THE POLICY INTERPRETATION OF ECONOMETRIC
TESTS OF THE SCHUMPETERIAN HYPOTHESIS
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Numerous econometric studies have tested the hypotheses of Schumpeter and Galbraith that large firms with market power dominate privately-financed investment in research and development.[1] These hypotheses have been tested with data sets at both the firm- and the industry-level. Firm-level models--that is equation estimated with structural data on individual firms--directly test the firm-level hypotheses of Schumpeter and Galbraith. On the other hand, industry-level models have less severe data requirements and they directly test Schumpeter's policy conclusion that

> ...perfect competition is not only impossible but inferior and has no title to being set up as a model of ideal efficiency.[2]

One question these studies have not addressed is the relation between firm- and industry-level tests of the Schumpeterian-Galbraithian hypotheses. Specifically, if firm-level tests are consistent with the Schumpeterian-Galbraithian hypotheses, can one logically infer, from this alone, Schumpeter's industry-level policy conclusion on market-restructuring? Conversely, given a statistical test at the industry-level of Schumpeter's policy conclusion on market-restructuring, can one logically infer the structure of firm-level R&D conduct? The answer is no, and no. This study demonstrates that statistical evidence at the firm-level consistent with the Schumpeterian-Galbraithian hypotheses logically implies nothing about Schumpeter's industry-level policy conclusion, and vice versa. Firms may be Schumpeterian and yet when firm sizes and market power increase total industry R&D may decline. Structural relationships at the firm-level require supplemental analysis before their implications for public policy are readily understood. Conversely, statistical models at the industry-level of Schumpeter's policy conclusion have no basis in economic theory, and their statistical tests are not tests of the firm-level hypotheses.

This paper first develops the general, canonical model of expected firm R&D, which model forms the basis for the succeeding analysis. Section II defines the canonical model of expected industry R&D, considers constraints on the market power and firm size variables imposed by this definition, and decomposes changes in expected industry R&D into three effects. An illustration of how this trichoto-mization provides a method for analyzing changes in expected industry R&D is presented in Section III using the regression model from Culbertson and Mueller (1980). Section IV considers the implications of the analysis in Sections II and III for industry-level tests of Schumpeter's policy conclusion, and Section V presents selected reservations on the use of expected industry R&D as a policy goal.

## I. Canonical Model of Firm R&D

Schumpeter and Galbraith assert that large firms with market power produce the bulk of privately financed R&D. Scherer (1980) identifies four reasons why firm size might positively affect firm R&D. First, and distinctly Galbraithian, is the argument that small- and medium-sized firms have depleted the stock of modestly priced R&D projects, leaving only those very expensive projects that can be undertaken only by the largest industrial firms. Further, Galbraith and Schumpeter both hypothesize that substantial uncertainty attends R&D investments. Large firms can reduce this uncertainty by diversifying their R&D portfolio, while small firms may be limited to at most a relatively few R&D projects with correspondingly greater uncertainty attending their R&D portfolio. Clearly these two hypotheses have a interactive role, so that large firms will have the greatest advantage in industries where R&D projects are both very expensive and very risky.

Economies of scale may be a third reason why large firms might have an advantage over smaller firms in the production of invention and innovation.

There may be economies of scale at the level of the research and development laboratory due to the specialization of labor or the intensive use of specialized expensive laboratory equipment. Economies of scale at the firm-level in advertising and the attraction of capital will also place the large firm at an advantage.

Finally, Scherer observes that the return on process innovations is positively correlated with firm size. If an innovation is adopted that reduces costs by x percent per unit, the firm's total cost saving is the product of x and the number of units produced. Thus, even if large firms cannot perform R&D at a lower cost than can small firms, large firms may still have an advantage because their returns on process innovations are greater.

The Schumpeterian-Galbraithian firm size hypothesis has been tested statistically by testing whether firm R&D increases nonproportionately with firm size. If firm R&D increases proportionately with firm size, this is evidence inconsistent with Schumpeter's and Galbraith's hypothesis. Their hypothesis is supported if firm R&D increases at an increasing rate with firm size.

Schumpeter and Galbraith assert that it is the coexistence of market power with large firm size that provides the economic environment conducive to the production of R&D. In markets where firms enjoy market power final output is reduced, prices are enhanced above competitive levels, and firms earn an above normal return on investment. This financial slack and lessening of competitive pressures provides firms with the financial capability to engage in R&D. Further, since oligopolists earn an above normal return on invested capital, their payback period on investments is shorter. This lessens the probability that imitation by competitors will reduce prices before an acceptable return on investment is earned.

Richard R. Nelson (1959) hypothesizes that firm diversification is positively correlated with firm R&D activity. Nelson asserts that many of the results of R&D are unanticipated, so research in one product may produce results of greatest

value for another product. Diversified firms are more likely to recognize the economic value of unanticipated research results and may be better able to capitalize on them if these results fall in product lines in which the firm has production and marketing experience.

Regression studies testing the hypotheses of Schumpeter, Galbraith, and Nelson use two different regression models. Many studies regress total firm R&D directly on the firm size, market power, firm diversification, and control variable regressors. Others deflate R&D activity by firm size, giving an intensity model. The intensity model is used for two reasons: (1) to correct for heteroscedasticity and (2) to ensure that observations on large units do not dominate the regression analysis.3/ These two motivations are, in fact, identical; if the disturbance term is homoscedastic, the regression estimator is not unduly influenced by observations on large units. Thus, the intensity model is not chosen as the theoretically specified model, rather it is adopted as a procedure for correcting for heteroscedasticity in the model of total R&D that theory specifies. Since the analysis below is concerned with the logical relation between firm- and industry-level models, and not with their statistical estimation, we use the model of total firm R&D. If the coefficients in this model are to be estimated, the generalized least squares estimator is efficient and unbiased.

For the analysis below the structural variables can be usefully divided into two groups. In the first fall those that are a function of one or more firm sizes. Included here are the firm size variables and some of the market power variables: firm market share, relative firm market share (market share divided by four-firm concentration), four-firm concentration, and the Herfindahl Index (obviously no study uses all of these variables simultaneously). Those variables independent of firm size--barriers to entry, firm diversification, and control

variables--form the second set. In the subsequent analysis the second set of variables and the constant term are combined, and the analysis focuses on the first set of variables.

Equation (1) presents the formal canonical model of expected firm R&D activity with K market power regressors, $M_{ij}$, and P firm size regressors, $S_{qj} = \ln^q(\text{firm size}_j)$ for $q=1, 2,\ldots, P$, testing the Schumpeterian-Galbraithian hypothesis that expected firm R&D increases with market power and increases at an increasing rate with firm size.

$$(1) \quad E(R\&D_j) = c + \sum_{i=1}^{K} b_i m_{ij} + \sum_{q=1}^{P} a_q S_{qj}$$

The polynomial $\sum_{q=1}^{P} a_q S_{qj}$ is a P-th order polynomial in the natural logarithm of firm assets. For P greater than one this specification allows for the hypotheses that firm R&D increases at an increasing rate with firm size, increases at a decreasing rate with firm size, or initially increases at an increasing rate and then increases at a decreasing rate with firm size. All three functional forms have been hypothesized by economic theory, and the use of a second degree or higher polynomial allows the data to discriminate among these hypotheses. In Culbertson and Mueller where a quadratic is used $S_{1j}$ is the natural logarithm of the jth firms' assets, $S_{2j}$ is the squared natural logarithm of the jth firms' assets, and $\sum_{q=1}^{2} a_q S_{qj} = a_1 \ln(\text{firm assets}_j) + a_2 \ln^2(\text{firm assets}_j)$. In this model the three hypothesized size relationships above are that

$$(2) \quad \frac{\partial \left( \sum_{q=1}^{2} a_q S_{qj} \right)}{\partial (\text{firm assets}_j)} > 0$$

and that

$$(3) \quad \frac{\partial^2 \left( \sum_{q=1}^{2} a_q S_{qj} \right)}{\partial (\text{firm assets}_j)^2}$$

is respectively positive, negative, or initially positive and then negative throughout the range of firm sizes (that is, for all j).

The polynomial of size-dependent market power variables, $\sum_{i=1}^{K} b_i m_{ij}$, is composed of both linear and quadratic terms of several size-dependent market power variables testing the Schumpeterian hypothesis that firm R&D increases with market power and the qualified Schumpeterian hypothesis that firm R&D initially increases, and then decreases, with market power. These market power variables are, in general, functions of the size distribution of all N firms in the industry

$$(4) \qquad m_{ij} = f_{ij}[\exp(S_{11}), \exp(S_{12}), \ldots, \exp(S_{1N})]$$

If the regressors $m_{(2I-1)j}$ for $I=1,2,\ldots,K/2$ are the linear (untransformed) market power variables, the Schumpeterian hypothesis is that

$$(5) \qquad \frac{\partial}{\partial m_{(2I-1)j}} \left[ \sum_{i=1}^{K} b_i m_{ij} \right] > 0 \qquad I=1,2,\ldots,K/2$$

over the range of $m_{(2I-1)j}$. If this derivative is initially positive and then for larger values of market power negative, only a qualified Schumpeterian relationship exists for this variable.

## II.  Theoretical Model of Expected Industry Research and Development

Expected industry R&D is the sum over all N firms in the industry of expected firm R&D

$$(6) \qquad E(IR\&D) = \sum_{j=1}^{N} \left[ c + \sum_{i=1}^{k} b_i m_{ij} + \sum_{q=1}^{P} a_q S_{qj} \right]$$

Equation (6) is subject to constraints that greatly complicate its interpre-
tation. We are interested in determining the effect on total expected industry
R&D of changes in the size distribution of firms and certain market structure
variables while holding all other variables constant. One variable held constant
is industry size; there is no theoretical reason to expect that changes in the
size distribution of firms simultaneously leads to changes in industry size.
This constraint is expressed in equation 7.

$$(7) \qquad \sum_{j=1}^{N} [\exp(S_{11}), \exp(S_{12}), \ldots, \exp(S_{1N})] = I$$

Since industry size is the sum of the sizes of all firms in the industry,
assuming all firms are completely specialized, the size of one firm cannot
change independently of others. Thus, changing the size of one firm induces
changes in the sizes of others or in the number of firms in the industry.

The other constraint occurs because the market power variables, $m_{ij}$,
are by assumption functions of the size distribution of all firms in the industry.

$$(8) \qquad m_{ij} = f_{ij}[\exp(S_{11}), \exp(S_{12}), \ldots, \exp(S_{1N})]$$

If one firm size changes, inducing corresponding changes in other firm sizes
or the number of firms, this will in turn lead to changes in some or all of
the market power variables. Conversely, if one market power variable changes
then logic dictates that other market power variables, firm sizes, and numbers
of firms must change. There are additional constraints on the market power
variables that depend on the specific variables used. For example, if four-firm
concentration is a regressor, the sum of the market shares of the leading four
firms must equal the value for four-firm concentration. These constraints
cannot be generalized, but are readily apparent in any model.

The change in expected industry R&D due to a change in market structure is easily calculated by substituting into equation (1) the values for firms' structural variables, subject to all constraints, and then directly comparing the sums of expected firms' R&D. While this calculation is simple, it does not illuminate the process whereby changes in market structure lead to changes in expected industry R&D. We can decompose the changes in expected industry R&D into three distinct parts, and this analysis illustrates clearly the complicated way in which changes in market structure change expected industry R&D.

## Decomposition of Changes in Expected Industry R&D: Numbers-Effect

One factor in this decomposition is that part of the change in industry R&D due solely to the change in the number of firms in the industry, the numbers-effect. This factor is traditionally ignored in interpreting studies of R&D. Recall that the size unrelated variables, barriers-to-entry and control variables, together with the constant term determine the constant c in equation (1). The value for c can be interpreted as the point estimate of firm R&D for a small firm in a competitive industry, thus c should be non-negative. This variable is independent of the size distribution of firms. If an industry initially is composed of $m_0$ firms and an increase in firm sizes and market power is accompanied by a reduction in firm numbers to $m_1$, there will be a numbers-effect reduction in expected industry R&D of

(9)     $(m_1 - m_0) \, c$

Even if all of the estimated coefficients for the market power and firm size variables are positive supporting the Schumpeterian-Galbraithian hypothesis, industry R&D may decline with increasing firm size and market power if the numbers-effect is sufficiently strong. Since c is the point estimate of firm

R&D for a small firm in a competitive industry, for a given reduction in the number of firms the numbers-effect will be larger the greater are technological opportunities in the industry.

## Decomposition of Changes in Expected Industry R&D:  Size-Effect

The Galbraithian firm size hypothesis has been formally interpreted above as hypothesizing that firm R&D is a strictly convex function of firm size. The second factor explaining changes in expected industry R&D, the size-effect, is that contribution to the change in expected industry R&D due solely to changes in the firm size variables.  Suppose that firm 1's assets exceed firm 2's and that firm 1's assets increase and firm 2's assets decrease by $h.  The change in expected industry R&D due solely to the change in these two firms' sizes is

$$(10) \quad \sum_{q=1}^{P} a_q \ln^q(\text{firm assets}_1 + h) - \sum_{q=1}^{P} a_q \ln^q(\text{firm assets}_1) + \sum_{q=1}^{P} a_q \ln^q(\text{firm assets}_2 - h)$$

$$- \sum_{q=1}^{P} a_q \ln(\text{firm assets}_2)$$

If the firm size function is strictly convex, (10) must be positive since the first derivative of a strictly convex function is increasing and thus

$$(11) \quad \frac{\sum_{q=1}^{P} a_q \ln^q(\text{firm assets} + h) - \sum_{q=1}^{P} a_q \ln^q(\text{firm assets}_1)}{h} >$$

$$\frac{\sum_{q=1}^{P} a_q \ln^q(\text{firm assets}_2) - \sum_{q=1}^{P} a_q \ln^q(\text{firm assets}_2)}{h}$$

Multiplying both sides of the inequality by h gives the desired result.  Ignoring the numbers-effect and the market-power-effect (discussed below) the conventional interpretation of the estimated coefficients on the firm size variables is correct.

If the firm size relationship is strictly convex, increasing the sizes of larger firms at the expense of smaller ones increases expected industry R&D.

## Decomposition of Changes in Expected Industry R&D:  Market-Power-Effect

The change in expected industry R&D due solely to the change in the market power variables, the market-power-effect, is the most complicated of the three effects because of the complex interrelationships that may exist among the market power variables.  A change in one market power variable, for example one firm's market share, implies a change not only in at least one other firm's market share but also a change in, say, the Herfindahl Index for every firm in the industry. The extent of the interdependence among market power variables depends on the particular variables chosen.  Market share and four-firm concentration are the market power variables most frequently used in firm R&D studies.  Here, changes in the market shares of firms have an indeterminant effect on four-firm concentration without additional information of their initial and final market shares and the market shares of each of the leading four firms.

The market-power-effect may be negative, neutral, or positive even if the data are consistent with the Schumpeterian-Galbraithian hypothesis.  To illustrate this, suppose that market power is measured by market share and the four-firm concentration ratio, and the estimated coefficients on each are positive.  If firms' market shares change without changing four-firm concentration or the number of firms, the market-power-effect will be zero (of course there will still, in general, be a size-effect).  If firms' market shares change and there is a reduction in the number of firms while four-firm concentration remains unchanged, the market-power-effect is negative because the loss of each firm reduces expected industry R&D by an amount equal to the product of

four-firm concentration and its estimated coefficient.4/ Finally, if four-firm concentration increases without a reduction in the number of firms, the market-power-effect is positive. However, if the increase in market concentration is effected through mergers, the market-power-effect may be positive or negative.

### III. Decomposition of Changes in Expected Industry R&D: An Illustration

The relative contributions of the size-effect, market-power-effect, and numbers-effects in determining the change in market structure is illustrated below. Culbertson and Mueller's single equation model has three market power variables: weighted four-firm concentration (CR4), weighted relative firm market share (RFMS), and weighted industry advertising intensity (AS). Four-firm concentration and relative firm market share are size-dependent market power variables, while industry advertising intensity is independent of the firm size distribution. Firm size (L) is measured by the natural logarithm of firm assets. Technological opportunity class and percent nonfood control variables are also included in the model, but are independent of the firm size distribution. Equation 12 presents the point estimates and t-statistics from Culbertson and Mueller's regression model.5/

$$(12) \quad \text{R\&D Expenditures} = 12.22 + 0.13 \text{ CR4} - 0.0011 \text{ (CR4)}^2 + 0.027 \text{ RFMS} - 7.97 \text{ L}$$
$$(2.03)* \quad (-1.97)+ \quad (2.06)* \quad (4.81)**$$

$$+ \ 1.03 \text{ (L)}^2 \qquad\qquad R^2 = 73$$
$$(5.40)**$$

Significance levels: ** 1 percent; * 5 percent; + 10 percent

The constant term is the sum of the estimated intercept and the estimated coefficients on the control and the size-independent market power variables in the model. For purposes of illustration it is assumed that all firms are specialized in one food industry with advertising intensity of 2.7%, which

advertising intensity is the simple average for all firms in Culbertson and Mueller's 1967 sample.

In Culbertson and Mueller's model the coefficients on the size-dependent regressors all are significant at the 10 percent level or better. The quadratic function in four-firm concentration has a maximum at CR4=60. The relationship between firm size and expected firm R&D has a point of inflection at a firm asset size of about $130 million (1967 dollars).

The relative contributions of the firm-size, market-power, and numbers-effects to the change in expected industry R&D from a change in market structure is illustrated below with the two industry structures given in Table 1. The initial industry configuration is composed of seven firms each with assets of $130 million. This figure was chosen because the size function has a point of inflection at about $130 million. Further, assuming that firms' assets are proportional to their sales and that all firms are specialized, industry sales will be $910 milllion.

Table 1

|  | Four-firm concentration | Relative firm market share | Firm assets (millions) |
|---|---|---|---|
| I | 57% | 25% | $130 |
| II | 29 | 25 | 65 |

Thus four-firm concentration is 57, which is close to the maximum in the quadratic function in four-firm concentration. In the intial industry configuration both firm size and market concentration variables are near their optimal values.

The less concentrated industry structure is constructed by halving firm sizes and doubling the number of firms in the industry. Firms now have assets of

$65 million, four-firm concentration is 29, and relative firm market share is unchanged at 25.

Table 2 presents total expected industry R&D for the two industry structures and the size-effect, numbers-effect, and market-power-effect explaining this change.

Table 2--Determinants of the Change in Expected Industry R&D

| | | |
|---|---|---|
| 1) Total expected industry R&D | | |
| Industrial structure I | $16.38 | |
| Industrial structure II | 5.88 | |
| 2) | Difference | $10.50 |
| 3) Numbers effect | | $ 85.54 |
| Size effect | | -113.77 |
| Market power effect | | 17.64 |
| Due to CR4 | $12.88 | |
| Due to RMS | 4.76 | |
| 4) | Sum of three effects* | $-10.59 |

*Line (4) differs from line (2) due to rounding.

The total change in expected industry R&D between industrial structures I and II is $10.50 million. This net change reflects a balancing of the positive market-power and numbers-effects of $17.64 million and $85.54 million respectively with the negative size-effect of -113.77. Surprisingly, the decline in expected industry R&D effected through market restructuring is due entirely to the size-effect.

In the analysis above it is hypothesized that the numbers-effect will be positive and the size-effect negative if all firm sizes decline with corresponding increases in the number of firms. The sign on the market power effect could not be predicted a priori, and the result above that it is positive may be regarded as counter-intuitive. Since the relationship between relative firm

market share and expected firm R&D is linear and since relative firm market

share equals 25 with both industry structures, the contribution of relative

firm market share to expected industry R&D doubles with a doubling in the number

of firms. The market power effect due solely to relative firm market share is

4.76 (which equals 7 times .68, the estimated coefficient on relative firm

market share).

The market-power-effect due to four firm concentration is also positive,

with a value of 12.88. Expected firm R&D decreases with decreasing market

concentration, but since this function is concave the reduction in individual

firms' R&D is more than offset by the growth in the number of firms. The

total market-power-effect of 17.64 is the sum of that due to RMS, 4.76, and

that due to four-firm concentration, 12.88.

## IV.   Industry-Data Tests of the Schumpeterian Hypothesis

The theoretical analysis developed above was concerned with drawing

inferences about the relationship between market structure and expected industry

R&D from a regression model of the relationship between market structure and

expected firm R&D. Many tests of the Schumpeterian-Galbraithian hypothesis

avoid the need to draw this inference since the regression equation is estimated

with industry data. In his seminal study Horowitz (1962) found a significant,

positive rank correlation betwen each of four measures of R&D activity and four-

firm concentration with two separate samples of 18 two-digit industries.

Phillips (1966) estimated a multiplicative model with eleven industries and

three size classes of firms within each industry. The estimated coefficients

for the logarithm of size and the logarithm of four-firm concentration were both

positive, but did not differ significantly from zero. Scherer (1967) estimated

both additive and multiplicative models of industry R&D employment for three

measures of R&D employment and 56 industry groups. While the regression results differ somewhat among models, market concentration and total industry employment generally have significant, positive effects. Since these regression models are estimated with industry data as observations, the estimated regression coefficient on four-firm concentration is directly interpreted as the expected increase in total industry R&D due to a change, ceteris paribus, in market power.

Regression models estimated with industry data as observations test the same hypotheses as models estimated with firm data: that firm R&D increases with market power and increases at an increasing rate with firm size. However, if the model is estimated with industry data, the economic hypotheses concerning these relationships at the firm-level are tested only indirectly as they are reflected in industry relationships. Econometric tests of the Schumpeterian hypothesis estimated with industries as observations rely on the assumption that the Schumpeterian-Galbraithian relationship exists at the industry level if and only if it exist at the firm level. Yet it is precisely this assumption that is rejected by the theoretical analysis in this paper. Relationships existing at the firm level are not necessarily translated into corresponding relationships at the industry level. Expected firm R&D may increase at an increasing rate with firm size, yet when firm data are aggregated into industry data no relationships between industry R&D and market power and industry shipments need exist. Therefore, in a regression model estimated with industries as observations, the finding that expected industry R&D does not increase significantly with market power nor significantly increase at an increasing rate with firm size is not evidence in contraposition to the Schumpeterian and Galbraithian hypotheses. The absence of a statistically significant relationship at the industry level does not imply a similar absense at the firm level.

Conversely, the the finding of a significant, positive relationship between industry R&D and the market power variables is not necessarily evidence supporting the Schumpeterian hypothesis. As analyzed above, expected industry R&D may increase with market power even if expected firm R&D is not a significant function of market power. Rejection of the statistical null hypothesis in an econometric study using industries as observations is consistent with the Schumpeterian hypothesis, but it is not a test of the Schumpeterian hypothesis.

## V. Some Reservations on the Use of Expected Industry R&D as a Policy Goal

The analysis above focuses on the determination of expected industry R&D. The Schumpeterian and post-Schumpeterian hypotheses predict a relationship between expected firm R&D and firm and market structure, and these hypotheses are appropriately tested with firm-level data. Schumpeter, in his presentation of the hypothesis relating firm R&D to market power, developed the additional hypothesis that the industry output of R&D--the sum of the R&D outputs of all of the firms in the industry--would be greater, ceteris paribus, in more highly concentrated industries. The analysis above determines the relationship between the positive firm-level and the normative industry-level Schumpeterian hypotheses. In so doing, it is implicitly assumes that total expected industry R&D is the appropriate policy variable: that increased expected industry R&D implies increased expected industry progressiveness.

Expected industry progressiveness need not be a strictly monotonic function of expected industry R&D. Market structure affects not only the production of R&D within the industry, but also the diffusion of R&D into the industry. The importance of inter-industry diffusion of technology embodied in capital and material inputs varies widely among industries. Rosenberg (1979) hypothesized

that the size of the market for inputs and their complexity importantly influences

whether the research embodied in these inputs will be produced within the

industry. The secular increase in the sales of food processing industries and

the increasing sophistication of the mechanical, electronic, and chemical

processes used by food processing firms has likely led to the development and

growth of the industries supplying inputs to the food industries. Culbertson

and Mueller (1980) found that for a sample of significant innovations in the

food industries, only 13 percent were produced by food and ingredients manufacturers

while industries supplying inputs to the food industries accounted for over 60

percent. If, as these statistics suggest, embodied technological change influences

significantly progressiveness in the food industries, the effect on industry

progressiveness of market restructuring depends on the relative effect of that

restructuring on R&D performed within the industry compared with its effect on

the rate of diffusion of new technologies into the industry. At present little

is known about the factors influencing the diffusion of technology into the

food industries.

Yet even if the question of the influence of market structure on the dif-

fusion of the technology into the food industries is ignored, serious objections

remain to societies adopting the goal of restructuring industry to maximize

total industry inputs into R&D. Schumpeter argued that the long-run expansion

of output due to innovations developed and adopted in monopolistic markets are

the decisive factor enhancing social welfare. Since, for Schumpeter, innovations

occured only in monopolistic industries, the social policy dilemma arose of

choosing between a perfectly competitive market structure where there exists

an efficient static allocation of resources but with no technological change or a

monopolistic structure where price exceeds marginal cost and, Schumpeter hypothesized,

the rate of innovation is maximized. Most econometric studies hypothesize a more complicated relationship where expected firm R&D changes along the continuum of market power. The emerging consensus is that the relationship between firm R&D and market power reaches a maximum at moderately high levels of market concentration, and that increases in concentration above this critical level reduce expected firm R&D. Further, the analysis above demonstrates that even if the relationship between market power and firms' R&D is linear, expected industry R&D may depend nonlinearly on market power. The real policy calculation involves the comparison of the incremental loss in allocative efficiency against the incremental gain in technological change from a marginal increase in market power, and the analysis above further demonstrates that this calculation is sensitive to the way in which market concentration is increased. The relevant policy consideration is not likely to be the comparison of static and dynamic efficiencies at the corner solutions of perfect competition and monopoly, but the consideration of the net social gain from an increase in concentration in the range of workable competition.

An additional consideration arises from the uncertain nature of the R&D process itself. The production of invention and innovation is necessarily an uncertain production processes, with greater uncertainty attending the former than the latter. Both invention and innovation require searching the appropriate set of existing products and production techniques, and then formulating a research plan to extend the set of existing knowledge. The production function generating new knowledge is unknown, so different researchers or research groups will approach any existing R&D problem differently. Since only certain approaches generate the invention or innovation, the probability that a given invention

will be made is an increasing function of the number of independent research units attempting to invent the product or production process. However, as the number of firms engaged in R&D in an industry increases, the probability of duplicative research on any given R&D project likely also increases. Since industrial R&D is typically carried out in secret, no mechanism exists to ensure that firms engage in the optimal number of independent research efforts for a given research problem.

## VI. Conclusion

Econometric studies of the relationship between between market structure and firms' R&D investments can be used to determine the effect of market structural changes on expected industry R&D. However, this calculation is significantly more complicated than is generally recognized and requires that the distinct market-power, firm-size, and numbers-effects--together with the interrelationships among these effects--be considered explicitly. Even if expected firm R&D increases with market power and increases more than proportionately with firm size, expected industry R&D may decline with increasing firm size and market power. The extent to which expected industry R&D will be enhanced by modifying market structure depends on the strength of the relationship between market structure and firm R&D, technological opportunities in the industry, and the particular restructuring under consideration.

This conclusion has broader implications. The Schumpeterian theory is a theory of firm conduct. Econometric studies using firms as observations directly test this theory. I have demonstrated that there is no direct relationship between the sign on the market power and firm size variables in firm studies and the corresponding sign on market power variables in industry studies.

Even if the Schumpeterian-Galbraithian hypothesis is not rejected by the data, there may be a negative relationship between market concentration and R&D if industries, not firms, are the observations.  Econometric studies having industries as observations have no theoretical basis and are never appropriate tests of the Schumpeterian-Galbraithian hypotheses.

## FOOTNOTES

1/ See Scherer (1980) pp.  481-422 and 433-438 for a recent review of the empircal literature.

2/ Schumpeter p. 106.

3/ Culbertson (1979) pp. 79-86.

4/ Recall that the size-effect is the product of the change in firm numbers with the sum of the size-independent regressors; this calculation excludes size-dependent market power variables.  One part of the market-power-effect is the effect of changing firm numbers on market power variables.

5/ Equation 2, p. 8.

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