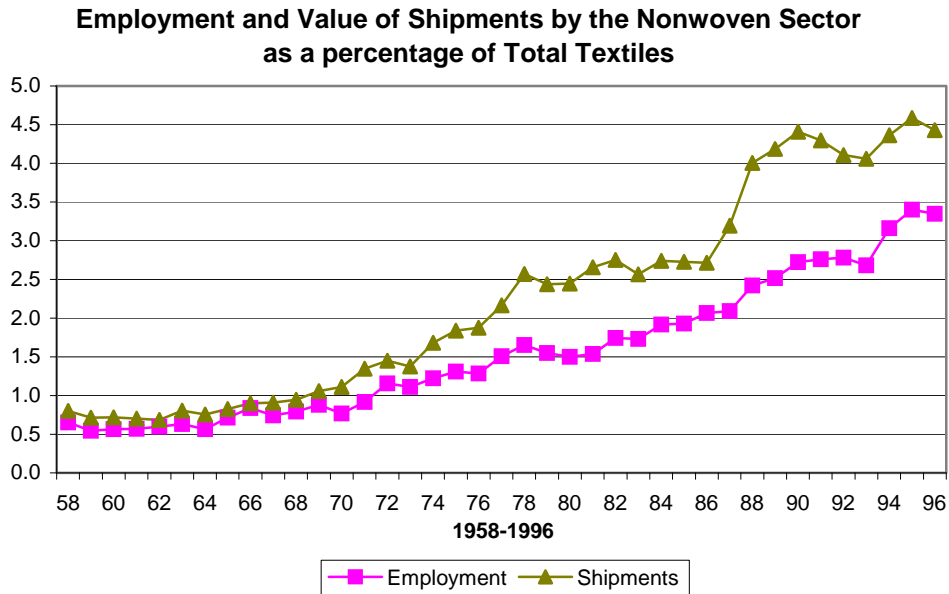


I.

Innovations in the Nonwoven Sector

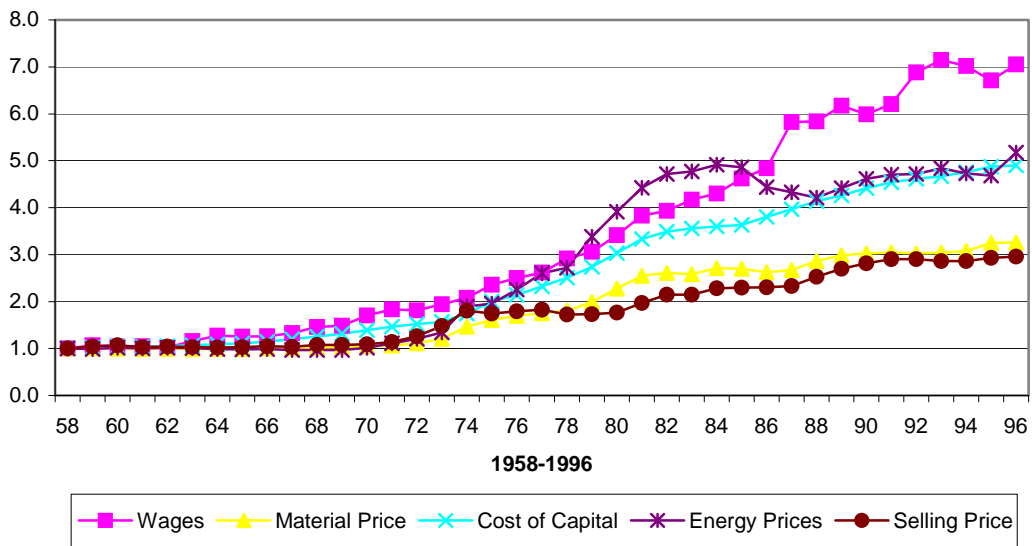
What was once a niche market and now exemplifies the future of textiles in the US. From disposable diapers to bleach wipes, medical and industrial apparel to house wrapping, new products are entering the market; these products are made possible by technological advancements in adhesion techniques, fiber modifications and delivery advancements.

Growth of the Nonwovens Sector



The prices of inputs have been steadily increasing, outpacing increases in the final prices for output. The chart below highlights these price pressures.

Price Indices for Nonwovens



Labor shows the greatest increase over the period; the most modest price increase is for the final product. The cost of material very closely tracks the final price of the product which diverges from the general pattern for textile sectors.

II.

Using data for 39 years (1958-1996) we apply econometric techniques to analyze this sector's success, particularly with regard to changing patterns of input use, that is, the degree of substitutability between inputs as costs change, as well determine the economies of scale.

If firms minimize total costs of production, the cost function can be represented as

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

where production cost (C), is expressed as a function of the prices of inputs, (capital (K), labor (L), energy (E), materials (M)), the level of output (Q) and technical change (T).

$$\ln C = \alpha_0 + \alpha_q \ln Q + \sum_i \alpha_i \ln P_i + \frac{1}{2} \gamma_{qq} (\ln Q)^2$$

In its translog form as

$$+ \frac{1}{2} \sum_i \sum_j \gamma_{ij} \ln P_i \ln P_j + \sum_i \gamma_{iq} \ln P_i \ln Q$$

$$+ \sum \theta_{it} \ln P_i T + \theta_{qt} \ln QT + \beta_t T + \frac{1}{2} \beta_{tt} T^2$$

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

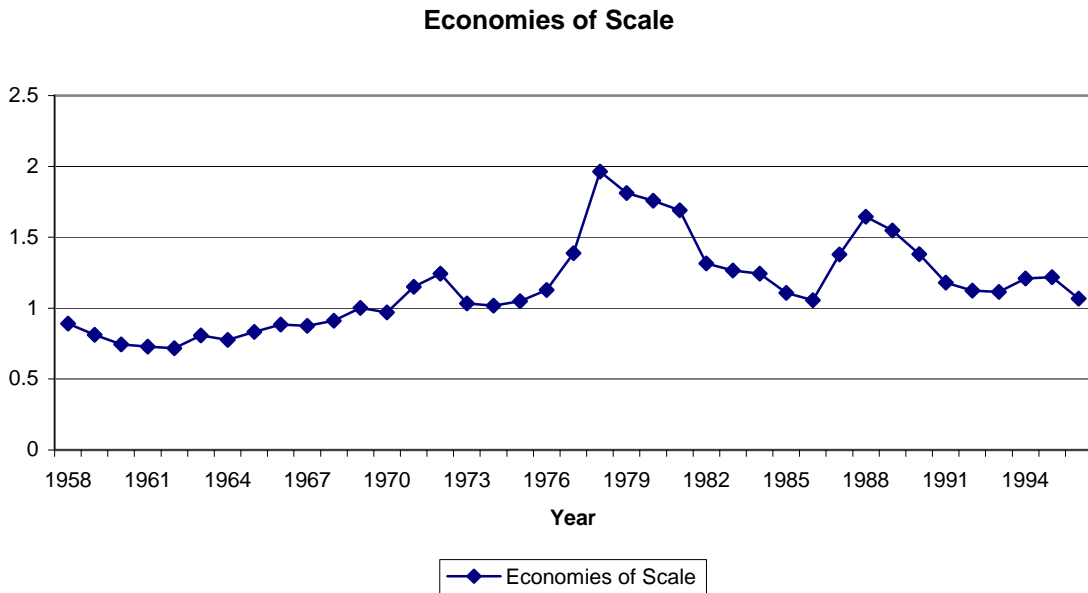
III

Economies of Scale

Scale economies (\cdot_Q) are measured as the reciprocal of elasticity of cost (ϵ_{CQ}) with respect to output,

$$\cdot_Q = \left[\frac{\partial \ln C}{\partial \ln Q} \right]^{-1} = \left[\alpha_q + \sum \gamma_{iq} \ln P_i + \gamma_{qq} \ln Q + \theta_i T \right]^{-1}$$

which varies with relative factor prices, levels of output and technology of the time period. Our estimates yield the following results.



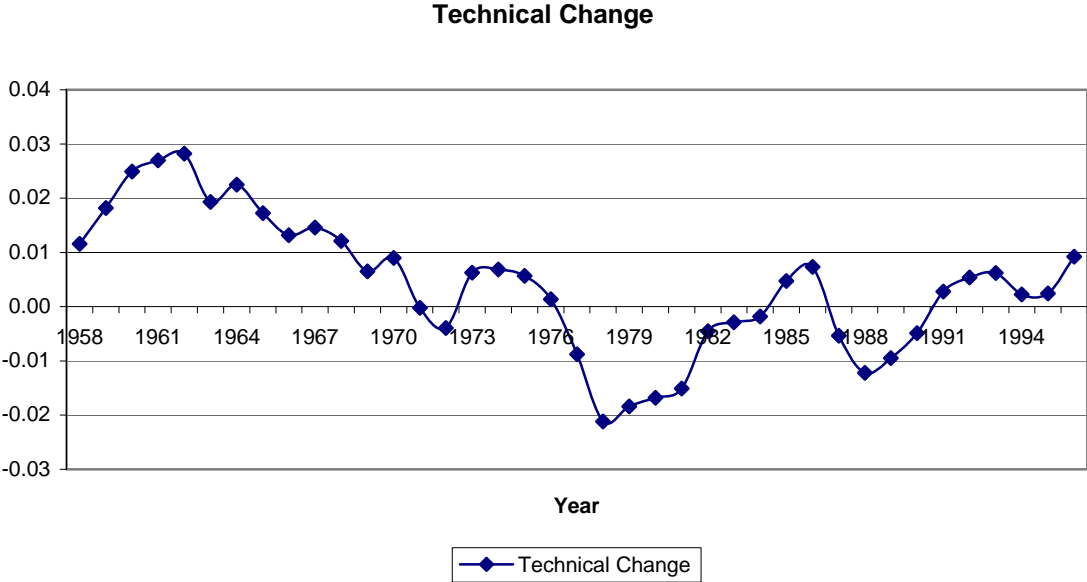
Decreasing returns to scale, where costs increase more than proportionate to the increase in output, are observed up until the 1970's; firms are operating at full capacity, expansion causing pressure on the costs. After 1975, however, we see a transformation to increasing returns to scale. There is sufficient capacity that if the firm expands the scale of operation, they would experience falling per unit costs consistent with mass production. This is consistent with a capital intensive industry, requiring large fixed costs. As demand for the products grows, labor is added to take advantage of the scale economies.

IV

Technical Change

The rate of technical change (\dot{T}) equals the negative of the rate of growth of total cost with respect to time, holding output and prices of all inputs constant.

$$\dot{T} = -\frac{\partial \ln C}{\partial T} = -[\beta_t + \sum \theta_{it} \ln P_i + \theta_{qt} \ln Q + \beta_u T]$$



For this sector we find capital-saving and energy using technical progress. An increase in the price of capital encourages the substitution of other inputs which makes the adoption of capital-saving technology more cost effective; this may be attributed to the growing importance of material and labor in the cost structure. We find costs are going down over time, at a decreasing rate.

V

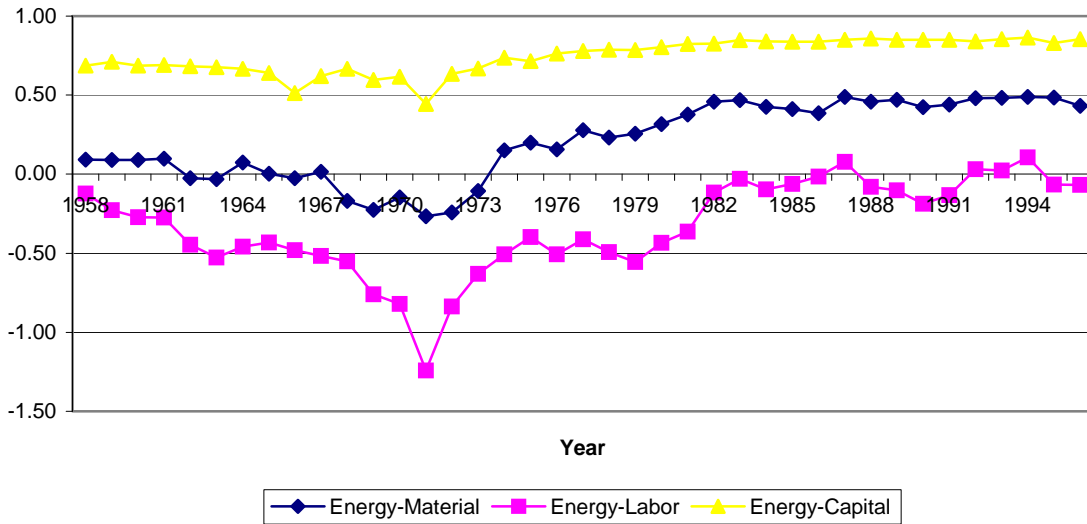
Elasticities of Substitution

As costs change and technologies evolve, one may shift the way one uses inputs; we estimate the degree to which one can substitute various inputs to the production process over time.

$$\sigma_{ij} = \frac{\gamma_{ij} + S_i S_j}{S_i S_j} ; \quad \text{for } i \neq j$$

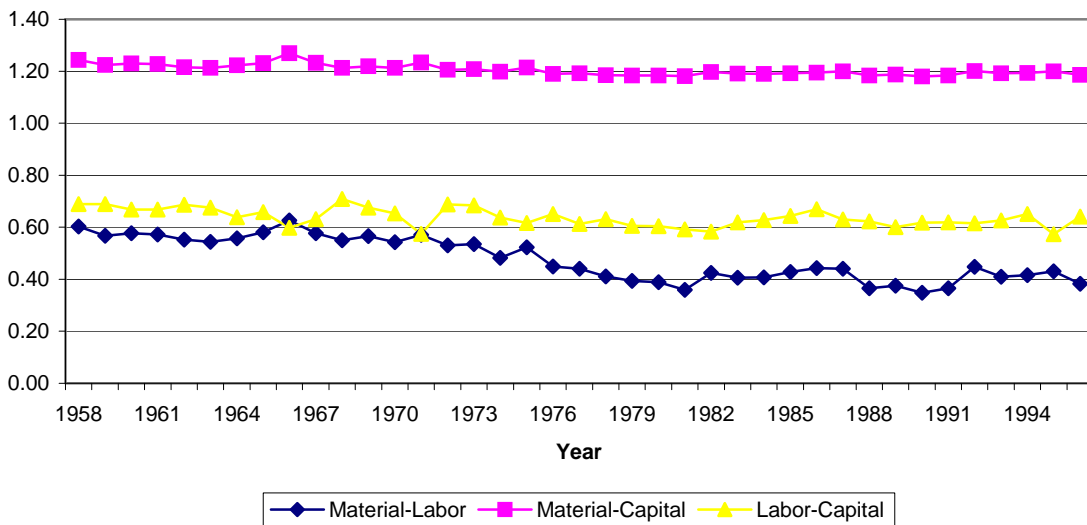
Having four inputs (labor, materials, capital and energy) creates six pairs for which we estimate elasticities of substitution. A positive elasticity indicates that the inputs are substitutes, a negative estimate indicates complements.

Substitution Elasticities: Energy



A change in technology is in evidence in the early 1970's, energy and materials switch from complements to substitutes. Previous to 1974, if one were to increase production, using more labor or material, one would necessarily use more energy. After 1974, one could substitute more capital or material for energy, perhaps indicating new energy saving capital investment.

Substitution Elasticities: Non-Energy



Material and labor become less substitutable in production as technological becomes more capital intensive. As fewer workers are involved with the production process, they are more critical and less substitutable for other inputs.

The high degree of substitutability between materials and capital seems counterintuitive; how can one use more machines and less fiber to achieve a certain level of production? Could one produce the same amount of sweaters, for example, with more looms and less wool? This reflects the ability of the industry to outsource; that is “to make or buy”. If they are making the intermediate inputs, they invest in capital; if the prices shift, an agile manufacturer buys the intermediate inputs, thereby substituting material for capital.

VI

Conclusions

Clearly there has been a fundamental transformation in the non-wovens sector. We attribute this to both product and process innovations. Existing products are being improved (diapers) and new products are continually arising (clean-up wipes). This is clearly reflected in the data. After 1975, there is a shift to increasing returns to scale in production; there is sufficient capacity that as the scale of operation expands, unit costs fall, consistent with mass production. Process innovations are evidenced by a shift in technology taking place around 1970 with the growing importance of material and labor in the cost structure. Nonwovens is a paradigm for growth; it exemplifies the value of innovation in an industry often mistakenly dismissed as “old manufacturing”.

