Market Structure, Firm Structure, and Research and Development

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Economists have long investigated the impact of market structure on innovation. Modern discussions have been shaped by the fundamental conjectures of Joseph Schumpeter [28], who argued that monopoly is more compatible with innovation than competition.

In this article, we report the results of tests of a number of hypotheses (discussed in detail later) concerning the impact of market structure on innovation.

Two observations of M. I. Kamien and N. L. Schwartz [7] have influenced our methodology. They remark [7, p. 81] that many studies of the impact of firm size on innovation have failed to control for the effect of other variables that may explain innovation. We try to avoid this problem. Second, they [7, p. 52] recognize that market structure and innovation may be simultaneously related and suggest the use of estimation techniques that take account of this. We follow this advice.

Stephen Farber [4] develops a simultaneous equation model to study the impact of industry concentration on the employment of research personnel, with special attention to the impact of the structure of buying industries. By using variables designed to describe the structure of supplier (as well as buyer) industries, we are able to extend Farber’s analysis. Since we benefit from a fine set of disaggregate data, we are able to control for the impact of firm structure on innovation in ways that have not hitherto been possible. In this sense, we extend the results of D. J. Ravenscraft [20] and Stephen Martin [15].

In the second section, we outline a simple formal model, which is the framework for our analysis, and then we discuss the empirical specification of the model. In the third section, we report and discuss estimates of the model. The fourth section contains a few final observations.

SPECIFICATION
Theoretical

We present a model that is a straightforward generalization of Dorfman-
R & D. Suppose that a firm selects price $P$, advertising $A$, and a level of research $R$ to maximize profit:

\[
\pi = PQ(P, A, R) - C[Q(P, A, R), R] - p_aA - p_r(R)R.
\]

For the demand function, we assume:

\[
Q_p < 0 \quad Q_A > 0 \quad Q_R > 0.
\]

To the extent that research develops new products, it contributes (like advertising) to product differentiation. Like Farber [4, p. 340], we expect advertising and product R & D to be complementary.

Research may also develop new processes, reducing production cost. We thus assume:

\[
C_Q > 0 \quad C_R < 0.
\]

To allow for the possibility of nonconstant returns to scale in R & D, we allow the average cost of $R$, $p_r$, to vary with $R$. If the Schumpeterian Hypothesis as usually formulated holds, $p_r$ will fall as $R$ rises.

The first-order condition for profit maximization with respect to $P$ yields, after some manipulation, the familiar Lerner rule. The first order condition for profit maximization with respect to $A$ similarly yields the Dorfman-Steiner rule. As our interest is in R & D, we pass immediately to the first-order condition for profit maximization with respect to $R$. This may be written as:

\[
(p_rR/pQ) = [(P - C_Q)/P] \epsilon_{Q,R} - (C/pQ) \epsilon_{C,R} - (p_rR/pQ) \epsilon_{p_r,R}.
\]

The left-hand side of (4) is the ratio of the cost of R & D to total revenue. The first right-hand-side term, which reflects the presence of $R$ in the demand function, is the product of the price-marginal-cost margin and the elasticity of demand with respect to $R$ (presumed positive). The interpretation of this part of the first-order condition is precisely the same as the interpretation of the Dorfman-Steiner rule for advertising: the more profitable is the marginal sale, the more does it pay to promote sales, by differentiating the product.

But R & D may also lower production cost. As the elasticity of production cost with respect to $R$, $\epsilon_{C,R}$, is negative, the R & D-sales ratio will rise the more sensitive is $C$ to $R$ and the larger is production cost ($C$) relative to revenue ($pQ$).

If there are economies of scale in R & D, so that the average cost of $R$ falls as $R$ rises, then $\epsilon_{p_r,R}$ will be negative and the R & D-sales ratio will rise, the greater are economies of scale and the larger is research cost relative to revenue. Of course, if there are diseconomies of scale in R & D, $\epsilon_{p_r,R}$ will be positive, and the R & D-sales ratio will be lower on that account.

Our model thus suggests four general factors that combine to determine
the R & D-sales ratio: profitability, the elasticity of demand with respect to R & D, the elasticity of production cost with respect to R & D, and the nature of returns to scale in R & D. We now proceed to discuss the empirical specification of our model, in terms of these general factors.

**Empirical**

**Profitability**

The model developed above suggests a positive effect of profitability on research intensity. The economic interpretation is familiar, from Dorfman-Steiner models of advertising.

The literature contains two other sorts of stories about the relationship between profitability and R & D. The first involves liquidity: because an ongoing R & D program is the kind of intangible asset that is difficult to finance in imperfect capital markets, only firms that are profitable enough to generate a large cash flow can finance substantial R & D programs. This story, like our model, predicts a positive structural effect of profitability on R & D intensity.

On the other hand, it may be that it is only when conventional price competition is severe that R & D becomes attractive as a product differentiating strategy [7, pp. 94–95]. In this interpretation, profitability appears not in its own right, nor as a proxy for liquidity, but as an index of the state of rivalry in the marketplace; the expected impact of profitability on R & D intensity is then negative.

The measure of profitability employed here (PCM75) is a price-average cost margin. For details of definition (of this and other variables) see Martin [15].

**Demand Elasticity**

A host of variables that arise in the economic analysis of R & D are relevant, in the end, because of their impact on the relationship between R & D and the quantity demanded of the firm. It is convenient to divide these variables into groups.

**Market Structure.** Lunn [12] argues that one should expect a positive relationship between variables that index market power and R & D: under an attenuated property rights system with positive monitoring costs, firms with market power may be better able to monitor the use of innovations than firms in competitive industries. They may likewise be able to appropriate more of the profit attributable to an innovation. For these reasons, we expect both market share (MS75) and market concentration (CR472) to have positive effects on R & D intensity. The hypothesis that R & D will rise with market concentration is, of course, classically Schumpeterian; see Kamien and Schwartz [7, pp. 86–91]. As they note "The other side of the picture, however, is that the firm already in possession of monopoly power feels less threatened by rivals and therefore less compelled to innovate."
W. S. Comanor [3, pp. 652–53] deals carefully with the interaction of differentiability and technical entry barriers:

... research resembles other market strategies which are designed to promote product differentiation in that it affects not only the rivalry which exists among established firms but also the barriers faced by new firms wishing to enter an industry. ... This incentive, however, is likely to be significant only where entry has not been previously barred on account of other factors. Where entry has been impeded as a result of substantial economies of scale or high absolute capital requirements ... existing firms are less likely to feel compelled to allocate funds for these purposes.

On this analysis, barriers to entry should have a negative effect on R & D intensity. We use an estimate of minimum efficient scale (MES) and the cost-disadvantage ratio (CDR) (Caves, Khalilzadeh-Shirazi, and Porter [1]) to measure entry barriers. MES should have a negative effect on R & D intensity. When CDR is greater, small firms are more nearly as productive, in terms of labor, as large firms. Entry should then be easier, all else equal, which should stimulate R & D. CDR should, therefore, have a positive effect on R & D intensity.\(^7\)

Demand/Demand Shares. Jacob Schmookler [27] suggests that firms will allocate resources toward innovations related to goods favored by increases in demand. To test this, we include the industry growth rate of sales (GR7475) as an explanatory variable for R & D intensity and expect a positive effect.\(^8\)

Four demand-share variables will help control for differences across industries in the elasticity of demand with respect to R & D: the share of industry output going to final consumer demand (CONS), to the federal government (FEDSR), to state and local governments (SLSR), and to industry (IND). Sales to industry or to the federal government should be less susceptible to differentiation, all else equal; R & D should be less, per dollar of sales, in industries for which such sales are important. But sales to consumers and to state and local governments (which attract both advertising and nonadvertising sales efforts [15]) should be more susceptible to differentiation. R & D should be a more attractive product-differentiating strategy when sales to these groups are important.

International trade flows may also affect R & D intensity. The expected impact of the share of imported sales in the market (IMSR) on R & D is ambiguous. On the one hand, the greater is the share of foreign suppliers, the more difficult should it be for an innovator to appropriate the profits of his innovation, all else equal. This suggests a negative impact of import sales on R & D. However (recall the discussion of profitability as an index of the state of competition), the stimulus of competition from foreign sources may well motivate investments in R & D. We assume an agnostic stance concerning the expected effect of IMSR on R & D.

T. A. Pugel [19, p. 78] notes that "... exporting increases the rewards
to innovation by expanding the market for innovation." For this reason, we expect the R & D-sales ratio to rise as the share of exports in total sales (EXSR) rises.

Related markets. Farber [4, p. 338] gives a concise analysis of the impact of buyer industry structure on R & D:

The relative bargaining powers of the buyer and seller of the innovation will determine the share of the rent which is appropriable by the innovator. As the relative bargaining power of the buyer increases, the appropriability of the rent declines. In the case where seller market power is low, increased buyer market power may reduce appropriability and discourage R & D by the selling industry.

On this argument, and following Farber, we expect the coefficient of our estimated buyer concentration ratio (BCR4) to be negative. S. L. Lustgarten [14, p. 493] points out that weighted average estimates of buyer concentration will tend to be biased upward if there are many buying industries, each with a high level of concentration. BDISP is a Herfindahl index of the dispersion of sales across buying industries. If it is high, sales are concentrated among a few industries. For any level of buyer concentration, buyer-industry bargaining power should be greater, the less dispersed are purchases. The expected sign of the coefficient of BDISP is thus negative.

Farber couches his arguments solely in terms of the relative bargaining power of an industry and those who purchase from the industry. But F. M. Scherer [23] has shown that innovations flow up and down vertical chains, literally in an input-output table of technology flows. R & D in an industry may translate into products or processes that can be used by its supplying industries, and the rent that the innovating industry can appropriate will depend on its bargaining power relative to the bargaining power of its supplying industries. All the arguments that Farber makes for purchasing industries go through for supplying industries. For this reason, we expect supplier-industry concentration (SCR4) and dispersion of supplying industries (SDISP) to have negative coefficients in the R & D-sales equation.

Technological environment. Technological environment will vary across industries. Two dimensions of technological environment are of interest for our purposes.

The technological environment of an industry conditions the extent to which products can be differentiated [32]. Since advertising is also related to product differentiation, advertising and R & D spending may be complementary [4]. On this hypothesis, the R & D-sales ratio should rise as the industry average advertising-sales ratio (IASR72) rises.

In terms of the model outlined above, this argument relates to the impact of technological environment on the elasticity of demand with respect to research. But it is recognized [21, 31] that technological
opportunity, which will vary across industries, is an important determinant of research activity. The aspect of technological environment relates to the elasticity of production cost with respect to R & D and the elasticity of the cost of R & D with respect to R & D. To control for differences across industries in technological opportunity, we employ a binary variable \( \text{HTDUMMY} \), set equal to one for industries judged to be high in technological opportunity, and zero otherwise.\(^{10} \)

*Size/Scale Economies*

The classic version of the Schumpeterian Hypothesis is that the elasticity of the R & D-sales ratio with respect to sales is positive: if size doubles, R & D more than doubles (so that R & D per dollar of sales increases). We measure size by the natural logarithm of assets \( \log(\text{LBKAP}) \). A positive coefficient will support the Schumpeterian Hypothesis.\(^{11} \)

*Other Variables*

Our formal model offers no guidance on the impact of firm structure on R & D, because it is (by construction) a model of a firm that operates in a single industry. It is our judgment that the marginal cost of extending the model to consider explicitly diversification exceeds the marginal benefit. We instead rely on the arguments that appear in the literature.

The classic hypothesis concerning firm diversification and R & D is offered by R. R. Nelson [18], who suggests that more diversified firms will invest more intensely in R & D, all else equal, because they are more likely to be able to use the results of uncertain and unpredictable research projects.

We include two variables to test this hypothesis. The first is a Herfindahl index of the diversification of firm sales across industries \( \text{DIV75} \). Lower values of \( \text{DIV75} \) indicate that the parent firm is more diversified; on the Nelson argument, the coefficient of \( \text{DIV75} \) should be negative.

We also use a variable that is the fraction of LB sales in the firm — firm share \( \text{FS75} \). Martin [15] interprets firm share as an index of the allocation of the intangible assets of the firm across lines of business. The larger is firm share, all else equal, the less diversified the firm. On the Nelson argument, the coefficient of \( \text{FS75} \) should be negative. For reasons that are discussed below, it is actually the sum of the coefficients of \( \text{FS75} \) and \( \text{DIV75} \) that is relevant to the Nelson hypothesis.

**RESULTS**

We employ the line of business sample of Martin [15]. The sample consists of 2,297 lines of business, which are components of 424 firms and operate in 218 industries. The LB data is taken from the Federal Trade Commission's 1975 Line of Business Survey, which employs an industry classification scheme between the 4-digit SIC and the Imput-Output Table Detailed Industry classification in aggregation.
The estimates reported below are obtained by instrumental variables; variables followed by the superscript "E" are treated as endogenous. Ordinary least-squares estimates, which are similar, are available on request from the authors. The estimates reported below are for company-financed R & D. We have estimated the same specification for federal government financed R & D and for R & D financed by other sources. These results are also available on request.

When the model is estimated for the entire sample, the coefficient of $HTDUMMY$ is positive, as expected, and quite significant. This confirms the results of Scherer [22] on the importance of technological opportunity. To explore the role of technological opportunity further, we estimate the model separately for low technology ($HTDUMMY = 0$) and high technology ($HTDUMMY = 1$) industries.

Profitability/Market Structure/Entry Conditions

The coefficient of profitability is negative and statistically significant in all three samples. It is very much larger in magnitude and more significant in the high-tech subsample. These results do not support the "liquidity" theory of R & D. They do confirm the importance of conventional price competition as a spur to innovation, especially when the technological base exists to support innovation.

Lunn [12] has argued that technological opportunity and market power may be substitutes in the determination of R & D intensity. This will be the case if technological opportunity is a proxy for stronger property rights on innovation, while market power enables a firm to appropriate more completely the returns to innovation when property rights are not strong. In this case, one would expect market power to have a larger and more significant effect on R & D intensity in the low-tech sample than in the high-tech or pooled samples. Our results confirm this expectation.

Although industry advertising has the expected positive coefficient in the complete sample, with considerable statistical significance, this effect vanishes in the subsamples. This suggests that one industry characteristic that is captured by the low-tech/high-tech split is the potential for product differentiation: high-tech industries have more potential for product differentiation, whether through R & D or through promotional activity, than do low-tech industries. If so, the two dimensions of the technological environment singled out above have similar effects on R & D intensity.

Our results, like those of Comanor's [3] study, fail to show the expected reduction in research intensity when entry is more difficult. The coefficients of $MES$ are not statistically significant. $CDR$ has a negative and significant coefficient in the low-technology sample. An after-the-fact explanation for this unexpected result revolves around appropriability. When $CDR$ is larger, smaller firms are better able to compete with larger firms. This may mean that it is more difficult for larger firms to appropriate the benefits of their
own R & D. If this is the case, R & D intensity should be less when CDR is greater. This is what the low-tech sample results show.

**Firm Structure**

The coefficient of LB firm share is negative, as predicted by the Nelson diversification hypothesis: the smaller is the LB in the firm, the more diversified is the firm and the more likely are the results of LB R & D to find a home somewhere in the parent company. R & D intensity should rise as firm share falls, which is the case.

The coefficient of parent firm diversification is positive. This contradicts the Nelson hypothesis, but not as strongly as first appears. The Nelson hypothesis really refers to the impact of firm diversification on firm R & D. We have estimated the effect of firm structure on LB R & D:

\[
R_{ij}/S_{ij} = \alpha FS_{ij} + \beta DIV_i + \ldots .
\]

Here \( R_{ij} \) is the expenditures of the division of firm \( i \) in industry \( j \) on R & D, \( S_{ij} \) is the sales of firm \( i \) in industry \( j \), \( FS_{ij} \) is the share of industry \( j \) sales in firm \( i \) sales, and \( DIV_i \) is a Herfindahl index of the diversification of firm \( i \) sales across industries. Thus,

\[
FS_{ij} = S_{ij}/S_i \quad DIV_i = \sum_{j=1}^{n_i} (FS_{ij})^2,
\]

where \( S_i \) is total firm \( i \) sales and \( n_i \) is the number of industries in which firm \( i \) operates.

To infer the effect of firm diversification on firm R & D, multiply (5) by \( FS_{ij} \) and sum over all divisions of the firm; the result is

\[
R_i/S_i = (\alpha + \beta)DIV_i + \ldots ,
\]

where the omitted variables are now weighted averages over the divisions of the firm.

It follows that the appropriate test for the effect of firm diversification on firm research intensity involves the sum of the coefficients of \( FS75 \) and \( DIV75 \) from the Table. These sums are positive for the complete sample and the high-tech sample, and negative for the low-tech sample, but insignificantly different from zero in each case.\(^{15}\)

**Demand/Related Markets**

Unexpectedly, the growth rate of industry sales has no significant effect on research intensity. \( IMSR \) and \( EXSR \) have coefficients of the expected sign. The estimated coefficients of \( EXSR \) are particularly large and significant.\(^{14}\)

The four demand-share variables, \( CONS, FEDSR, SLSR, \) and \( IND \), sum to one. To avoid perfect collinearity with the constant term, \( IND \) was omitted in estimation. Following the arguments of D. B. Suits [30], the
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coefficients of the four demand-share variables have been renormalized so that they sum to zero. The coefficients of the demand share variables indicate deviations from average R & D intensity over each sample, not from a base implied by an omitted variable.

As expected, the coefficients of \( \text{IND} \) and \( \text{FEDSR} \) are negative, suggesting that the products of industries that sell largely to these classes of customers are less susceptible to differentiation on that account. It should be mentioned that \( \text{FEDSR} \) has a large, positive, and highly significant coefficient when federal-government-financed R & D per dollar of sales is the dependent variable. This suggests that federal-government-financed R & D is to some extent a substitute for company-financed R & D.

Also as expected, the coefficient of \( \text{SLSR} \) is positive, and statistically significant. This is especially the case for the high-technology sample. Unexpectedly, the coefficients of \( \text{CONS} \) are significantly negative. Martin [15] reports that \( \text{CONS} \) has positive effects on both advertising and nonadvertising sales efforts. This suggests that for consumer good industries, product differentiation occurs more through marketing than through the development of new products.

On balance, the results for the buyer and supplier market structure variables support Farber's bargaining-power arguments; there are some
inconsistencies. BCR4 has a negative effect on R & D in each subsample. In the low-tech subsample, the coefficient is just short of statistical significance at the 10 percent level. BDISP has a negative and significant coefficient in the low-tech sample, but its coefficient in the high-tech sample is unexpectedly positive and significant. Concentration in buying markets thus has the predicted effects in the low-tech sample. SCR4 has the expected negative effect in the high-tech sample, while the coefficient of SDISP is not statistically significant. Supplier concentration has the expected effect in the high-tech sample. While the coefficient of SDISP is negative, as expected, for the low-tech sample, SCR4 has an unexpectedly positive and significant coefficient.

Farber's results suggest that interactions between related market concentration and own-market concentration might eliminate the anomalous results. Constraints on computer time prevent us from exploring this possibility.

**Size**

The estimated coefficients of \( \text{LOG(LBKAP)} \) are positive and highly significant. All else equal, large LBs invest more per dollar of sales than smaller LBs. The estimated elasticities of company financed R & D per dollar of sales with respect to LBKAP are 0.1939, 0.1605, and 0.1561 for the complete sample, the low-tech sample, and the high-tech sample, respectively (with LBKAP evaluated at the sample mean). These results support the Schumpeterian Hypothesis; in terms of our formal model, they are consistent with the existence of economies of scale in the R & D process.

**CONCLUSION**

More than anything else, our results demonstrate the complexity of industrial research and development.

As suggested by Schumpeter, larger LBs invest more per dollar of sales than otherwise identical smaller LBs. Market power — as evidenced by market share and market concentration — is conducive to R & D, among industries that are low in technological opportunity.

But it is the absence of profit — the spur of competition — that also stimulates investment in R & D, especially in high technology industries. Among such industries, market power is of little importance for R & D. Although our sample shows the effects that Schumpeter expected for size, it also shows the importance of conventional competition as a motive for investing in R & D.

We find no strong effect of firm diversification on firm R & D. There is some evidence, albeit mixed, that LBs that buy from or sell to concentrated industries invest less heavily in R & D than would otherwise be the case.
Methodologically, our results suggest that the results of studies that employ ordinary least squares are robust to the use of simultaneous equations techniques.

NOTES

* The representations and conclusions presented herein are those of the authors and have not been adopted in whole or in part by the Federal Trade Commission, its Bureau of Economics, or any other entity of the Commission. The Manager of the Line of Business Program has certified that he has reviewed and approved the disclosure avoidance procedures used by the staff of the Line of Business Program to ensure that the data included in this article do not identify individual company line of business data.

1. The model can be generalized to a dynamic world in which it is stocks of accumulated advertising and R & D that influence the demand and cost functions. The qualitative nature of the results of the model do not change; we follow Kamien and Schwartz [7, p. 53] and let the available data guide the nature of the analysis.

2. It is possible to write down a model in which process R & D and producer R & D are distinct variables. It is not obvious that this dichotomy exists in the real world; it certainly does not exist in our data set.

3. For a careful discussion, see Kohn and Scott [9].

4. The final right-hand side term and the left-hand side term in (4) may be combined to obtain a "reduced-form" solution for the R & D-sales ratio; (4) seems easier to interpret.

5. Martin [16] discusses the use of the price-average-cost margin as a measure of profitability.

6. Scherer [25] found that concentration positively affected productivity, which suggests that firms with large market shares are able to appropriate a large share of the benefits of cost-reducing innovation.

7. It should be noted that Comanor's empirical tests did not support the argument quoted earlier; he found the incentive to invest in R & D low for both low and high entry barriers, but high when entry was moderately impeded [3, pp. 655-56].

8. Recent empirical studies suggest that Schmookler's focus was too narrow [24, 30].


10. LBs in the chemical, electrical, electronic, and metallurgical industries were assigned \( HTDUMMY = 1 \), and all others \( HTDUMMY = 0 \). The precise FTC industry codes are available on request.

11. For more complete discussions, see Fisher and Temin [5], Kohn and Scott [9], and Lunn [11].

12. Instruments include all exogenous and predetermined variables of the five-equation system estimated by Martin [15], plus lagged endogenous variables. In the belief that the underlying, reduced-form equations are probably nonlinear in nature, and following Kelejian [8], squares and cross-products of several exogenous variables were also used as instruments.

13. The t-statistics for the complete, low-tech, and high-tech samples are 0.2110, 0.4297, and 0.8988, respectively.

14. These coefficients may reflect another phenomenon. Recent work in
international trade (Koo and Martin [10]) suggests that the United States has a comparative advantage in commodities that involve considerable research activity. The coefficients of IMSR and EXSR in the Table may reflect this comparative advantage.

REFERENCES


