Firm Size and Efficient Entrepreneurial Activity: A Reformulation of the Schumpeter Hypothesis

Link, A. N. (August 01, 1980). Firm Size and Efficient Entrepreneurial Activity: A Reformulation of the Schumpeter Hypothesis. Journal of Political Economy, 88, 4: 771-782.

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This paper examines empirically the relationship between innovative activity, as measured by the rate of return to research-and-development expenditures, and firm size using a sample of firms from the chemicals and allied products industry (SIC 28). We find that size is a prerequisite for successful innovative activity. The estimated rate of return to research and development for the smaller firms is 30 percent, while for the larger size firms it is 78 percent. Statistical tests for structural stability were used to divide the sample into these two behavioral regimes.

Since the writing of *Capitalism, Socialism, and Democracy* (Schumpeter 1947), economists have increasingly been willing to associate economic growth through innovation with monopoly power and large firm size. This so-called Schumpeterian hypothesis is posited on the view that in a capitalistic system, economic growth occurs through a process of "creative destruction" whereby the "old" industrial structure—its product, its process, or its organization—is continually changed by "new" innovative industrial activity. This "industrial mutation . . . that incessantly revolutionizes the economic structure *from within* . . . is the essential fact [of] capitalism" (Schumpeter 1947, p. 83). The motivating force behind the process of creative destruction is the promise of economic profit achieved through innovative activity. According to Schumpeter, large firm size is essential to the success of

I am grateful to Robert Hèbert, Richard Higgins, and several anonymous referees for comments on earlier versions of this paper.

[*Journal of Political Economy*, 1980, vol 88, no 4]

such innovative activity. Larger firms can provide economies of scale in production and innovation which make available sufficient resources necessary for successful completion of this process.[1]

During the past 2 decades, statistical tests of the Schumpeterian hypothesis have focused on two relationships: (1) between firm size and innovative activity and (2) between market concentration and innovative activity. Recently, Kamien and Schwartz (1975) have surveyed these studies and have concluded that the statistical evidence supporting Schumpeter's hypothesis is, in general, "wanting."[2] Perhaps the lack of empirical verification results from the inadequacy of data to measure innovative activity or from the fact that the large industrial research complexes of today have changed the structure of capitalism that Schumpeter envisioned.[3] An alternative explanation was first offered by Markham (1965) and more recently by Fisher and Temin (1973). They contend that the existing empirical literature relating innovative activity, as measured by some absolute index like R & D expenditures, to firm size or market concentration is a test of a hypothesis different from that suggested by Schumpeter.[4]

In this study, innovative activity is viewed as an entrepreneurial *process*. The process notion of innovation is clear from Schumpeter's discussion of creative destruction wherein the entrepreneur is continually creating disequilibria from equilibrium states.[5] Whenever a process notion is considered, the question arises as to what is the best criterion to evaluate its success. Here we suggest that the rate of return earned on R & D expenditures is conceptually more appropriate as a measure of innovative activity than those measures used

[1] Schumpeter claimed that the monopoly firm will have a greater *demand* for innovative activity than will the competitive firm since it can profit from the innovation as a result of its market power. Arrow (1962) first demonstrated that this demand argument is incorrect. Arrow's analysis has been criticized by Demsetz (1969), but the more recent work of Ng (1971) and Hu (1973) seems to resubstantiate Arrow's argument. Most analyses of Schumpeter's hypothesis, however, focus on the *supply* of innovations.

[2] In particular, note the studies by Worley (1961), Hamberg (1964), Comanor (1965), Scherer (1965*a*, 1965*b*), Grabowski (1968), Rosenberg (1976), and Loeb and Lin (1977).

[3] See Grabowski and Mueller (1970) for a detailed discussion of data problems associated with empirical tests of the Schumpeterian hypothesis.

[4] The quantitative arguments developed by Fisher and Temin are basically that a positive and increasing relationship between innovative inputs and firm size (the general empirical test) is neither necessary nor sufficient to imply a positive and increasing relationship between innovative output and firm size (the Fisher-Temin interpretation of Schumpeter's hypothesis), given economies of scale in production of output and in production of innovations. Scherer (1973), however, strongly disagrees with the Fisher-Temin conclusion. In support of Fisher and Temin, Kamien and Schwartz (1969) have demonstrated theoretically and Link (1978) has shown empirically that the transformation between R & D inputs and innovative output is not necessarily monotonic.

[5] The more modern views of entrepreneurship stress perception (not creation) of disequilibria and then adjustment to an equilibrium (Kirzner 1973; Schultz 1975).

previously. We thus formulate an empirical test of Schumpeter by testing whether the rate of return to R & D is a function of firm size.

The remainder of this paper is outlined as follows. In Section I an empirical model for measuring the rate of return to R & D activity is formulated and estimated using a cross section of firms from the chemicals industry. Then the Brown and Durbin (1968; Brown, Durbin, and Evans 1975) and Quandt (1958, 1960) tests for structural change are employed to test the hypothesis that the rate of return to R & D increases with absolute firm size. In Section II these results are interpreted and some concluding remarks are offered.

I. The Analytical Framework

The Empirical Model

An important function in the entrepreneur's decision-making process is the successful use of R & D investments for innovation. A common model for estimating the rate of return to these expenditures is generally formulated on the assumption that the firm operates according to a three-factor production function:

$$Y = AF(L, K; T), \tag{1}$$

where Y is output; A is a neutral disembodied shift parameter; L and K are measures of the stock of labor and capital, respectively; and T is a stock of technical capital or technical knowledge (Mansfield 1965; Griliches 1973; Terleckyj 1974). In turn, T is written as a function of the relevant research capital, C, and "other" factors affecting its production, O:

$$T = G(C, O), \tag{2}$$

where research capital, C, is some weighted accumulation of previous R & D investments, R:

$$C = \Sigma a_i R_{t-i}. \tag{3}$$

The accumulation weights, a_i, reflect the influence of both a distributed lag effect of i periods on past R & D and the rate of obsolescence on research capital.

If equation (1) has the form of a Cobb-Douglas production function, the model becomes

$$Y = A_0 e^{\lambda t} T^{\alpha} L^{\beta} K^{(1-\beta)}, \tag{4}$$

where A_0 is a constant, λ is a disembodied rate of growth parameter, and α and β are output elasticities. Constant returns to scale are assumed with respect to L and K (Griliches 1973, 1975; Terleckyj

1974). Differentiating equation (4) with respect to time, "residual" productivity growth is defined as:

$$\dot{F}/F = (\dot{Y}/Y) - \beta(\dot{L}/L) - (1 - \beta)(\dot{K}/K) = \lambda + \alpha(\dot{T}/T), \tag{5}$$

where the dot notation represents a time rate of change ($\dot{F} = dF/dt$) and $\dot{F}/F$ represents those productivity changes not attributable to L or K. The parameter α is the output elasticity of technical capital,

$$\alpha = (\partial Y/\partial T) \cdot (T/Y). \tag{6}$$

Thus, using this definition of α, equation (5) becomes

$$\dot{F}/F = \lambda + \rho(\dot{T}/Y), \tag{7}$$

where $\rho = (\partial Y/\partial T)$ is the marginal product of technical capital, and $(\dot{T}/Y)$ is the net private investment in R & D per unit of output. If, for a given industry or firm, equation (7) is not deterministic but, rather, stochastic,

$$\dot{F}/F = \delta + \gamma(I_T/Y) + \mu, \tag{8}$$

where $I_T = \dot{T}$ and μ is a random disturbance term. The slope coefficient, $\hat{\gamma}$, will be an empirical estimate of the marginal rate of return to R & D assuming that per period R & D expenditures represent the relevant *net* investments (I_T) into the firm's stock of technical capital.

The Data Set and Empirical Estimates

Equation (8) was estimated using a sample of 101 firms from the chemicals and allied-products industry (SIC 28) for 1975. This industry was selected for two reasons. First, it has been an industry extensively investigated in other empirical studies of Schumpeter's hypothesis (Hamberg 1964; Comanor 1965; Mansfield 1965; Scherer 1965*b*; Grabowski 1968). Second, it is one of the four leading manufacturing industries in R & D activity, but it is that industry least dependent on government R & D support. Implicit in our model is the assumption that the entrepreneur directs R & D investments toward activity that will increase the firm's technological growth. The greater the percentage of R & D which is federally financed, the less the discretionary power of the entrepreneur. As well, in these federally supported industries their R & D "output" (as space exploration) is sold directly to the public sector. Since these outputs are conventionally valued at cost by the selling industry, they have a zero contribution to residually measured productivity ($\dot{F}/F$) (Griliches 1973). Thus $\hat{\gamma}$ will understate the true rate of return the greater is government support. In 1975 less than 9 percent of R & D activity in the chemicals industry was federally supported, compared with 45 percent support in electrical equipment and 79 percent in aircraft and missiles. The chemicals industry seems to relate more closely to the underlying assumptions of equation (8) than do the other industrial R & D leaders.

Data were taken from the COMPUSTAT tapes of Investor's Management Sciences, Inc., a subsidiary of Standard & Poor's Corporation. The sample available represents 73 percent coverage of the industry in terms of sales and 71 percent of the industry in terms of R & D expenditures.

The estimation of equation (8) requires data for the rate of growth in residual productivity, $\dot{F}/F$; for net investments in R & D, I_T; and for current output, Y; $\dot{F}/F$ was computed according to equation (5) as an annual average rate over the period 1970–75:

$$\dot{F}/F = 1/5[(\ln Y_{75} - \ln Y_{70} - \ln PD) - \beta(\ln L_{75} - \ln L_{70}) - (1 - \beta)(\ln K_{75} - \ln K_{70})]. \tag{9}$$

Few firms reported R & D data to COMPUSTAT prior to 1970; hence this period defines the availability of data. In equation (9) output, Y, is measured as net sales of the firm defined as gross sales and other operating revenue less discounts, returns, and allowances. The industry-specific wholesale price deflator (1970 = 100), PD, is published by the Bureau of Labor Statistics in *Wholesale Prices and Price Indexes*. The average share of labor in total sales, β, over the period 1970–75 was calculated as the total labor expenditures of the firm in 1973 per unit of 1973 sales. Many of the firms did not report their labor-related expenditures; therefore these data were approximated by the product of the average two-digit manufacturing wage for each grouping as reported in the *Census of Manufactures* and the total number of workers for each firm in 1973. Labor, L, was measured as the total number of employees as reported to stockholders. The capital stock, K, was measured as the historic book value of gross plant representing tangible fixed property such as land, buildings, and equipment. The average share of capital in total sales is $(1 - \beta)$.

Theoretically, I_T represents the time derivative of the stock of technical knowledge, T; but having no estimate of the lag between R & D expenditures and the resulting change in T or of the rate of obsolescence on innovations, any measure of I_T will be subject to error. In addition, there exist the usual caveats associated with accounting inconsistencies regarding that which is actually included under the heading R & D (Griliches 1973). The COMPUSTAT definition of R & D includes all private costs, such as salaries and departmental expenses, charged to operations as research expense. Being unable to offer any substantial alternative to these data problems associated with R & D measures, I have measured (I_T/Y) conventionally as 1975 R & D expenditures per unit of 1975 sales.

The estimated least-squares results from equation (8) are:

$$\dot{F}/F = \underset{(-10.42)}{-\ 0.07} + \underset{(3.43)}{0.62}(I_T/Y), \tag{10}$$

where $R^2 = .11, F = 11.79$, and $N = 101$; numbers in parentheses are t-statistics. The estimated rate of return to R & D is 62 percent, which is not inconsistent with the empirical findings of others (Hamberg 1964; Mansfield 1965; Griliches 1973, 1975; Terleckyj 1974; Link 1978). Our interest here, however, is to test for structural changes in equation (8) over varying levels of firm size in order to determine if the rate of return to R & D, our measure of successful innovative activity, increases with firm size.

Estimates of Structural Change in the Rate-of-Return Equation

To determine, statistically, if the rate of return to R & D varies over alternative size firms, equation (8) was first tested using the Brown and Durbin (1968; Brown et al. 1975) test for structural stability.[6] If the structure of equation (8) changes over the ranking of the regressor by firm size, this will result in a shift of the residuals when compared with a model assuming constant coefficients. The test statistic, S_r, is based on the normalized cumulative sum (cusum) of squared residuals from a recursive estimation model:

$$S_r = \left(\sum_{k+1}^{r} w_t^2 \Big/ \sum_{k+1}^{N} w_t^2\right); r = k + 1, \ldots, N, \tag{11}$$

where w_t are the orthogonalized recursive residuals, k is the number of independent variables in the equation, and N is the number of observations; S_r has a beta distribution with mean $(r - k)/(N - k)$. If the regression coefficients are constant, a plot of S_r will lie along its mean value line within the confidence limits $\{\pm C_0 + [(r - k)/(N - k)]\}$ defined by Pyke's modified Kolmogorov-Smirnov statistic, C_0.

In our case, the null hypothesis is that the structure of equation (8) is constant over all levels $(1, \ldots, N)$ of firm size:

$$\begin{aligned} &\delta_1 = \delta_2 = \ldots = \delta_N = \delta, \\ H_0\colon\ &\gamma_1 = \gamma_2 = \ldots = \gamma_N = \gamma, \\ &\sigma_1^2 = \sigma_2^2 = \ldots = \sigma_N^2 = \sigma^2, \end{aligned} \tag{12}$$

[6] See Khan (1974) for a discussion of the Brown-Durbin test vis-à-vis other tests of structural change.

for σ_i^2 ($i = 1, \ldots, N$) being the variance of the error term in equation (8), μ_i. The alternative hypothesis is that a threshold effect exists and that the estimated slope coefficient increases over alternative size regimes—Schumpeter's hypothesis.

The plot of the S_r's against the observation numbers of (I_T/Y), ranked in ascending order of firm size, is shown in figure 1. Size has been measured by other researchers as either the dollar value of sales or of total assets, or by the firm's total employment; we have used 1975 sales measured in millions of dollars for our ranking. Departure of S_r from its mean denotes that observation where the structural shift becomes significant. It does not necessarily denote that observation where the shift initially began or that where only one shift occurred. Clearly, the null hypothesis of structural stability can be rejected at the 99 percent level. It remains as a methodological problem to determine that size level for dividing the data.[7]

In order to determine that firm size for dividing the data into alternative regimes, the plot of the estimated rate of return coefficients over cumulated observations of (I_T/Y) corresponding to successively larger firms was examined. This forward plot is shown in figure 2. Two characteristics of the plot are immediately evident: (1) The sporadic nature of the regression slope coefficient over the initial observations reflects the sensitivity of regression analysis to additional degrees of freedom, and (2) beyond observation 77 the additional influence of data from successively larger firms does not seem to affect the value of the estimated rate of return coefficient. From an inspection of figure 2, the exact division(s) of the data is strictly a matter of judgment.[8] The criterion used here, however, is based on Quandt's likelihood test (1958, 1960) under the maintained hypothesis of two regimes.[9] The likelihood function obtained a "maximum

[7] The Brown-Durbin test has been applied in several other studies (Khan 1974; Hodgson and Holmes 1977), but the question of dividing the data and reestimating each structural regime has not been addressed.

[8] The backward plot of estimated rate-of-return coefficients was also examined. It was sporadic over initial observations but was not useful in isolating a clear point(s) of division.

[9] I am grateful to James Durbin for pointing out that the likelihood test should be used as the dominant criterion for dividing the data and for stressing that individual judgment and inspection of the specific data may, in some instances, be the more accurate method to employ. Postulating the existence of two regimes, $\dot{F}/F = \delta_1 + \gamma_1(I_T/Y) + \mu_1$ and $\dot{F}/F = \delta_2 + \gamma_2(I_T/Y) + \mu_2$, where μ_i ($i = 1, 2$) is normally and independently distributed with zero mean and variance σ_i^2, Quandt's likelihood test estimates, over a total of N observations, those points where the system switches from one regime to another (1958). Methodologically, it seems appropriate to employ this test only after the assumption of structural stability has been statistically rejected. The likelihood function is $L(n_i) = -N \log \sqrt{2\pi} - n_1 \log \hat{\sigma}_1 - n_2 \log \hat{\sigma}_2 - (N/2)$, for all possible values of n_i ($n_1 + n_2 = N$ and $n_i \geq 3$). From inspection of figure 2 it is not unreasonable to suspect that three regimes of behavior are present: a division for the smallest firms near observation 30 and a division for the larger firms near observation

maximorum" at observation 42 (in an ascending ranking) corresponding to a firm size of \$297.2 million. Given this point of division, equation (8) was reestimated using a dummy variable, $D_1 = 1$ for firms with sales greater than or equal to \$297.2 million, interacted with (I_T/Y) to estimate the rate of return in each size regime.[10] These estimated least-squares results are:

$$\dot{F}/F = \underset{(-10.50)}{-0.07} + \underset{(1.32)}{0.30}(I_T/Y) + \underset{(2.32)}{0.48}D_1 \cdot (I_T/Y); \tag{13}$$

$R^2 = .15$, $F = 8.85$, and $N = 101$; numbers in parentheses are t-statistics. The estimated rate of return to R & D for the smaller firms is 30 percent (significant at the 80 percent level) and for the larger firms it is 78 percent (significant at the 99 percent level).[11]

II. Interpretation of the Empirical Findings and Conclusions

The estimated results in equation (13) suggest that efficient innovative activity, as measured by the rate of return to R & D expenditures, is a function of firm size. The estimated rate of return in the larger size grouping is significantly greater than in the smaller firms.

The estimated threshold level for the smaller firms is \$297.2 million. This level is relatively small compared with the sample's median level of sales of \$451 million or to its mean level of \$912 million.[12] The importance of economies of scale in the efficiency of innovative activity becomes evident at a relatively small size, but its effect appears to remain constant as firm size increases beyond that level. It does not appear that "gigantic" firm size is a prerequisite for R & D efficiency in the chemicals industry.

The methodology employed in this paper makes it difficult to compare our findings with those of other researchers. For example, Scherer (1965*b*) finds from his study of the chemicals industry that

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[9] Accordingly, Quandt's test was generalized to three regimes The likelihood function reached an absolute maximum at $n_1 = 46$, $n_2 = 4$, and $n_3 = 51$ corresponding to an ascending ranking of firms by size. This implies either that the medium region is extremely small or that only two regimes are statistically evident. On reestimating equation (8) with dummy variables interacted with (I_T/Y), it was concluded that the smaller two regions did not behave significantly different from each other. Consequently, the assumption of two regimes was accepted.

[10] The reestimation initially accounted for separate intercepts as well as slope coefficients for each size regime. The intercepts were not significantly different from each other and thus were omitted.

[11] The estimated standard error for the rate-of-return coefficient in the larger size grouping is 0.17.

[12] The range of firm sales in the chemicals industry is \$10.1 million to \$7,221.5 million, with SD of \$1,298.0 million.

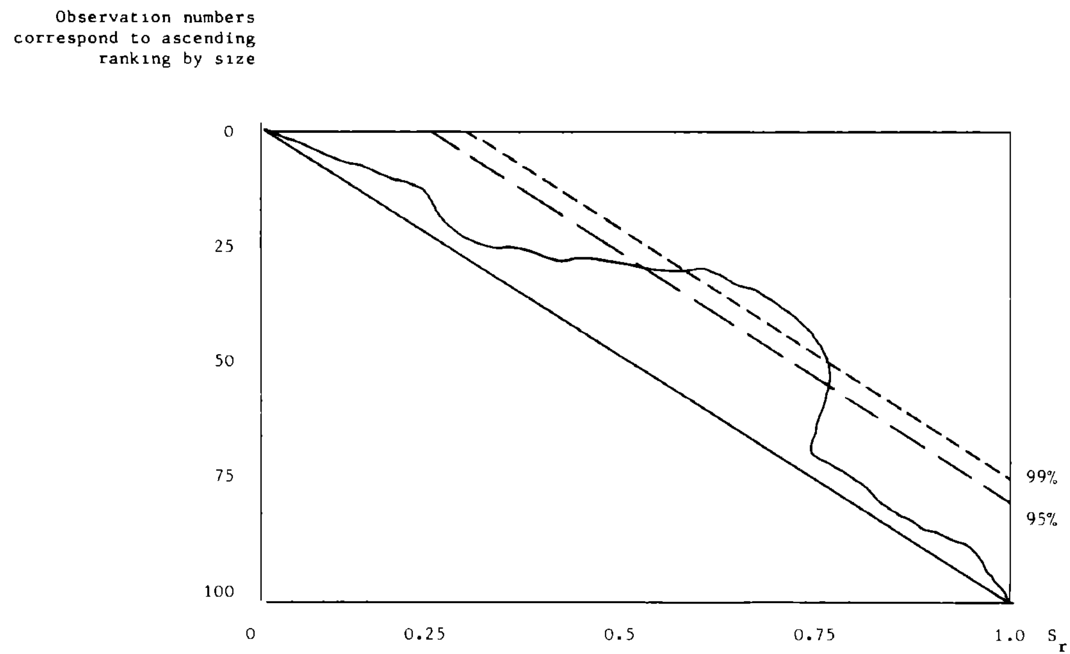

Fig. 1.—Forward plot of recursive residuals. Solid diagonal = mean value line of S_r; dotted lines = 95 percent and 99 percent confidence limits. Only the plot of the forward calculation of the recursive residuals is shown. However, this is generally considered the more meaningful (Brown et al. 1975).

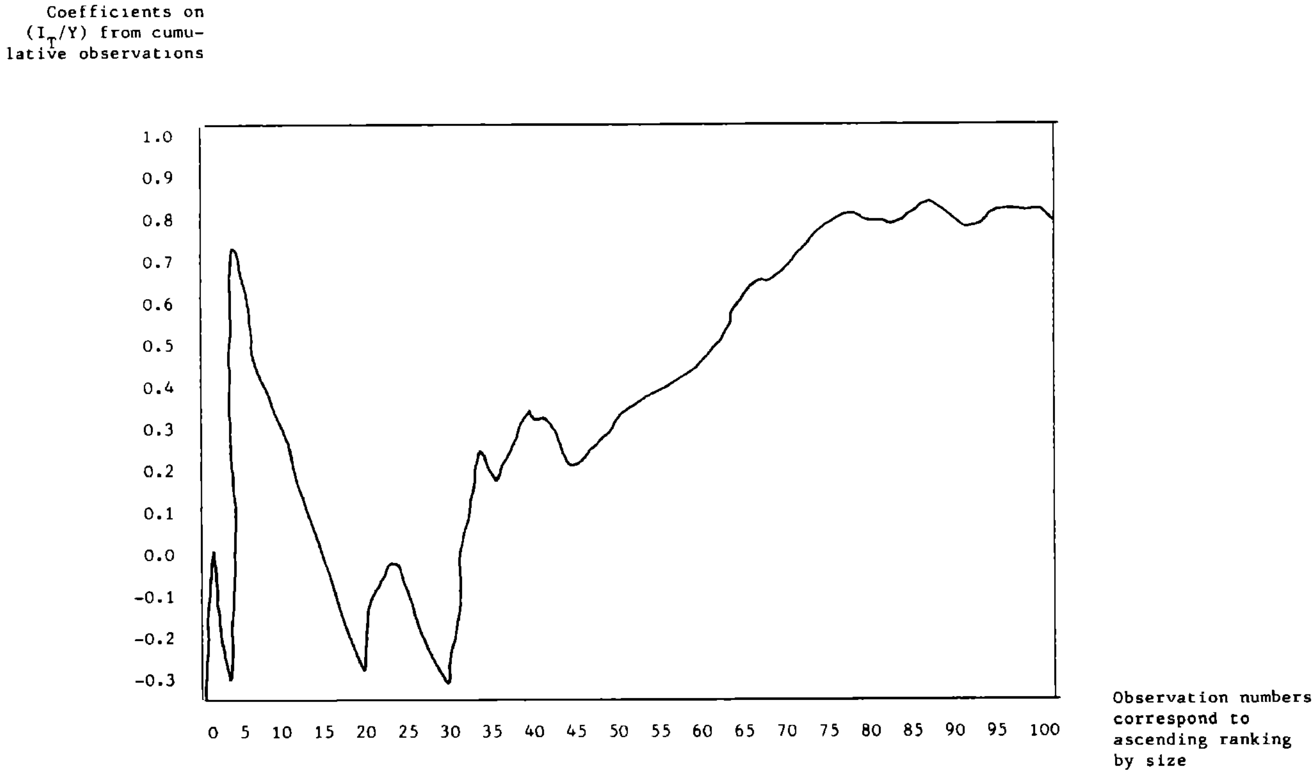

FIG. 2.—Forward plot of rate-of-return coefficients

there is a positive and increasing relationship between R & D expenditures and increasing levels of firm size, and he therefore concludes that larger firm size is a prerequisite for innovative activity. We, on the other hand, conclude that large firm size is a prerequisite for *efficient* innovative activity *only* to a point, and then the influence of size remains constant. If the findings of these forms of research are important to antitrust "thinking" about the benefits and costs of large firm size and even of market dominance, the contrasting conclusions reached here may warrant a rethinking of methodology and of the relevant interpretations and implications of Schumpeter's hypothesis.

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