Competing with Machines for Jobs? Evaluation of Labor-Capital Substitution in the U.S. Apparel Industry by Job Occupations from 2002-2011

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Background: The U.S. apparel industry (North American Industry Classification System, NAICS, 315) experienced a sharp decline of employment from 333 thousand in 2002 to only 152 thousand by the end of 2011 (BLS, 2012). The traditional view holds import competition mainly responsible for the job shrinkage (Dickerson, 1999); however, such a view has raised questions under the new circumstances. Particularly, since 1990s key business function of the U.S. apparel industry has substantially shifted from manufacturing to design, distribution and marketing, the associated jobs of which are suggested no longer in a competing relationship with rising imports (Lu & Dickerson, 2012). Various extents of job losses were also found in non-manufacturing occupations since 2002, such as sales and management, further implying import competition alone is no longer able to fully explain job patterns in today's U.S. apparel industry.

Research question: One critical factor seldom has been discussed is capital, because apparel industry traditionally is regarded as highly "labor intensive" with little role for capital to play (Dickerson, 1999). However, it should be noted that concurrent with declining employment in recent years, more and more capital-intensive equipments and technologies are being used in the U.S. apparel industry, ranging from computer aided design (CAD) to a great variety of supply chain management systems. In many other sectors, capital inputs are found with a substitution effect on labor supply (Henningsen, 2012). Therefore, this study intends to explore: does capital-labor substitution effect also exist in today's U.S. apparel industry? If so, are certain types of occupations more easily substituted by capital than others? The answer is important because: 1) it may provide new explanations to the job decline in the U.S. apparel industry; 2) it may indicate future job availability in the U.S. apparel industry and deepen our understanding of the nature of the sector.

Theoretical framework: Theoretically, the substitution effect between capital (K) and labor (L) in an industry can be measured by the elasticity of substitution (σ_{KL}). Mathematically, $\sigma_{KL} = \frac{d(K/L)}{(K/L)} \Big/ \frac{d(MPL/MPK)}{(MPL/MPK)} = \ln(\frac{K}{L}) \Big/ \ln(\frac{MPL}{MPK})$, where MPK and MPL stand for the marginal product of capital and labor respectively. When $\sigma_{KL} > 0$, it means capital can replace labor in the production of a given level of output, i.e. the capital-labor substitution effect exists; the larger the value of σ_{KL}, the stronger the effect is (Schotter, 2008).

To describe the behavior of the U.S. apparel industry, assuming the production function is $Y = A[\delta_i K^{-\rho_i} + (1-\delta_i)L_i^{-\rho_i}]^{-\frac{v_i}{\rho_i}}$ where: Y denotes the value output of the sector; A denotes the efficiency parameter; δ_i denotes the distribution parameter of capital (K) and labor input (L_i);

υ_i denotes the returns-to-scale parameter; ρ_i is a parameter reflecting the capital-labor substitution effect. Because we are interested in knowing what types of jobs are more easily substituted by capital, three major types of occupations in the sector were treated separately as the components of L_i: production (Standard Occupation Code, SOC 510000), fashion design (SOC 271022) and management (SOC 110000). It can be mathematically proved that $\sigma_{KL_i} = \frac{1}{1+\rho_i}$.

Methods and Data: To estimate σ_{KL_i}, the production function of the U.S. apparel industry was linearized into: $InY_t = \beta_1 + \beta_{2i} InK_t + \beta_{3i} InL_{it} + \beta_{4i}[\ln K_t - \ln L_{it}]^2 + \varepsilon_{it}$ (1)

Where: $\beta_1 = InA$; $\beta_{2i} = v_i\delta_i$; $\beta_{3i} = v_i(1-\delta_i)$; $\beta_{4i} = -\frac{1}{2}\rho_i v_i \delta_i(1-\delta_i)$; $\rho_i = -2\frac{(\beta_{2i}+\beta_{3i})\beta_{4i}}{\beta_{2i}\beta_{3i}}$; and ε_{it} is the error term.

To estimate Equation 1, Y_t was measured by the annual value added of the U.S. apparel industry (NAICS 315) in dollar amount (BEA, 2012); K_t was measured by the annual capital expenditure of the apparel industry in dollar amount (Census, 2012); and L_i was measured by the number of employees in the occupation of production, fashion design and management respectively (BLS, 2012). Data from 2002-2011 were used because 2002 is the first time when statistics collected based on NAICS were available and the latest statistics were through 2011. Because the data set involves both cross-sectional and time series data, the panel data modeling technique and the generalized least square method (GLS) were adopted to tackle the potential estimation problems such as cross-sectional heteroskedasticity and serial correlation.

Findings: first, at the 95% confidence level, capital-labor substitution effect was suggested present in the U.S. apparel industry from 2002-2011 ($F = 36.61, p < 0.01$); Second, at the occupation level, production related jobs were found more easily substituted by capital ($\sigma_{KL} = 0.907$) than fashion design ($\sigma_{KL} = 0.849$) and management related jobs ($\sigma_{KL} = 0.865$) in the U.S. apparel industry from 2002-2011.

Discussions and Implications: first, results of the study imply it may no longer be appropriate to treat the U.S. apparel industry simply as a "labor intensive" sector. Instead, more attention should be given to the role played by capital in shaping the future landscape of the sector. Second, the results imply capitalization rather than import competition could be a leading factor contributing to the decline of employment in the U.S. apparel industry in recent years. Third, for U.S.-based textile and apparel educational programs, the results call for a realistic view of the future job availability for their graduates. Particularly, the return of "made in USA" should not be misinterpreted as "job return in the USA" according to the findings. Future study can further explore the structural change of employment in the U.S. apparel industry and analyze the labor-capital substitution effect at more disaggregated occupation level.

Estimates of Elasticity of Substitution between capital (K) and labor (L_i)

Parameters	Job Occupations		
	Production (P)	Fashion Design (D)	Management (M)
β_1	7.677**	7.677**	7.677**
	(0.00)	(0.00)	(0.00)
β_2	1.251**	1.251**	1.251**
	(0.00)	(0.00)	(0.00)
β_3	-0.745**	-0.778**	-0.767**
	(0.01)	(0.02)	(0.01)
β_4	-0.094**	-0.184**	-0.154**
	(0.00)	(0.01)	(0.00)
ρ_i	0.102	0.179	0.156
σ_i	0.907	0.849	0.865

F =36.61**(0.00); R^2=0.91

Note. p values are shown in parentheses; * indicates statistically significant at the 95% confidence level; ** indicates statistically significant at the 99% confidence level.

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