THE PRODUCT CYCLE AND SHIFTS IN THE LOCATION OF MANUFACTURING

*Caryl R. Ersenkal and B. L. Dillman**

The United States currently is undergoing major changes in its industrial structure. These changes have been associated with losses in central city population, gains in suburban population, net out-migration from metropolitan areas and redistribution of population toward the "rimland" and "sunbelt." Associated with these patterns of change, and perhaps their fundamental cause, is an important shift in the location of manufacturing activity from the north and north-central regions of the country to the South and West and from large metropolitan areas to smaller cities and rural areas, Hansen [2]. In South Carolina, for example, employment in manufacturing was 1.45 percent of national manufacturing employment in 1960 and 1.9 percent by 1979. Over this period, manufacturing employment in South Carolina grew by 63 percent while national growth was only 25 percent.

Such a trend is consistent with the concept of spatial-industrial filtering as articulated by Thompson [7, p. 8]. The "filtering-down" theory of industrial location is related to the concept of product life cycle in which a product is regarded as passing through three broad stages from its invention to maturity, Hirsch [3, pp. 16-34]. This movement is accompanied by changes in the relative importance of various factors of production.

In the early stage, skilled human capital, including the expertise of scientists and engineers, is essential to the development of the product and the production process. Technology is continually changing and production runs are short. Because producers depend upon external economies and sub-contracting, capital outlay is relatively low. During the growth phase, capital intensity increases as mass production techniques are introduced. Competition increases, and management skills are vital if firms are to stay in business. Finally, in the mature phase, production is routine and mechanized, and little technological innovation occurs. Less skilled, inexpensive labor is the major human input. Larger amounts of specialized equipment are employed, thus capital intensity increases further. The firm then is confronted with an altered production function as the relative importance of capital and labor inputs change, Figure 1.

An abstract illustration of the level and makeup of average total cost (ATC) in the three stages of the product cycle is illustrated in Figure 2. In the early phase, ATC is high because costs of developing knowledge (T) and designing the product are high. Production costs (P) are also quite high, while costs for management (M) remain low. At this stage, a low level of output is produced

* Department of Economics and Department of Agricultural Economics, Clemson University, respectively.
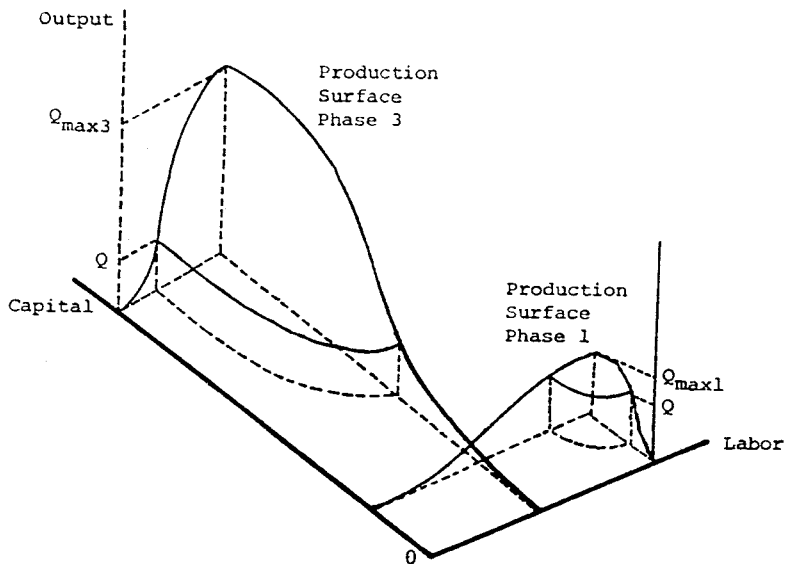
Figure 1. Production Surfaces Over the Product Cycle
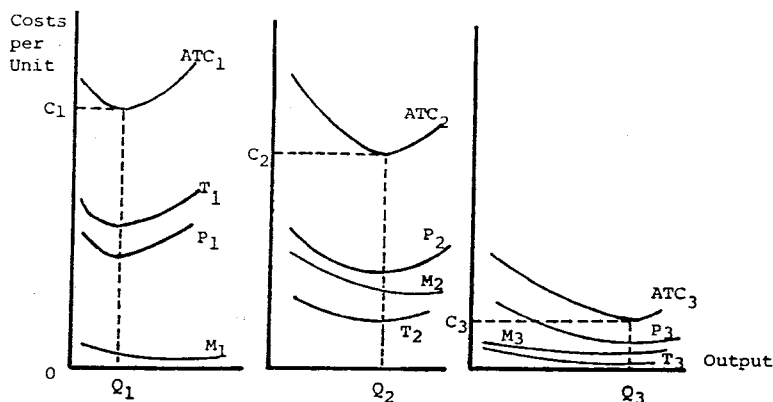
Figure 2. Function Costs Over the Product Cycle

(Q_1) with a high average cost (C_1). In the growth or second phase, management costs increase considerably, production costs fall as mechanization increases, and costs of process redesign also become relatively less. At the third or mature stage, little process redesign occurs and costs of producing knowledge are negligible. Management's primary function is to monitor the smooth functioning of a relatively mechanized production process, and its costs also drop. Production costs also fall as economies of scale are realized

and costs per unit of output are reduced. The firm operates at a high level of output Q_3 with low total average costs C_3.

In attempting to minimize costs, the corporate organization often responds to this changing pattern of input requirements by altering the geographic location of production facilities. Thus, the production unit, initially located in a metropolitan urbanized area where external economies and management skills were prominent, is replaced by a large-scale branch plant located in a smaller city or nonmetropolitan area where labor and other costs are lower, Hansen [2].

The South, historically, has been associated with low wage industrial sectors, i.e., textiles, apparel, furniture, lumber and wood. However, much of the recent growth has been led by more capital intensive industries, such as paper products and chemicals. The simultaneous growth of both labor-intensive and capital-intensive industry in the region may be explained using product cycle theory.

Hypotheses

The major hypothesis upon which this study is based is that South Carolina is attracting industries in the mature (third) phase of the product cycle. It is tested through examination of the relationship between two variables relating to stage in the product cycle, skill level and capital intensity. Specifically, it is hypothesized that

a. a positive relationship exists between the change in value added for an industry in South Carolina and the change in the relative proportion of production workers in the same industry, and

b. a positive relationship exists between the change in value added in an industry in South Carolina and the change in relative capital intensity in the industry.

In addition to these two variables relating to the product cycle, the model also explores the relationshi between value added in manufacturing and the more traditional variables used to explain industrial location: the relative wage, market potential, agglomeration economies, national industrial growth, and availability of raw materials.

The Model

The hypotheses were tested empirically using the following ordinary least squares model:

(1) VASC = f(WKRS, KLRATIO, EW, LQV, AGGL, VAUS, RM).

The model states that value added by a specific industry in South Carolina (VASC) is a function of certain characteristics of that industry. Two variables relating to the product cycle theory are the relative skill level (WKRS) and the capital intensity (KLRATIO). The remaining six variables represent alternative

explanations usually presented for southern industrial growth. Each variable is outlined in the following discussion.

VASC

VASC, the dependent variable, is a monetary measure of the growth in level of output. Assuming that relative prices remain constant over time, value added (va) may be computed as the value of sales minus the value of inputs, and for the ith industry in South Carolina

$$(2) \quad VASC_i = (va_{t_2}/va_{t_1}).$$

WKRS

WKRS represents the change in relative skill level of workers in the ith industry in South Carolina compared to the United States from t_i to t_2. The skill level is measured by the ratio of production workers (PROD) to total employees (TE). For the ith industry in South Carolina the change is measured as:

$$(3) \quad WKRS_i = \frac{(PROD/TE)_{sc,t_2}}{(PROD/TE)_{us,t_2}} \quad / \quad \frac{(PROD/TE)_{sc,t_1}}{(PROD/TE)_{us,t_1}}$$

Over time, as an industry develops, it is expected to be increasingly dominated by a large proportion of production workers. A higher proportion of production workers in an industry at the regional level in comparison to the nation would indicate that the industry in the region employs more routine, well-established production processes than the industry as a whole.

If South Carolina is attracting principally industries in the mature phase, one would expect the most rapid growth in industries where growth of production workers as a proportion of total employment is also high. Thus a positive relationship between $WKRS_i$ and VASC is hypothesized.[1]

KLRATIO

KLRATIO is a measure of the change in relative capital intensity in the ith industry in South Carolina compared to the United States from t_1 to t_2. Capital labor ratios (KL) were calculated by dividing estimated gross book value of capital investment, a proxy for capital stock, by the production worker man-hours for the same year.[2] Gross book value of plant equipment for 1964 was

---

[1] A negative sign on $WKRS_i$, could occur only in a region where growth in value added is related to growth in high-skilled technical employees (first stage). Such a relationship would lead to rejection of the hypothesis about the South Carolina Region.

[2] The book value method of estimated K-stock has been compared with the perpetual inventory method in Hunt [4] who found that variation across states in the two methods was very similar.

available in a supplement to the *Survey of Manufactures* for that year [8]. It was updated to 1967, 1972, and 1977 in constant 1967 dollars using data on new capital investment for the intervening years, deflated by the implicit price deflator for nonresidential fixed investment [9]. For the ith industry in South Carolina, the relative change is measured as:

$$(4) \qquad KLRATIO_i = \frac{(KL)_{sc,t_2}}{(KL)_{us,t_2}} \Big/ \frac{(KL)_{sc,t_1}}{(KL)_{us,t_1}}$$

If the state is attracting industries with mature production processes, capital intensity for faster growing industries within the region should be greater than capital intensity of the same industries at the national level. Therefore, a positive relationship between KLRATIO and VASC is expected.

EW

EW is a measure of the change in relative efficiency wage in the ith industry in South Carolina compared to the United States from t_1 to t_2. The efficiency wage of a region (ew) is defined as the ratio of an index of money wage (W) to an index of productivity as measured by value added per man-hour for the region (T); i.e., ew = W/T. High regional growth rates are associated with slower growth of relative efficiency wages; thus, a negative coefficient was expected for this variable, Richardson [6,31]. The relative efficiency wage for the ith industry in South Carolina is measured as:

$$(5) \qquad EW_i = \frac{ew_{sc,t_2}}{ew_{us,t_2}} \Big/ \frac{ew_{sc,t_1}}{ew_{us,t_1}}$$

LQV

LQV for the ith industry in South Carolina is a measure of market potential for that industry. A location quotient indicates whether a region is relatively more or less specialized in the industry in question than the nation as a whole. It may be calculated for the proportion of value added by the ith industry as:

$$(6) \qquad LQV_i = \frac{va_{i,sc,t_1}}{\Sigma_i va_{i,sc,t_1}} \Big/ \frac{va_{i,us,t_1}}{\Sigma_i va_{i,us,t_1}}$$

A location quotient of less than unity indicates that relatively less of the product is being produced in the region than in the comparison area; thus, a negative sign was expected on this measure of market potential, since a low relative location quotient indicates a relative paucity of regional production of the product.

AGGL

AGGL, an agglomeration was developed for each industry, using the technical coefficients matrix from a South Carolina input-output table for 1973

[5]. The agglomeration index is similar to that suggested by Andrikopoulos [1, p. 48]. The magnitudes of backward linkages (BL_j), forward linkages (FL_i), and intraindustry linkages (IL_i) for each industry are estimated by weighting each element in the technical coefficients matrix by the level of employment in each sector and summing them over all industries, thus,

(7) $AGGL_i = BL_j + FL_i + IL_i$ and $i = j$

where,

$$AGGL_i = \text{agglomeration index in the region for industry i, in the ith row of the regional matrix of technical coefficients;}$$

$$BL_j = \sum_{i=1}^{n} (a_{ij})(E_i) \text{ and } i \neq j,$$

$$FL_i = \sum_{j=1}^{n} (a_{ij})(E_j) \text{ and } i \neq j,$$

$$IL_i = (a_{ii})(E_i)$$

i = industry in row i of the regional matrix of technical coefficients;

j = industry in column j of the regional matrix of technical coefficients;

a_{ij} = technical coefficient in row i and column j of the regional technical coefficients matrix, and

E = employment.

It is anticipated that those industries to which greater agglomeration economies are available in a region will experience higher rates of growth. A positive relationship between agglomeration economies (AGGL) and the growth of output (VASC) was hypothesized.

VAUS

VAUS is a measure of growth of national value added in industry i from time t_1 to t_2. Inclusion of this variable is in recognition of the fact that regional industry growth may not be explained by specific regional industry characteristics, but is reflected in the growth of the industry nationally. Change in this variable over time is calculated as

(8) $VAUS_i = \dfrac{va_{i,us,t_2}}{va_{i,us,t_1}}$

A positive relationship between growth of national output (VAUS) and regional industrial growth is hypothesized.

RM

RM is a dummy variable utilized to indicate industries for which raw

35

materials produced or available in the state comprise a significant proportion of inputs as measured by a table of raw material technical coefficients [5]. A value of one was assigned to RM for industries dependent on raw materials. For all other industries, RM was set equal to zero. Accessibility to necessary raw materials is a positive feature influencing an industry's location decision. Thus, a positive relationship is expected between availability of raw materials (RM) and growth of industrial output (VASC).

Industrial Sectors and Time Periods

Within the limitations of data availability, observations were taken on all two-digit SICs. Capital labor ratios could not be calculated for all two-digit industries because of lack of information on capital investment for some industries.

Separate equations were generated for three- and four-digit industries for which data were available for South Carolina. Again, no capital investment data were available for most of these industries. In addition, little agglomeration data were available for the three- and four-digit industries since the technical coefficients table includes so few industries at this level of disaggregation.

Data were analyzed for three time periods: 1963-67; 1967-72; and 1972-77. Beginning and ending dates for each time period comprised the t_1 and t_2 values for which all changes were measured.

To increase the sample size, the data for the three time periods was pooled. Using the appropriate F-tests, the equality of the regression coefficients was examined and slope and intercept shifters introduced if necessary.

Empirical Results

Different formulations of the model, equation (1), produced several equations, each of which reveal interesting results. In the interest of brevity, only three are presented in Table 1. Equations (1a) and (1b) are linear; equation (1c) is in log-linear.

Equation (1a) explained 93 percent of total variation in South Carolina industrial growth as measured by change in value added (VASC). The coefficients on WKRS and KLRATIO were both positive and significant at the .05 level. Thus, both principal hypotheses were supported. The state does attract industries in the latter stage of the product cycle, as indicated by higher proportional growth in production workers and higher proportional growth in capital-labor ratios. Efficiency wage is also significant at the .05 level and has the hypothesized negative sign, indicating that the wage-to-productivity ratio is inversely related to growth in value added. VAUS was significant as well, indicating that industries growing in the nation were also growing in South Carolina. Intercept shifters (DV2 and DV3) were positive and significant for both 1967-72 and 1972-77, perhaps reflecting the much more rapid industrial growth in South Carolina relative to the nation in the two periods.

Equation (1b) is essentially the same formulation as equaltion (1). But, in order to investigate the possibility that traditional location variables explain the change in value added equally well, the two product cycle variables (WKRS) and (KLRATIO) were omitted. Location quotient (LQV) is used in place of (VAUS), with which it is highly correlated. The negative sign on (LQV) is the hypothesized one. Another significant variable (RM), the dummy associated with raw materials found in South Carolina, appears with an unexpected negative sign. The negative relationship between (RM) and (VASC) may result from a tendency for the state's raw material oriented industries to be slow growth industries. The most interesting difference between equation (1a) and (1b) is the much lower R^2 in the latter, with the product cycle variables absent.

Table 1. Selected Equations.

Equation Number	Sample Size		R^2
(1a)	39	VASC $= -.662 + .266$ DV2 $+ .1566$ DV3	
		$(-1.94)^{**}(4.85)^{***}$ $(2.36)^{***}$	
		$+ 1.96$ WKRS $- 1.64$ EW	
		$(13.28)^{***}$ $(-12.47)^{***}$	
		$+ .534$ KLRATIO $+ .888$ VAUS	.93
		$(4.22)^{***}$ $(6.01)^{***}$	(82)
(1b)	50	VASC $= 4.09 - .051$ LQV $- 2.06$ EW	
		$(12.18)^{***}(-2.61)^{***}$ $(-6.47)^{***}$	
		$- .41$RM	.57
		$(3.24)^{***}$	(20)
(1c)	40	1nVASC $= .0427 - .412$ DV2 $+ .807$ 1n WKRS	
		(1.16) $(-3.04)^{***}$ $(9.89)^{***}$	
		$+.470$ DVWKRS2 $- 1.11$ 1n EW	
		$(3.57)^{***}$ $(-17.70)^{***}$	
		$- .0869$ 1n KLRATIO $+ 1.11$ 1n VAUS	.967
		(-1.14) $(11.65)^{***}$	(164)

[a] Numbers in parentheses under coefficients are student's t-values.
*** t-test significant at .95 level of confidence.
** t-test significant at .90 level of confidence.
   F value in parenthesis, significant at .99 level of confidence.

A logarithmic formulation of the model was included in order to test whether any of the more traditional variables were significant in a non-linear form(Ic). The variables consistently found significant in the linear equations were also significant in the logarithmic equation. The hypotheses regarding skill level, efficiency wage and national industrial growth were supported as in the linear equations.

The intercept shifter and slope shifter on WKRS were significant for the second period (DV2 and DVWKRS2), indicating that the relationship between VASC and WKRS changed over time. None of the other variables included in the original formulation of the model were found to be significant. The results concerning the precise nature of the relationship between capital intensity and national growth appear to be inconclusive. Although the coefficient on KLRATIO is not significantly different from zero in equation (1c), the sign is negative suggesting an inverse relationship between KLRATIO and VASC. This coefficient is an estimate of the elasticity of capital intensity with respect to state industrial growth. A separate estimate of the elasticity can be derived using the coefficient on KLRATIO in equation (1a). The confidence limits for these two estimates overlap in the positive range at three standard deviations from the mean and, therefore, do not exclude the possibility of a positive relationship.

Conclusions

The principal aim of this study has been to examine whether industrial growth in South Carolina can be explained by its ability to attract industries in the later stages of the product cycle. Empirical analysis clearly suggests that the state is attracting industries in the mature phase. The rate of change in the proportion of production workers employed in South Carolina industries, relative to the nation, is positively related to industrial growth. The results concerning the relationship between change in relative capital intensity and industrial growth are somewhat less conclusive. While the linear equation developed for two-digit industries supports the hypothesized positive relationship between capital intensity and growth, the log-linear equation failed to generate a significant relationship. While the state is attracting third stage industries, a more precise measure is needed to examine more fully the relationship between capital intensity and industrial growth. Because data were unavailable for finer industrial classifications, the relationship could be examined only at the gross two-digit level of aggregation. At this level, specific industries, differing within a general two-digit classification, cannot be represented precisely. Observations at this level, therefore, represent averages of finer levels of disaggregation.

This study has defined more precisely the types of industries which have been attracted to the state. If policymakers determine that an overabundance of such industry is not desirable, perhaps it is necessary to continue attempting to alter some regional characteristics in order to stimulate growth in industries dependent upon factors which, in the past, have not been sufficiently developed in the state to attract industry in earlier stages of the product cycle.

REFERENCES

1. Andrikopoulos, Andreas A. "Regional Growth Differentials in Manufacturing Employment: The Case of the Province of Ontario, Canada," *The Review of Regional Studies,* 7 (1977), 45-61.

2. Hansen, Niles M. "The New International Division of Labor and Manufacturing Decentralization in the United States." *The Review of Regional Studies,* 9 (1979), 1-11.

3. Hirsch, Seev. "The United States Electronics Industry in International Trade." *National Institute Economic Review,* 34 (1965), 92-97.

4. Hunt, Timothy L. "Estimating Regional Capital Stocks." *The Review of Regional Studies,* 9 (1979), 1-5.

5. Mulkey, David. "Interregional Input-Output Matrices from Secondary Data." (Unpublished Doctoral Dissertation). Department of Agricultural Economics and Rural Sociology, Clemson University, Clemson, South Carolina, 1977.

6. Richardson, Harry W. *Regional Growth Theory.* London: MacMillan Press, Ltd., 1973.

7. Thompson, Wilbur R. "The Economic Base of Urban Problems," in Chamberlain, Neil W. (ed.), *Contemporary Economic Issues.* Homewood, IL: Richard D. Irwin, Inc., 1969.

8. U.S. Bureau of the Census. "Book Value of Fixed Assets, Special Geographic Supplement to 1962-64 Data," *Annual Survey of Manufacturers, 1964.* Washington, DC: U.S. Government Printing Office, 1972.

9. _____ . *Annual Survey of Manufacturers,* 1964 and 1965, 1966, 1968, 1969, 1970, 1971, 1973, 1974, 1975, and 1976. Washington, D.C.: U.S. Government Printing Office.