginning of the sample period, increased steadily to around 10% by the end of 2001. Energy costs have remained roughly around 1% of costs in apparel.

3. Approach

Cobb-Douglas and constant elasticity of substitution (C.E.S.) production functions used in literature to model the production process assume that elasticity of substitution between inputs is either equal to one or constant. This restricts the ability of these models to study changes in input mix and technology that occur in response to changes in the external market environment. These shortcomings are overcome by using a *transcendental logarithmic* (translog) cost function approach developed by Christensen, Jorgensen and Lau [1971, 1973]. The translog cost function does not impose any *a priori* restrictions on elasticities of substitution between inputs and therefore is easily adaptable to handling multiple inputs[3]. The generalized Leontief, used in similar recent studies [e.g. Morrison (1988, 2003) Xia and Buccola (2003)], is another flexible form with analogous properties. These approaches have been widely used in literature to study input substitution, technical change, scale economies and productivity growth at the industry level.

Production function studies of the U.S. textile and apparel industries include Batavia, 1979; Gupta and Taher, 1984; and Ramcharran, 2001 a, b. Batavia employs a linear homogeneous Cobb-Douglas production technology to analyze biases in technological progress in textiles for the period 1949-1974, using Annual Survey of Manufactures data. Gupta and Taher, employ the same data to estimate substitution elasticities and technical

[3] For a detailed discussion see Fuss, McFadden and Mundlak (1978), pp. 224-225, and Lau (1986), pp. 1515-1564.

change (including learning by doing), using a translog specification [Christensen et. al, 1973]. Finally, Ramcharran (1976-93) uses a variable elasticity of substitution (VES) [Vinod, 1972] model employing data from *The OECD Stan Database for Industrial Analysis 1975-94*. The latter approaches allow the substitution elasticities between inputs to vary. All previous studies, however, have considered only two inputs - capital and labor, while optimizing output/cost and therefore cannot account for the effect of the changes in energy and material prices on the choice of input mix.

Assuming firms minimize total costs of production, the general form of the aggregate cost function can be represented as

$$\min C = G(P_K, P_L, P_E, P_M, Q, T) \quad (1)$$

where production cost *(C)*, is expressed as a function of prices of inputs, capital (K), labor (L), energy (E), materials (M), the level of output (Q) and technical change (T). The general form of the cost function is expressed in its translog form, a second-order approximation to an arbitrary twice-differentiable surface [Christensen et al. (1973)], as

$$\begin{aligned} \ln C = \alpha_0 &+ \alpha_q \ln Q + +\Sigma_i \alpha_i \ln P_i + \tfrac{1}{2}\gamma_{qq} (\ln Q)^2 \\ &+ \tfrac{1}{2}\Sigma_i \Sigma_j \gamma_{ij} \ln P_i \ln P_j + \Sigma_i \gamma_{iq} \ln P_i \ln Q \\ &+ \Sigma \theta_{it} \ln P_i T + \theta_{qt} \ln QT + \beta_t T + \tfrac{1}{2}\beta_{tt} T^2 \end{aligned} \quad (2)$$

where $i,j = K,L,E,M,$ and $\alpha, \beta, \gamma, \theta$ are the parameters to be estimated.

Linear homogeneity in input prices and symmetry of the input-price Hessian matrix are imposed to satisfy the well-behavedness conditions on the cost function.

(i) Linear homogeneity: $\sum \alpha_i = 1$; $\sum \gamma_{ij} = \sum \gamma_{iq} = 0$; $\sum \beta_i = 0$; $\sum \theta_i = 0$ (3)

(ii) Symmetry: $\gamma_{ij} = \gamma_{ji} \qquad i \neq j$ (4)

The total cost function is estimated with the cost share equations; doing so increases the degrees of freedom without increasing the number of parameters to be estimated. The cost share equations are obtained using Shephard's lemma [Diewert, 1971][4], by differentiating Eqn (1) with respect to the input prices.

$$S_i = \frac{\partial \ln C}{\partial \ln P_i} = \alpha_i + \tfrac{1}{2}\sum \gamma_{ij} \ln P_j + \gamma_{iq} \ln Q + \theta_i T \qquad i, j = K, L, E, M \qquad (5)$$

where $S_i = P_i X_i / C$ is the share of costs accounted for by factor *i*. The cost share equations must satisfy the adding-up criteria i.e. $\sum S_i = 1$. This is also ensured by the linear homogeneity condition.

An important objective of this study is to identify the sources of cost savings that can allow the U.S. textile and apparel industries to remain competitive. Cost savings can occur through scale economies, represented by movements along the average cost curve, technical change, associated with the downward displacement of the unit cost curve, and the factor bias of technical change, which alters the optimal level and mix of inputs. Scale economies (▪$_Q$) are measured directly as the reciprocal of elasticity of cost ($>_{CQ}$) with respect to output,

$$▪_Q = \left[\frac{\partial \ln C}{\partial \ln Q}\right]^{-1} = \left[\alpha_q + \sum \gamma_{iq} \ln P_i + \gamma_{qq} \ln Q + \theta_i T\right]^{-1} \qquad (6)$$

[4] $\frac{\partial C(q,p)}{\partial P_i} = x_i(q,p)$, where *q* represents output level and *p* is a vector of input prices.

which vary with relative factor prices and the levels of output and technology. If ▪$_Q$ equals unity, cost responds proportionally to changes in firm output, which characterizes constant returns to scale. If ▪$_Q$ is greater (less) than unity, cost increases less (more) than proportionally, implying the existence of increasing (decreasing) returns to scale.

The rate of technical change ($>_T$) equals the negative of the rate of growth of total cost with respect to time, holding output and prices of all inputs constant.

$$>_T = -\frac{\partial \ln C}{\partial T} = -\left[\beta_t + \sum \theta_{it} \ln P_i + \theta_{qt} \ln Q + \beta_{tt} T\right] \quad (7)$$

In equation (7), $\theta's$ measure the biases in technical progress. Technical change is *i*th factor saving if $\theta_{it} < 0$ and factor using if $\theta_{it} > 0$. For example, $\theta_{LT} < 0$ and $\theta_{KT} > 0$ would indicate labor-saving and capital using technical progress. The parameters β_t and β_{tt}, measure neutral technical change, characterized by pure shifts in the cost function.

The cost function also yields direct estimates of the various Allen-Uzawa elasticities of substitution. These parameters are the key to describing the pattern and degree of substitutability and complementarity between the factors of production. The Allen-Uzawa partial elasticities of substitution between two factors *i* and *j*, σ_{ij}, and the output-compensated own- and cross-price elasticities of factor demand, ε_{ii} and ε_{ij}, can be computed directly from the translog cost function [Nadiri and Schankerman, 1981]

$$\sigma_{ij} = \frac{\gamma_{ij+}S_i Sj}{S_i S_j} \; ; \varepsilon_{ij} = \frac{\gamma_{ij+}S_i Sj}{S_i} \text{ and } \varepsilon_{ii} = \frac{\gamma_{ii+}S_i^{\,2} - S_i}{S_i} \qquad \text{for } i \neq j \quad (8)$$

The equality $\sigma_{ij} = \sigma_{ji}$ is ensured by the condition $\gamma_{ij} = \gamma_{ji.}$ Also note that $\varepsilon_{ij} = S_j\sigma_{ij}$.

The adding-up condition for the cost shares in (5) renders the disturbance covariance matrix to be singular. Therefore the system of equations is estimated by deleting one of the share equations. The model is estimated using the Iterative Zellner procedure for seemingly unrelated regressions with restrtictions (3) and (4) imposed using the RATS software. Kmenta and Gilbert [1968] show that iteration of the Zellner procedure until convergence yields maximum likelihood estimated which is invariant to the choice of equation deleted. The estimated cost function is a multi-input, non-homothetic function, which allows for non-constant returns to scale, non-neutral technical progress and variable elasticity of substitution.

This study is based on data for the period 1953-2001. Data on cost and prices of labor, capital service, energy, non-energy materials and real output for textiles (SIC 22) and apparel (SIC 23) are taken from the Bureau of Labor Statistics' Multifactor Productivity database. Total cost is computed as the total of labor, capital, energy and material cost.

4. Model Estimates

Parameter estimates for textiles and apparel are reported in Table 1. The adjusted R^2s for both industries equal 0.99, indicating a good fit. The R^2s for cost share equations are equally high[5]. All estimates for the textile cost function are statistically significant at the 1%, with the exception of two, the coefficients for output square (γ_{qq}) and the interaction term between energy and time *(θ_{et})*.

Table 1. Cost Function Estimates: Textiles and Apparel 1953-2001

	Textile		Apparel	
Parameter	Estimate	t-statistic	Estimate	t-statistic
$\alpha 0$	1.417	13.942*	0.218	3.822*
αe	0.039	18.200*	0.006	2.237*
αm	0.399	32.807*	0.261	8.910*
αl	0.514	50.556*	0.679	23.907*
αk	0.048	8.509*	0.054	10.005*
αq	1.295	6.641*	0.464	8.413*
βt	-0.050	-11.591*	0.005	1.704
γee	0.033	28.987*	0.004	4.776*
γmm	0.189	11.917*	0.337	11.269*
γll	0.188	10.366*	0.305	10.416*
γkk	0.073	37.116*	0.043	14.822*
γqq	0.098	0.535	-0.437	-20.660*
γem	-0.020	-6.480*	-0.004	-1.644
γel	-0.011	-4.119*	-0.001	-0.264
γek	-0.003	-3.333*	0.000	0.303
γml	-0.129	-9.262*	-0.285	-10.109*
γmk	-0.040	-10.109*	-0.048	-9.535*
γlk	-0.031	-9.183*	0.005	0.833
γeq	0.008	3.702*	0.000	-0.365
γmq	0.093	7.536*	0.007	1.652
γlq	-0.060	-6.093*	-0.008	-2.164*
γkq	-0.041	-8.186*	0.002	2.349*
θqt	-0.010	-2.503*	0.010	5.176*
θet	0.000	1.327	0.000	2.653*
θmt	0.002	6.562*	0.007	8.654*
θlt	-0.004	-14.704*	-0.008	-10.569*
θkt	0.002	12.289*	0.001	7.299*
βtt	0.001	8.827*	0.000	-5.464*
R^2	0.999		0.999	

* Significant at the 5% level.

[5] The R^2s for textiles are: 0.98 for the energy share, 0.94 for the material share and 0.97 for the capital share equation. The R^2s for apparel are: 0.93, 0.89 and 0.98 respectively. This is especially encouraging as translog models often yield relatively poor fits for the cost-share equations.

For the apparel industry, the interaction terms between energy-labor, energy-capital, energy-output and labor-capital ($\gamma_{el,}$ γ_{ek}, γ_{eq} and γ_{lk}) are not statistically significant. The estimate for the trend variable (β_t) has the wrong sign, but is not significant at the 5% level. All other estimates are significantly differ from zero.

5. Substitution and Price Elasticities

A concise description of the production structure is provided by the Allen-Uzawa elasticities of substitution and the price elasticities of input demand. Table 2 reports the substitution elasticities and the price-elasticities for the 1953-2001 period. All the substitution elasticities in textiles and apparel, are significantly different from zero and from unity, and vary over time. This suggests, the Cobb-Douglas and C.E.S. functional forms would misrepresent the substitution possibilities.

Table 2: Allen-Uzawa Elasticities of Substitution

Textiles						
Period	**σlk**	**σlm**	**σle**	**σke**	**σem**	**σmk**
1953-1962	0.219	0.321	0.198	-0.170	-0.766	-0.216
1963-1972	0.529	0.240	-0.050	0.237	-1.198	0.320
1973-1982	0.356	0.279	0.369	0.401	-0.199	0.162
1983-1992	0.247	0.263	0.458	0.518	0.158	0.194
1993-2001	0.306	0.244	0.319	0.491	0.012	0.307
Mean	0.338	0.276	0.244	0.246	-0.501	0.115
Apparel						
Period	**σlk**	**σlm**	**σle**	**σke**	**σem**	**σkm**
1953-1962	1.303	-0.315	0.650	2.660	-0.354	-1.032
1963-1972	1.183	-0.333	0.695	2.041	-0.423	-0.481
1973-1982	1.160	-0.370	0.807	1.588	0.075	-0.330
1993-1992	1.133	-0.445	0.856	1.314	0.354	-0.034
1993-2001	1.131	-0.511	0.871	1.239	0.482	0.081
Mean	1.182	-0.395	0.776	1.768	0.027	-0.359

In textiles, the estimated substitution elasticities between capital, labor, and materials are positive, indicating they are substitutes. Energy and materials are complements prior to the oil crisis of 1975 (as indicated by the negative sign), thereafter there is evidence of substitution between the two. The average elasticity of substitution between capital and labor, for the period 1953-2001, is around 0.34, which is slightly higher than the 0.11 obtained for the period 1949-74, by Batavia, and Gupta and Taher. Nevertheless, even 0.34 is significantly below one, suggesting that the scope for substitution between capital and labor remains limited in textiles. Similarly, the magnitude of substitution elasticities between labor-materials, capital-materials and capital-energy are all less than 0.5, indicating low overall substitutability among all inputs in textile production.

In apparel, substitution elasticity between material and labor is negative, indicating complementarity in the production process. This result is fairly intuitive as garment production is highly labor and material intensive (see figure 2). The apparel industry displays strong substitutability between capital-labor and capital-energy. The Allen-Uzawa substitution elasticities are positive and greater than one for both pairs of inputs (1.18 and 1.76 respectively), suggesting the industry is more responsive to higher energy and labor prices.

Table 3: Price Elasticities (1953-2001)*

Textile				
	labor	**capital**	**Energy**	**material**
Labor	**-0.131**	0.044	0.012	0.119
Capital	0.154	**-0.260**	0.015	0.092
energy	0.132	0.047	**-0.077**	-0.101
Material	0.115	0.025	-0.260	**-0.131**
Apparel				
	labor	**capital**	**energy**	**material**
Labor	**0.177**	0.088	0.007	-0.210
Capital	0.446	**-0.355**	0.013	-0.104
energy	0.313	0.113	**-0.521**	0.095
Material	-0.152	-0.015	0.002	**0.165**

*Estimated at sample means. The magnitude of price elasticities did not show much variation over time.

Table 3 reports the own and cross price elasticity of demand for the input in the row due to a price change of the input in the column. Own elasticities are substantially less than 1 indicating fairly inelastic factor demands in both textiles and apparel. All the own price elasticities have the correct (negative) sign in textiles. The cross-price elasticities are not symmetric since they depend on input shares (Eq. 8). For example the estimates for cross-price elasticity between capital and labor indicate that the demand for capital increases (decreases) more in response to an increase in the price of labor (0.154), than the demand for labor to an increase (decrease) in the price of capital (0.044). Own price elasticities have the wrong (positive) sign for labor and materials in apparel. In apparel as in textiles, demand for capital is more responsive to a change in labor price (0.446), than labor demand is to a change in the price of capital (0.088).

6. Scale Economies

Scale economies ($\blacksquare_Q$) measured as the reciprocal of elasticity of cost with respect to output (Eqn. 6) are reported in Table 4. The average scale economies in textiles, for the period 1953-2001, is approximately equal to one, which suggests the industry is subject to constant returns to scale. However, a breakdown over time shows that scale economies in textiles rose steadily from the 1950s to the 1990s. In the initial period, between 1953-1957, average scale elasticity was around 0.82 indicating decreasing returns. By the mid-1980s the number had increased to 1.03, and finally by 1998-2001 scale economies in textiles rose to 1.21, indicating a 0.21% decrease in total cost for every 1% increase in output. The average scale economies in apparel were higher, at about 1.16 for the period 1953-2001. However, scale economies seem to have declined over time. From a high of 1.21 for the period 1968-1972, the value declined to around 1.06 for 1998-2001.

Table 4: Scale Economies (1953-2001)[*]

Period	Textile	Apparel
1953-1957	0.822	1.180
1958-1962	0.880	1.162
1963-1967	0.912	1.188
1968-1972	0.949	1.216
1973-1977	0.966	1.207
1978-1982	0.996	1.182
1983-1987	1.033	1.170
1988-1992	1.094	1.107
1993-1997	1.142	1.108
1998-2001	1.214	1.066
1953-2001	1.001	1.159

[*] Evaluated at actual data.

Table 5: Rates of Technical Change (1953-2001)[*]

Period	Textile	Apparel
1953-1957	0.035	-0.004
1958-1962	0.031	-0.001
1963-1967	0.030	0.001
1968-1972	0.029	0.004
1973-1977	0.027	0.005
1978-1982	0.024	0.008
1983-1987	0.021	0.010
1988-1992	0.018	0.013
1993-1997	0.016	0.014
1998-2001	0.012	0.017
1953-2001	0.024	0.007

[*] Evaluated at actual data.

7.1 Technical Change

Independent of scale effects, cost savings is also a function of technical change. The dual technical change rates $>_T$, the annual percentage cost savings induced by technical change are shown in Table 5. Overall, technical change in textiles is much higher than in apparel. Annual cost reductions from technical change have averaged 2.4% per year in textiles and about 0.7% per year in apparel. This result is consistent with the observations made by Chmura [1985] and Fairchild's Textile and Apparel Financial Directory [1990], who note that the textile industry made more technological improvements during the 1980s than the apparel industry. Surprisingly, however, technical change in textiles declined from an annual rate of 3.5% between 1953-1957 to 1.3% between 1998-2001. In apparel on the other hand, cost reductions due to technical change have improved from -0.4% per year to 1.7% per year during the same period.

7.2 Factor Bias in Technical Progress

Changing input prices affect the least cost combination of inputs and therefore the rate of technical change. For instance if technical progress is labor-saving, an increase in the price of labor encourages the substitution of other inputs for labor, which in turn makes the adoption of labor-saving innovations more cost effective. If on the other hand technical progress in labor-using, an increase in the price of labor makes the adoption of such technology more costly, thereby reducing the cost savings associated with such innovation. The direction and magnitude of these price effects depend on the parameters γ_{kt}, γ_{lt}, γ_{et} and γ_{mt}. The parameter estimates for textiles in Table 1 indicate that, γ_{lt} is negative and statistically significant, while γ_{kt}, γ_{lt}, γ_{et} and γ_{mt} are positive although γ_{et} is not statistically different from zero. This suggests that technical change in textiles is labor-saving, and capital- and material-using. The apparel industry displays similar results. Technical change in apparel is labor-saving, and capital-, material- and energy-using. The technical change parameters for all inputs are statistically significant. This suggests that the effect of increased competition from low-wage countries has been for rational producers to shift to a more capital- and material-intensive production in textiles and capital-, material- and energy-intensive production in apparel, in order to economize on the use of the relatively more expensive labor input. This result is in keeping with the findings of Levinsohn and Petropolous (2001) who find evidence of increased capitalization in textiles but not in apparel.

8. Sources of Productivity Growth

Stated in the dual form the rate of productivity growth ξ_G equals the negative of the rate of change in average production cost holding input prices constant.

$$\xi_G = -\frac{d\ln AC}{dT}\Big|_p \tag{8}$$

where AC equals average cost. The change in cost holding input prices constant can be viewed as the sum of static and dynamic sources of economic growth [Gollop and Roberts, 1981].

$$\frac{d\ln AC}{dT}\Big|_p = \frac{d\ln C}{d\ln Q}\frac{d\ln Q}{dT} + \frac{d\ln C}{dT} = \xi_{CQ}\frac{d\ln Q}{dT} - \xi_T \tag{9}$$

The rate of productivity growth equals the sum of the contribution of scale economies and technical change. Subtracting the growth rate of output from both sides of (9) gives us a measure of productivity growth associated with reductions in total cost due to scale effects and technical change.

$$\frac{d\ln C}{dT}\Big|_p = \left(\frac{d\ln C}{d\ln Q} - 1\right)\frac{d\ln Q}{dT} + \frac{d\ln C}{dT} = \left(\xi_{CQ} - 1\right)\frac{d\ln Q}{dT} - \xi_T$$

from (8)

$$\xi_G = \left(1 - \xi_{CQ}\right)\frac{d\ln Q}{dT} + \xi_T \tag{10}$$

Holding input prices constant, productivity growth equals the sum of the rates of cost reduction due to movements along the average cost curve (scale economies) and a shift in the average cost curve (technical change)[6]. Under constant returns to scale, elasticity of cost with respect to output, ξ_{CQ}=1, productivity growth is solely determined by technical change.

Table 6 reports the contribution of scale economies and technical change to the average annual rates of productivity growth in textiles and apparel. Productivity growth in textiles outpaced that in apparel. The average annual growth rate over the sample period is around 2.1% for textiles and about 1% for apparel. Technical change is the dominant source of productivity growth in textiles, with an average annual rate of 2.4%.

Table 6: Sources of Growth

	Average Annual Contribution Scale Effects $\left(1-\xi_{CQ}\right)\frac{d \ln Q}{dT}$	Technical Change ξ_T	Average annual rate of Productivity growth ξ_G
Textile			
1953-1962	-0.005	0.032	0.027
1963-1972	-0.004	0.029	0.025
1973-1982	0.000	0.025	0.024
1983-1992	0.002	0.019	0.020
1993-2001	-0.003	0.013	0.010
1953-2001	-0.002	0.024	0.021
Apparel			
1953-1962	0.003	-0.001	0.002
1963-1972	0.006	0.003	0.009
1973-1982	0.002	0.007	0.009
1983-1992	0.002	0.012	0.014
1993-2001	0.001	0.016	0.017
1953-2001	0.003	0.007	0.010

[6] Technical change in this approach is treated as an exogenous process, measured simply by a shift in cost function. Alternative approaches to productivity decomposition e.g. Datta (2003) further characterize technological progress by estimating the effects of endogenous R&D decisions of firms.

Average contribution of scale effects in textiles is small and negative. Both scale effects and technical change make a positive contribution to productivity growth in apparel. Of the 1% average rate of growth, 0.7% is explained by technical change and 0.3% by scale economies.

The pattern of growth rates reported for the five sub-periods, indicate that productivity growth in textiles which was a little more than 2% for the most part, declined to 1% in the most recent 1993-2001 period. The decline in productivity growth is mostly explained by a falling rate of technical change. In apparel, on the other hand, productivity growth increased from 0.2% for the period 1953-1962 to 1.7% for the period 1993-2001. The increased rate of technical change accounts for much of the increase in growth.

9. Conclusion

In this paper we explored the production structure and sources of cost savings in the U.S. textile and apparel industries for the period 1953-2001. The cost structure is approximated by a translog cost function. The evidence indicates that there is some scope for substitution between labor, capital and materials in textiles, but in all cases the elasticities of substitution are smaller than unity. In apparel, labor and materials are complements, but there is evidence of substitution between labor-capital and labor-energy.

The results indicate that there are increasing economies of scale in textiles. Scale economies increased from 0.85 for the period 1953-1962 to 1.17 for 1993-2001. Overall, scale economies were higher in apparel (1.12) than in textiles (1.00). Annual cost reductions from technical change have averaged 2.4% per year in textiles and about 0.6%

per year in apparel, suggesting a higher rate of technical progress in textiles than in apparel. In both industries technical change has been labor-saving and capital using.

The decomposition of the growth in productivity indicates that technical change has contributed to almost all the productivity growth in textiles. In apparel, on an average, about 30% of the growth in productivity has resulted from scale economies while 70% came from technical change.

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