Since this elasticity is defined as the percentage change in research output for a unit percentage change in R and D, holding S constant, it will describe the findings on economies of scale in research which are implicit in the equation results. Elasticities were computed at values of S equal to 1,000, 10,000, and 50,000 (pharmaceutical sales in thousands of dollars).[21] When S equaled 1,000, the calculated elasticity was 1.39. At S equal to 10,000 and 50,000, the corresponding figures were 0.61 and 0.54. While there are likely to be increasing returns to scale in R and D at low values of S, decreasing returns seem to be the case when S becomes moderately large.[22] [23]

SOME ALTERNATIVE HYPOTHESES

Up to this point we have proceeded on the assumption that the direction of causation runs from research and development to technical change, and have implied that the degree of diversification affects the rate of technical change. It is necessary, however, to consider some alternative hypotheses. It may be that successful new product introduction influences the extent of research activities rather than or in addition to the opposite alternative. A rapid rate of technical change may stimulate the firm to expand the scale of R and D facilities; accelerated technical change may result in higher profit rates which enable the firm to increase its investment in research and development. Similarly, it may be hypothesized that the rate of new product introduction is the vehicle by which diversification proceeds. If these alternative hypotheses are correct, we should expect that technical change at the start of the period would be better correlated with R and D and diversification at the end, than if the lead-lag relationship were reversed. Our original hypotheses would postulate that R and D and diversification should lead the variables denoting technical change. To investigates these questions, we shall consider our regression equations with alternative lead-lag structures.

The empirical findings concerned with this matter are presented in table 3. The research and development variables denote the number of professional research personnel employed in either 1955 or 1960, while the technical change and diversification variables span the period which is designated. The size variable remains the same as in the previous analyses.

The results are striking. With a lead-lag structure consistent with our original hypotheses, all coefficients are significant at the 99% level. With the opposite lag structure, the R^2's are not significant, the parameters of diversification are smaller than their standard errors and alternate in sign, and the coefficients for size, interaction, and the quadratic expression for research are not significant. There is, however, some positive linear association between technical change in 1955–1957 and research in 1960 when the variable Y_2 is used, but this relationship may be relatively weak for it fails to appear in the regression equations dealing with the entire six-year period. We may conclude, therefore, that the apparent lead-lag structure is not inconsistent with our original hypotheses.

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[21] Corresponding values of R were determined by taking the mean value of that variable for firms in the neighborhood of the appropriate value of S. For S equal to 1,000, firms were included between S equal to 500 and 1,500; for S equal to 10,000, the corresponding figures were 5,000 and 15,000; while for 50,000, the firms with S between 40,000 and 60,000 were included. The three values of R which were determined in this fashion were 13.1, 59.2, and 353.3, respectively. D was computed at its mean value throughout.

[22] One qualification of the above results should be mentioned. It may be that large firms undertake more "basic research" than smaller firms. Although it is assumed that the returns from this activity are obtained through its advancement of the rate of new product technical change, the time horizon in this case may be substantially longer than that of "applied research and development" so that the six-year period under examination may not be long enough to measure accurately the returns. As a result, the level of research output for larger firms would be understated relative to smaller firms. It does appear that larger firms spend somewhat larger proportions of their R. & D. budgets for "basic research." For 1959, National Science Foundation data for industry group "Drugs and Medicines" (SIC 283) disclose that firms with total employment over 5,000 undertook 50% of total industry funds for the performance of R. & D. while these firms accounted for nearly 63% of industry "basic research." The difference between the elasticities is, therefore, likely to be somewhat overstated.

[23] One further implication of the functional form of (1) should be mentioned. Since b is negative and c is positive, the function, at given values of S, originally declines, reaches a minimum, and then increases. This minimum is reached at values of R equal to $\frac{-b}{2c}$. In addition; since b is an inverse function of S, the values of R at which the minimum is reached increases with S. At values of S equal to 1,000, 10,000, and 50,000 the minimum is reached at values of R equal to 4.4, 16.0 and 298. Actual values of R will, in nearly all cases, be greater than these values. At the extreme upper tail of the distribution of S, however, the marginal productivity of research estimated by equation (1) in table 1 will be negative.