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ABSTRACT

Using data from the Federal Trade Commission's Line of Business Program and survey measures of technological opportunity and appropriability conditions, this paper finds that overall firm size has a very small, statistically insignificant effect on business unit R & D intensity when either fixed industry effects or measured industry characteristics are taken into account. Business unit size has no effect on the R & D intensity of business units that perform R & D, but it affects the probability of conducting R & D. Business unit and firm size jointly explain less than one per cent of the variance in R & D intensity; industry effects explain nearly half the variance.

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I. Introduction

Two sets of well-known hypotheses are associated with the later work of Joseph Schumpeter. The first concerns the effects of market concentration on research and development investment and on innovative performance. The second bears on the effects of firm size on R & D and innovation. In a recent paper (Levin, Cohen, and Mowery [1985]), we re-examined the first set of hypotheses. Simple regressions at the line of business level replicated the established findings that both R & D intensity and innovative performance first increase and then decrease as industrial concentration rises. The effect of concentration, however, was sharply attenuated when we controlled for interindustry differences in technological opportunity and in the appropriability of returns from new technology. Our results suggested that it is probably unwarranted to conclude that market concentration favors R & D investment and innovation.

In this paper we investigate the Schumpeterian hypothesis that large size is conducive to R & D investment. This relationship has been studied at least as intensively as the link between concentration and R & D, but our approach is novel in two respects. First, using data collected by the Federal Trade Commission's Line of Business Program, we are able to distinguish scale effects associated with the business unit from those associated with the size of the firm as a whole. Second, survey data collected by Levin, Klevorick, Nelson, and Winter [1984] and used in our previous paper allow us to control for previously unmeasured differences in technological opportunity and appropriability across lines of business.

We find little support for Schumpeter. Without close attention to the data it would appear that the size of the firm as a whole, though not the size of the business unit, has a significant but small positive effect on the R & D intensity of business units. When a mere handful of outliers is removed from the sample, we find that controlling for interindustry differences eliminates the apparent influence of firm size. Business unit and firm size jointly explain only a negligible fraction of the variance in R & D intensity among business units that perform R & D. Fixed industry effects, however, explain nearly half the variance in R & D intensity, and, in turn, measured industry characteristics explain about half the variance explained by these industry effects. Only one size-related effect withstands scrutiny. Although neither measure of size influences the behavior of R & D performers, business unit size does affect the probability of conducting R & D.

II. Motivation

The hypothesis set forth rather imprecisely by Schumpeter [1950] and more sharply by Galbraith [1957] is that in a mature capitalist economy large firms generate a disproportionately large share of society's technological advances. Several arguments have been offered in support of this hypothesis. One claim is that capital market imperfections confer an advantage on large firms in securing finance for risky R & D projects, because size is correlated with the availability and stability of internally-generated funds. A second claim is that there are scale economies in the technology of R & D. Another is that the returns from process R & D are higher where the innovator has a large volume of sales over which to spread the fixed costs of innovation. Finally, R & D is alleged to be more productive in large firms as a result of complementarities between R & D and other nonmanufacturing activities (e.g. marketing and financial planning) that may be better developed within large firms.

Each of these claims depends on assumptions about the nature and magnitude of transaction and adjustment costs that are rarely tested. Two other objections, however, are more germane to an assessment of the validity of the empirical evidence.

First, the arguments supporting Schumpeter's hypothesis are usually offered without adequate attention to the appropriate unit of analysis. The argument about capital market imperfections, for example, predicts a relationship between innovation and overall <u>firm</u> size. The fixed cost argument, by contrast, concerns the volume of a particular product or product line and hence predicts a relationship more likely to be observed at the level of the <u>business unit</u>. The R & D scale economies and the complementarity arguments may be applicable at either the firm or the business unit level, or both, depending on the nature of the relevant economies of scale and scope.

Second, the relationship between size and innovation may vary across industries with different technologies and market conditions, a possibility largely ignored by the arguments advanced in support of Schumpeter. Interindustry differences in technological opportunities and in the appropriability of returns from R & D investment may, for example, influence the degree to which size confers advantages or disadvantages. Indeed, a spurious statistical connection between R & D and size may arise as a consequence of failure to take adequate account of interindustry differences.

These two shortcomings -- inadequate attention to the unit of analysis and to industry effects --

pervade the extensive empirical literature on the relationship of size and R & D investment. In nearly all the studies reviewed by Scherer [1980] and Kamien and Schwartz [1982], both size and R & D have been measured at the firm level. When industry characteristics have been studied, the multiproduct character of large firms has been commonly ignored. Typically each firm is assigned to a "primary" industry and assumed to face conditions in all product markets identical to those prevailing in its primary industry.

Despite these methodological problems, there existed until recently a tentative "consensus" on the stylized facts concerning size and R & D. As summarized by Scherer and by Kamien and Schwartz, this consensus view held that firm size is associated with increasing R & D intensity up to some threshold (near the bottom of the Fortune 500). Among larger firms, R & D intensity does not increase, and it may even decline, with the possible exception of firms assigned to the chemical industry.

Recent work has cast doubt on the basis for this consensus. Employing data from the Federal Trade Commission's Line of Business Program for 1974, Scherer [1984] found "mild support" (p. 233) for the position that business unit R & D intensity increases with business unit size. A different dissenting note was sounded by Bound et al. [1984]. Using a larger and more comprehensive sample of American firms than any previously employed to study the size R & D relationship at the firm level, and implicitly assuming firms to be single product entities, they found that R & D intensity first falls and then rises with firm size. Thus, both very small and very large firms appeared to be more R & D intensive than those intermediate in size.[1]

This paper does not provide a definitive test of Schumpeter's hypothesis concerning innovative performance and size. We have data on R & D investment only and no adequate measure of innovative output (see Fisher and Temin [1973]). Our primary purpose is descriptive; we seek to establish more clearly whether size is systematically related to R & D intensity by examining the effects of both business unit size and firm size, and by controlling for interindustry differences in market structure, demand conditions, technological opportunity, and appropriability. An ancillary purpose is to assess whether available measures of industry conditions -- recently augmented by the survey research of Levin et al. -- explain a substantial fraction of interindustry variation in R & D intensity.[2]

III. The Data

Data on R & D expenditures, business unit size, and firm size were obtained from the Federal

Trade Commission's Line of Business program. Our sample includes 2,494 business units in 244 manufacturing lines of business operated by 345 firms. We excluded all firms in the FTC database that operate mainly in regulated industries, and we excluded firms with obvious intertemporal inconsistencies in reporting methods or other obvious reporting errors.[3] All business units operating outside the manufacturing sector, and those that were not continuously active during the period 1974-1977, were excluded as well.

The FTC data have certain limitations. Foreign activities of the sample firms are not reported, distorting our measure of R & D intensity for business units that do disproportionate amounts of their worldwide R & D in the United States. The FTC sample is drawn almost entirely from the 1000 largest firms in the economy, as measured by domestic sales of manufactured products. Nonetheless, the data have overwhelming advantages for our purposes. They represent the only available, reliable, disaggregated data on R & D expenditures,[4] and they allow us to distinguish between business unit size and firm size. Although large firms are overrepresented, the sample contains business units of all sizes.[5]

The three variables of primary interest were taken from the FTC data: (1) company-financed R & D expenditures (RDI) expressed as a percentage of business unit sales and transfers over the period 1975 through 1977, (2) business unit sales and transfers (BUSALES), measured in billions of dollars and averaged across 1974-1976, and (3) firm sales (FIRMSALES), also measured in billions of dollars and averaged across 1974-1976. Averages were employed to control for differences in the impact and timing of business cycles across industries. The size variables were lagged one year to reflect the fact that R & D funds are usually budgeted many months before they are spent.

Data on industry conditions were drawn from several sources. As in our 1985 paper, we use variables intended to capture three dimensions of technological opportunity: closeness to science, the importance of external sources of technical knowledge, and industry maturity. Using the Levin et al [1984] survey, we measure closeness to science with responses to questions concerning the relevance of eleven fields of basic and applied science.[6] We calculate for each line of business the mean of the responses (on a seven-point Likert scale) for each field of science.[7] We summarize this information with the variable, SCIENCEBASE, which represents for each line of business the maximum of the mean scores received (on a seven-point Likert scale) by a field of science. The survey also asked respondents to evaluate the importance (on a seven-point scale) of the contributions of various external sources to technical progress within each line of business. We consider four such sources here: upstream suppliers of raw material and equipment (MATERIALTECH and EQUIPTECH, respectively), downstream users of the industry's products (USERTECH), and government agencies and research laboratories (GOVTECH). Industry maturity may also affect opportunity conditions. A variable intended to reflect the relative maturity of an industry's technology, NEWPLANT, measures the percentage of an industry's property, plant, and equipment installed within the five years preceding 1977, as reported to the FTC's Line of Business Program.

Appropriability conditions are measured with two indices derived from the Levin et al. survey. Respondents were asked to rate (on a seven-point scale) the effectiveness of six mechanisms used by firms to capture and protect the competitive advantages of new processes and new products.[8] APPROPRIABILITY is the maximum of industry mean scores received by any one of these mechanisms for either process or product innovations. The survey also asked respondents to report for their line of business the range of imitation costs and time lags for major and minor, process and product, and patented and unpatented innovations. These measures tend to be highly correlated with one another, though they are not highly correlated with APPROPRIABILITY. We use here the average number of months required to duplicate a patented, major product innovation (IMLAG).

In the absence of an explicit structural model, prior expectations about the effects of the opportunity and appropriability variables are ambiguous. Greater opportunity should increase innovative output. To the extent that the contributions of external science, upstream suppliers, downstream users, and the government substitute for a firm's own R & D effort, however, these opportunity variables may be inversely related to R & D intensity. Appropriability may also have ambiguous effects on R & D incentives, as recent theoretical work has emphasized (Cohen and Levinthal [1986]).

Many previous studies of R & D have attempted to control for demand conditions, on the assumption that market growth increases the returns to investment in R & D. Typically, sales growth is used as an unsatisfactory proxy for growth in demand. We represent industry demand conditions with estimates developed by Levin [1981] of price elasticity (PELAS), income elasticity (INCELAS), and a time shift parameter (DGROWTH). These estimates were derived from consumer demand functions estimated by Almon et al. [1974] and the input-output tables.[9] We expect demand growth and income elasticity to be positively associated with R & D intensity, but the expected impact of price elasticity is ambiguous. Elastic demand should provide a positive incentive to investment in cost-reducing process R & D, since the returns from lowering cost are greater if demand is elastic. On the other hand, inelastic demand should encourage product R & D by magnifying the returns to a righward shift in the demand curve.

Market structure is measured with four-firm concentration ratios at the four-digit SIC level taken from the 1977 Census of Manufactures. When necessary, these concentration ratios are aggregated to the LB level using the value of shipments as weights.

Our effort to control for measurable interindustry differences in opportunity, appropriability, demand, and market structure restricts the size of our sample. The Levin et al. survey data are available for only a subset of the lines of business included in the FTC database. For much of the work reported in this paper, therefore, our sample is reduced from 2,494 business units, representing 345 companies in 244 lines of business, to 1,719 business units, representing 318 companies in 151 lines of business.

Within both of these samples, a significant minority of business units reported no R & D expenditures in at least one year from 1975 through 1977. As explained in the next section, for some purposes we employ samples containing only business units that performed R & D over the entire period. Table I indicates the composition of each of the samples that we used, and Table II presents descriptive statistics on the size and R & D variables for each sample. Firms and business units tend to be somewhat larger, and R & D intensity somewhat higher in the lines of business covered in the Levin et al. survey. Also, business units performing R & D are on average larger than those that do none, and tend to be operated by larger parent firms.

IV. Specification and Estimation

We begin by estimating simple regressions of R & D intensity on size. We then proceed to control for interindustry differences using fixed industry effects and, subsequently, measured industry characteristics.

Since business unit sales are a component of the sales of the firm, our benchmark specification is:

$$\text{RDI} = \alpha_1 + \alpha_2 \text{BUSALES} + \alpha_3 \text{OTHERSALES} + e, \tag{1}$$

where OTHERSALES is defined as the difference between FIRMSALES and BUSALES. With this specification we can test all hypotheses of interest. If business unit size alone affects R & D intensity, then we should be able to reject the hypothesis that $\alpha_2 = 0$, but should not reject $\alpha_3 = 0$. If the size of the firm as a whole is all that matters, then $\alpha_2 = \alpha_3$, but we should be able to reject the hypothesis that these coefficients are jointly equal to zero. If business unit and firm size have independent effects on R & D, we should be able to reject the hypotheses that $\alpha_2 = 0$, that $\alpha_3 = 0$, and that $\alpha_2 = \alpha_3$. If neither business unit nor firm size affects R & D intensity, then $\alpha_2 = \alpha_3 = 0$. Finally, if the scale of a firm's activities outside the business unit influences R & D intensity, but business unit size does not, then we should be able to reject both $\alpha_3 = 0$ and $\alpha_2 = \alpha_3$, but not $\alpha_2=0$.[10] By a straightforward extension, we can estimate the quadratic variant of specification (1) by squaring each variable and adding an interaction term. We can then test all hypotheses concerning the possible nonlinearity of size effects.

Two statistical issues required attention: the boundedness of the dependent variable and the possible heteroscedasticity of the disturbances.

As Table II indicates, only 72 per cent of the business units in our unrestricted sample and 76 per cent of those in our restricted sample performed R & D throughout the period 1975-77. If we follow the prevailing practice in the literature on Schumpeter's hypothesis and estimate specification (1) and its variants on samples that include only performers of R & D,[11] the truncation of the error term will bias the resulting parameter estimates. The Tobit model (Tobin [1958]) avoids this problem at the cost of restricting the way in which the explanatory variables simultaneously determine the probability of engaging in R & D and the amount of R & D spending. We thus present Tobit estimates of (1) using all available observations in each of our samples. To permit comparison of our results with prior studies, we also report OLS results for R & D performers only.

Reported Tobit and OLS coefficient estimates are not directly comparable. As McDonald and Moffitt [1980] demonstrate, a Tobit coefficient can be interpreted as a weighted average of two effects: (1) the effect of an increase in an independent variable on the probability that the dependent variable exceeds the limit (in our case, that R & D is greater than zero) and (2) the effect on the expected value of the dependent variable, given that it is above the limit. The magnitude of these effects depend on the values of the independent variables; as they grow large, the second effect converges to the value of the Tobit coefficent and the first effect goes to zero. OLS regression on a sample restricted to observations above the limit provides an estimate of the second effect, but OLS imposes a constant slope where the Tobit model implies a nonlinear response. Moreover, the OLS estimate is biased because the expected value of the truncated error term is positive. We can, nonetheless, assess the extent of this bias by using the decomposition of the Tobit coefficients proposed by McDonald and Moffitt.

A problem arises when we wish to control for industry effects using the Tobit estimator. We have 2,494 observations distributed over 244 industries. The average number of observations per industry is small, reflecting in many cases a characteristic of the population as well as a characteristic of the sample. In principle, we would like to obtain estimates of the coefficients on the size variables that are consistent as the number of industries tends to infinity, holding the number of observations per industry fixed. In the linear regression framework, least squares estimates of the fixed effects model have this consistency property. As Chamberlain [1980] has shown, however, in a nonlinear probability framework (such as the Tobit model), maximum likelihood estimates of the fixed effects model are inconsistent.

This problem could potentially undermine our efforts to explore the robustness of the size-R & D relationship to the inclusion of industry effects, as well as our efforts to compare the performance of measured industry characteristics against fixed effects. We can, however, use the Tobit model to obtain consistent estimates for specifications including measured industry characteristics, although it remains to determine whether measured industry characteristics are a reasonable substitute for fixed industry effects. Decomposing the Tobit coefficients, we can assess the direction and magnitude of bias in least squares estimates obtained from the sample of R & D performers. This information should yield insight concerning the validity of inferences drawn from comparing the performance of fixed effects and measured characteristics in the least squares framework.

Breusch-Pagan tests revealed no heteroscedasticity in specifications that included only size measures. When measured industry characteristics were included among the explanatory variables, however, we typically rejected the hypothesis of homoscedasticity. After some experimentation, we found the error structure in these specifications to be best described by the model of "multiplicative heteroscedasticity," in which the logarithm of the error variance is a linear function of the exogenous variables and the number of respondents to the Levin et al. survey questions in the relevant industry. We thus followed the procedure suggested by Harvey [1976] to obtain asymptotically efficient GLS estimates of the parameters.[12] Breusch-Pagan statistics were calculated for each specification estimated by GLS, and in no case could we reject homoscedasticity at the .05 level.

V. Results: The Effects of Size on R & D Intensity

For comparability with previous findings, we first report results obtained using two samples of R & D-performing business units. The first sample contains all R & D performers in our full set of 244 manufacturing lines of business; the second sample is limited to R & D performers in the 151 lines of business covered by the Levin et al. survey. Columns (1) and (3) of Table III display the results of simple regressions of R & D intensity on our two size variables. Columns (2) and (4) present the results of regressions of R & D intensity on the two size variables and industry fixed effects. Comparing columns (1) to (3), and (2) to (4), we see that the two samples produce very similar ordinary least squares estimates for comparable specifications.

The results in columns (1) and (3) support rejection of the hypothesis that α_2 and α_3 are jointly zero, but the hypothesis of equality of these two coefficients cannot be rejected. This pair of tests indicates that the size of the firm as a whole, but not business unit size, affects R & D intensity. Although the joint effect of both size measures is statistically significant, only one per cent of the variance in business unit R & D intensity is explained. Moreover, the magnitude of the firm size effect is small. The coefficient of OTHERSALES reported in column (1) implies that firm size must increase by 17 billion dollars to increase R & D intensity by one per cent of sales. Alternatively, doubling the size of the mean firm in our sample would produce an increase in R & D intensity of less than two-tenths of one per cent. There is no evidence of a nonlinear size-R & D relationship.[13]

The hypothesis that firm size alone influences business unit R & D intensity is further supported in the fixed effects regressions reported in columns (2) and (4) of Table III. The coefficient of OTHERSALES falls somewhat when fixed industry effects are included, but it remains statistically significant in both samples. The coefficient of BUSALES remains insignificant, but it becomes positive and moves much closer to the OTHERSALES coefficient, strengthening the conclusion that the size of the firm as a whole (BUSALES plus OTHERSALES) affects R & D intensity. Nevertheless, industry effects appear to be far more important than firm size; they explain nearly half the remaining variance in business unit R & D intensity.

To test the sensitivity of the results in Table III to outliers, we excluded those observations with large absolute residuals. Over a wide range of cutoff values, this procedure produced no change in our qualitative conclusions and only small changes in the estimated coefficients.

We also tested for systematic differences in the size-R & D relationship across industries. Since many lines of business contain few observations, estimation of separate slopes for each industry at the FTC line of business (LB) level was infeasible. Instead, while retaining LB-level fixed effects, we estimated separate size-related slopes for each two-digit industry.[14] The hypothesis of the homogeneity of the slopes across two-digit industries could not be rejected in either sample. In only six industries, however, was the influence of OTHERSALES on R & D intensity statistically significant in one or both samples. These six industries were printing and publishing (SIC 27), stone, clay, glass and cement (SIC 32), fabricated metal products (SIC 34), machinery (SIC 35), electrical equipment (SIC 36), and motor vehicles (SIC 37). The apparent absence of significant size effects in two-thirds of the two-digit industries suggested that our new "stylized fact" was fragile.

To probe further we looked carefully for outliers within each of these two-digit industries. A distinctive pattern appeared. Five of the six industries contained a total of seven outlier observations with a common characteristic. In each case a very large firm, much larger than typical for the particular line of business, had an uncharacteristically high R & D intensity. These firms were among the very largest in the manufacturing sector, and although the specific business units involved were not especially large for the relevant lines of business, the value of OTHERSALES was in each instance at least $2.78 billion above the mean for the line of business. There were three such observations in fabricated metals (SIC 34), and one each in SICs 27, 32, 35, and 36. Although the particular reasons for the exceptionally high R & D intensity differed, some form of measurement error is suggested in each instance. Two of the outliers appear to be the artifact of an excessively broad four-digit industry definition; these two business units manufacture products that are quite distinct from those supplied by others in the same line of business. Two other outlying business units produce inputs to downstream products manufactured by their parent companies. Their atypically high R & D intensities may result from understated transfer prices or from the method of allocating R & D between intermediate and final product. A similar case seems to involve the allocation of R & D among complementary final products. Finally, the two remaining outliers represent business units that sell military products. Their atypically high company-financed R & D expenditures may reflect the common practice of including "independent R & D" (IR&D) funds reimbursed by the Pentagon, or they may, alternatively, result from the behavior described by Lichtenberg [1986], where government contractors signal their ability to perform by privately financing R & D.

Deleting these seven observations from our sample of 1,797 (and deleting the five of these that appear in our restricted sample of 1,302 observations) dramatically altered the results. The statistical significance of OTHERSALES vanished within each of the five two-digit industries from which outliers were omitted, despite the fact that only one observation was deleted from four of these industries.

Furthermore, across all two-digit industries, tests of the joint significance of the size-related coefficients produced F-statistics below 1.0, as did tests on the homogeneity of the slopes across all two-digit industries.[15]

Table IV displays the results of deleting these few outliers and re-estimating the specifications reported in Table III. In each case the coefficient of OTHERSALES is approximately halved, and it remains significant at the .05 level only in the larger sample prior to the inclusion of industry effects. Even in this last instance, however, the hypotheses that α_2 and α_3 are jointly zero cannot be rejected at the .05 level. Moreover, the modest share of the variance in R & D intensity that is explained by the two size variables falls to less than one-third of one per cent when the outliers are removed.[16]

Table V displays maximum likelihood estimates of the Tobit specification of our simple benchmark equation with the outliers removed. Using a Tobit estimator, and adding nearly 700 observations on business units with no reported R & D, does not alter the qualitative results. Though insignificant, the coefficient of BUSALES turns positive, presumably reflecting fact that R & D - performing business units within this sample are slightly larger on average than nonperformers. The coefficient of OTHERSALES remains statistically significant in the more inclusive sample and insignificant in the smaller sample.

From a decomposition of the Tobit coefficient estimates, we find that, at the sample means of BUSALES and OTHERSALES, less than one-half of the total response of R & D to an increase in OTHERSALES is attributable to an increase of R & D by business units above the threshhold; the remainder is attributable to an increased probability of performing R & D. To be more precise, at the means of both size variables in our more inclusive sample, the R & D intensity of performers rises by .018 per cent per billion dollars of OTHERSALES. The OLS estimate from column (1) of Table IV of this same response is .032. Thus, there appears a modest upward bias in our OLS estimates of the effect of firm size on R & D intensity within the sample of R & D-performing business units. The robustness of this last inference is confirmed when we calculate the Tobit estimate of the R & D response of business units above the threshhold at values of OTHERSALES that bracket the vast majority of observations in our sample. Maintaining BUSALES at its sample mean and allowing OTHERSALES to vary from one per cent of its sample mean to ten times its mean, we find that estimates of the R & D response of performers range from .0175 to .0215. We conclude that over the relevant size range our OLS results overstate the effect of firm size on R & D intensity among R & D performers.

We next consider how the use of measured industry characteristics affects our conclusions about the size-R & D relationship. We defer discussion of the performance of these industry characteristics to the next section and focus here on the coefficients of the two size variables. Table VI presents Tobit, OLS, and GLS results for the smaller of our two samples. In this sample, once outliers were removed, size effects were absent in both the simple and fixed effects specifications.

The OLS estimates in column (2) of Table VI contain no evidence of size effects in the sample of R & D performers. Indeed, the coefficients of BUSALES and OTHERSALES are almost identical to the fixed effects estimates reported in column (4) of Table IV. The coefficient of OTHERSALES, however, is sensitive to the heteroscedasticity correction in the sample of R & D performers, as shown in column (3) of Table VI. The coefficient of OTHERSALES more than doubles, and it becomes significant at the .01 level. This anomaly results from the heteroscedasticity correction. The size variables receive little weight in the auxiliary equation. Instead, the survey variables reflecting technological opportunity, notably SCIENCEBASE, receive the greatest weight because the largest residuals occur disproportionately in industries with very high technological opportunity. Observations from high opportunity industries thus receive less weight in the GLS equation, and firm size becomes significant. The result hints that if firm size matters at all, it matters in low opportunity industries.[17]

The Tobit results in column (1) of Table VI reinforce the conclusion that the effect of OTHERSALES is insignificant. At the sample means of all variables, just over half of the reported Tobit coefficients represents the effect of the independent variables on the R & D intensity of performers. Thus, the insignificant OLS coefficient once again overestimates the effect of firm size on R & D intensity.

Contrary to all previously reported results, BUSALES has a significant positive effect in column (1) of Table VI. At the means of the independent variables, the estimated response of R & D performers to BUSALES is, however, identical to the comparable OLS coefficient estimate in column (2).[18] This suggests that the significance of BUSALES in the Tobit specification may be attributable to its influence on the probability of conducting R & D. To explore this possibility, we estimated probit equations using the explanatory variables from both our simple specification and the specification including the measured industry characteristics.[19] The effect of business unit size on the probability of conducting R & D was positive and significant at the .01 confidence level in both specifications. The coefficient of OTHERSALES was insignificant.

VI. Further Results: Fixed Effects vs. Measured Industry Characteristics

Table VI reveals that measured industry characteristics perform well as substitutes for industry fixed effects. In the OLS specification estimated on the restricted sample of R & D performers, industry characteristics explain 23.4% of the variance in business unit R & D intensity beyond that explained by size alone. This represents 48% of the incremental variance explained by industry fixed effects, with great economy in the use of parameters (11 instead of 151). In addition, about 50% more variance is explained by measured industry characteristics than by fixed two-digit industry effects.

Most of the industry characteristics are individually significant at conventional levels. In the OLS version, only the contribution of raw material suppliers (MATERIALTECH) is insignificant. The remaining opportunity variables are significant at the .01 level in all three equations, with the exception of SCIENCEBASE in the Tobit variant. The appropriability variables have a substantial impact on R & D intensity. Our demand growth measure performs rather poorly, but the price and income elasticity terms are significant in all three equations. Wald tests of the joint significance of the vectors of opportunity, appropriability, and demand variables, each compel rejection of the null hypothesis by all three methods of estimation.[20]

One widely employed industry characteristic, seller concentration, is excluded from the specification estimated in Table VI. As in Levin et al [1985], the coefficient of this variable is statistically insignificant in nearly all specifications reported in this paper. It is always insignificant when concentration appears along with our size measures as the only industry characteristic. All principal results concerning the the significance and importance of size and industry characteristics hold whether or not concentration is included in the specification.

There are insufficient degrees of freedom to test the homogeneity of the coefficients of the industry characteristics across two-digit industry groups, since there are not enough lines of business in most two-digit industries. Nonetheless, we investigated the performance of the measured industry characteristics within those two-digit groups with enough lines of business to support the specification. These include food (SIC 20), chemicals (SIC 28), machinery (SIC 35), and electrical equipment (SIC 36). These four two-digit industries respectively contain 21, 16, 24, and 16 lines of business. Together, they account for 77 of the 151 lines of business and 728 of the 1,297 R & D-performing business units in the restricted sample. The groups differ markedly in their opportunity and appropriability conditions. Food processing industries tend to score relatively low on survey measures of both opportunity and appropriability. Chemical industries score relatively high on both. Electrical equipment has high opportunity, but appropriability is average or below average. The machinery industries are more difficult to summarize; there is considerable heterogeneity within the two-digit group.

As noted previously, fixed effects regressions within each of these industrial groups produced no evidence of size effects after outliers were removed. Substituting measured industry characteristics for fixed effects, we estimated a Tobit equation for all business units within each two-digit group, and OLS and GLS equations on the R & D performing business units. With the exceptions noted below, the qualitative results on the influence of the two size variables were insensitive to the estimation technique. The Tobit estimates of the coefficients of the measured industry characteristics were generally less significant than the GLS or OLS estimates, but tests of the joint significance of each category of industry characteristics were largely identical.[21] Thus, we confine attention to the GLS estimates presented in Table VII.

Table VII indicates that firm size is insignificant in all four two-digit industries. Business unit size is however, negatively related to R & D intensity in the food processing industries. This result, however, is not robust; BUSALES is insignificant in the OLS and Tobit equations for food processing. Business unit size appears to be positively related to R & D intensity in the machinery industries (although not in the OLS estimates), but this result is driven by the historical anomaly of classifying electronic computing equipment as nonelectrical machinery. When a dummy variable is substituted for measured characteristics in the computer industry alone, the coefficient on BUSALES becomes insignificant.

The measured industry characteristics perform best in the chemical industries, where the vectors of opportunity, appropriability, and demand variables are each jointly significant at the .05 level or better. The opportunity variables do reasonably well in machinery and electrical equipment, but most of the appropriability and demand variables fare poorly outside the chemical industries. One exception is electrical equipment where short imitation lags appear to spur R & D investment.

Table VIII summarizes our results concerning the explanatory power of size, fixed industry effects, and measured characteristics. Both within and across two-digit industries, firm and business unit size explain very little of the variance in business unit R & D intensity. In chemicals, machinery, and electrical equipment, as well as across industries, both measured industry characteristics and fixed effects explain a substantial fraction of additional variance. Across all industries, the 11 measured industry characteristics capture nearly half the variance explained by 151 fixed effects, and capture between 78 and 86 per cent of the variance explained by fixed LB-level industry effects within the two-digit chemical, machinery and electrical equipment sectors.

The performance of measured industry characteristics may also be judged by how well they explain the between-industry variation in business unit R & D intensity. By regressing the LB-level means of R & D intensity against measured industry characteristics, we explain about one-third of this between-industry variation, whether or not we control for the effects of size. If we restrict attention to the 80 lines of business in which there were at least three responses to the Levin et al. survey questionnaire, thus reducing the likely magnitude of measurement error in the survey variables, industry characteristics account for 56 per cent of the between-industry variation in business unit R & D intensity.

VII. Conclusions

Our investigations of the FTC Line of Business data reveal that, among business units that perform R & D, there is no significant relationship between size and R & D intensity once care is taken to separate the influence of business unit and firm size, to control for interindustry differences in the R & D investment environment, and to remove outliers from the data. Once outliers are removed, a simple regression of R & D intensity on size measures alone suggests that the size of the firm is positively associated with business unit R & D intensity, although the effect is quite small. This result, however, appears only in the larger of our two samples, and it vanishes entirely once we control for industry effects. Moreover, the magnitude of the effect of either firm size or business unit size upon the R & D intensity of R & D performing business units is always minute, regardless of the associated significance level, or the sample or estimation technique employed. We also find that although business unit size exercises no influence on the R & D conducted by R & D performers, it does influence the probability of engaging in R & D.

Our results also suggest that previous findings supporting the connection between overall firm size and R & D intensity in samples of R & D performers may have resulted from inadequate attention to outliers and industry effects, and not from inappropriate estimation technique. Tobit regressions produce conclusions concerning the effect of size on R & D performers that are qualitatively identical to those based on OLS estimates derived from censored samples of the type used in most prior literature. On the other hand, we find that least squares results were somewhat sensitive to corrections for heteroscedasticity.

Taken together, the research reported in this and a previous paper provides little support for the much-tested Schumpeterian hypotheses that firm size and market concentration influence R & D intensity. Our inquiry also yields constructive results, however, suggesting that industry effects have a very important influence on R & D, and that industry effects can be reasonably well represented by measures of demand conditions, and by survey-based measures of technological opportunity and appropriability.

These findings do not, of course, rule out the possibility, supported in the work of Scott [1984], that there are characteristics of firms that influence R & D intensity. Our results suggest that firm size is not one such characteristic, at least not within the size range we observe. In this connection, it is important to recall that though our data include many small business units, all are drawn from firms that are among the largest in the U.S. manufacturing sector.

Notes

[1]Cremer and Sirbu [1978], and Pavitt [1985] have obtained results similar to those of Bound et al.. Cremer and Sirbu used data on French firms; Pavitt studied British firms.

[2]Although we attempt to control for industry effects, we do not consider the influence on R & D intensity of firm-specific variables other than size. These may be important; an analysis of covariance done by Scott [1984] indicates that firm effects explain roughly as much variance in business unit R & D intensity as do two-digit industry effects. In a related effort, Cohen and Mowery are exploring this issue.

[3]See Cohen and Mowery [1984, Appendix V] for a detailed discussion of the screening procedures used to check the validity of the FTC's Line of Business Program R&D data.

[4]Cohen and Mowery [1984, Appendix VI] compare the coverage and representativeness of the FTC's R & D data with the NSF's R & D data, which is reported at a higher level of aggregation. The coverage of the FTC data is just over 60% of that of the NSF, and the representativeness of the FTC data, judging from the similarity of overall and industry mean R & D intesities, is excellent.

[5]Although firms had the option of consolidating all business units with revenues below ten million dollars, many did not exercise it.

[6]The basic sciences listed in the survey questionnaire are biology, chemistry, geology, mathematics, and physics. The applied sciences are agricultural science, applied math/operations research, computer science, materials science, medical science, and metallurgy.

[7]There are numerous statistical problems associated with the use of Likert-scale survey responses as independent variables in regressions. The most fundamental is whether responses along a semantic continuum can be treated as if they were interval data. In the absence of adequate alternative measures of technological opportunity and appropriability, we assume that such treatment is reasonable. Given this assumption, there remain several potential sources of measurement error. One is that individual respondents may differ in their use of the seven-point scale. In related work Levin is exploring the importance of interrater differences in mean responses and in the variance of responses. Preliminary results indicate that the ranking of industry mean responses to particular questions is reasonably insensitive to correction for these individual effects. Another form of measurement error is introduced by using industry means instead of individual responses. We attempt to control for this type of error by

including the number of survey responses per industry among the variables used to correct regression results for heteroscedasticity.

[8]These mechanisms are patents to prevent duplication, patents to secure royalty income, secrecy, lead time, moving quickly down the learning curve, and complementary sales and service efforts.

[9]Almon et al. estimated demand functions for 56 input-output sectors in which the predominant share of output goes to personal consumption expenditures. For each sector a constant price elasticity, a constant income elasticity, and a parameter representing the annual percentage shift in the demand curve were estimated using time series data from 1947 to 1970. Using these parameters and the 1972 Input-Output Tables for the United States, Levin [1981] calculated demand elasticities for each of the remaining disaggregated input-output sectors in manufacturing. For the handful of consumer goods sectors for which Almon et al. found zero price elasticitics, alternative estimates were found by a search of the empirical literature. Where necessary, these derived elasticities were aggregated to the line of business level using sales-weighted averages.

The procedure requires some very strong, and obviously counterfactual, assumptions: a fixed coefficient technology and an input-output structure that can be partitioned into intermediate and final goods sectors. Nonetheless, the procedure produced only a few anomalies, and the relative magnitudes of the elasticities across industries accord reasonably well with intuition.

[10]Although the reader may be concemed with possible collinearity between BUSALES and OTHERSALES, the correlation between these variables is only .13. The large number of observations in our sample further mitigates concern over the effect of multicollinearity.

[11]A notable exception to this common practice is the work of Bound et al. [1984]. They find that estimates of the effect of firm size on R & D obtained on a sample of firms reporting R & D are essentially unchanged by correcting for selectivity bias in reporting.

[12]Specifically, where Breusch-Pagan test revealed the presence of heteroscedasticity, the logarithm of the squared residuals from OLS estimation was regressed against first and second order size terms. For specifications involving industry characteristics, the industry variables were also included at this stage, along with the number of respondents from the industry to the Levin et al. survey. The primary specification was then weighted by the square root of the antilog of the predicted values from this auxiliary

equation. The number of survey respondents per industry (NRESP) was included in the auxiliary equation to control for possible measurement error in the survey variables. In no instance, however, did NRESP have a statistically significant effect on the size of the residuals from the R & D equations.

[13]When second order terms were added to our benchmark specifications in columns (1) and (3), the coefficients were individually and jointly insignificant, and their magnitude implied that R & D intensity rises almost linearly throughout the range of firm sizes in our sample. The second order terms contributed virtually no explanatory power, and the qualitative inferences about the significance of size were unaffected. These conclusions hold for all least squares estimates reported in this paper.

[14]Our more inclusive sample contains observations from 19 two-digit industries; the lines of business covered by the Levin et al. survey are drawn from only 16 two-digit industries.

[15]Dropping one observation alone was sufficient to render the coefficient on OTHERSALES insignificant in the restricted sample.

[16]Although the degree to which our results are sensitive to a mere handful of observations in a large sample is surprising, the deleted observations are, after all, precisely those which might be expected to have the largest effect on the coefficient of OTHERSALES. We therefore proceeded to check the robustness of the results reported in Table IV by deleting all observations for which the value of OTHERSALES exceeded its LB-level industry mean by at least $2.78 billion, the smallest deviation among our seven outliers. In this way, we selected on the independent variable alone. This required us to drop 169 observations from our larger sample and 126 observations from our restricted sample. The results were qualitatively identical and quantitatively very similar to those reported for each of the four equations in Table IV.

[17]We explored this possibility by restricting our sample to lines of business with values of SCIENCEBASE below its sample mean of 6.2 (on a scale of 7.0) and, alternatively, below 6.0. The results were sensitive to the cutoff level. In the first case firm size had a significant but small effect on R & D intensity. In the second case, it did not.

[18]Whether or not it is significant, the quantitative effect of BUSALES, given R & D performance, is minute. An eleven billion dollar increase in business unit sales is required to increase R & D intensity by one percent.

[19]We estimated the probit specifications with two forms of our dependent variable. We defined the dependent variable to equal one if the business unit conducted R & D in any one of the three years, 1975-1977, and, alternatively, to equal one if R & D was conducted in all three years, 1975-1977. The qualitative results were insensitive to this variation in the dependent variable.

[20]It should be noted that tests on the joint significance of the technological opportunity variables include only the five opportunity measures drawn from the Levin et al. survey and exclude NEWPLANT, a measure of the age of the industry's physical plant and equipment. We adopt this approach because we are particularly interested in assessing the value of the survey data. Dropping NEWPLANT from the estimating equation, here and in Table VII, produces virtually no change in the remaining coefficients, and alters none of our qualitative conclusions.

[21]Of the twelve joint significance tests (three categories of industry characteristics by four industry groups) the only two exceptions were the appropriability variables in SIC 28, which were insignificant in the Tobit specification, and the demand variables in SIC 35, which were significant in the Tobit specification.

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TABLE I

Number of Firms and Business Units by Sample

	All Business Units		R&D Performers Only	
	All LBs	Survey LBs	All LBs	Survey LBs
Business Units	2494	1719	1797	1302
Firms	345	318	317	297

TABLE II

Descriptive Statistics on R&D Intensity, Business Unit Sales and Firm Sales by Sample

	R&D Intensity* (percent)				Business Unit Sales ($ billion)				Firm Sales ($ billion)			
	All Business Units		R&D Performers Only		All Business Units		R&D Performers Only		All Business Units		R&D Performers Only	
	All LBs	Survey LBs	All LBs	Survey LBs	All LBs	Survey LBs	All LBs	Survey LBs	All LBs	Survey LBs	All LBs	Survey LBs
Mean	1.59	1.81	2.12	2.31	0.20	0.25	0.25	0.30	2.31	2.46	2.44	2.57
Median	.68	.81	1.16	1.30	0.06	0.07	0.07	0.08	1.14	1.23	1.23	1.31
Minimum**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.11	0.11	0.12	0.12
Maximum**	22.35	22.35	22.35	22.35	16.04	16.04	16.04	16.04	34.13	34.13	34.13	34.13

*Business unit R&D spending as a percentage of business unit sales and transfers.
**To preserve the confidentiality of responding firms, we report the mean values of the four smallest and largest business units or firms, respectively.

TABLE III

The Effects of Size on R&D Intensity

R&D Performers Only

Parameter	Variable/ Hypothesis	Regression Coefficient (standard error) All LBs (1)	(2)	Survey LBs (3)	(4)
α_1	Intercept	1.957** (0.076)	a	2.165** (0.096)	a
α_2	BUSALES	-0.024 (0.067)	0.049 (0.073)	-0.043 (0.072)	0.054 (0.076)
α_3	OTHERSALES	0.058** (0.013)	0.045** (0.011)	0.052** (0.016)	0.043** (0.013)
	H_o: $\alpha_2, \alpha_3 = 0$	F(2,1794) 9.86**	F(2,1551) 9.13**	F(2,1299) 5.21**	F(2,1149) 5.90**
	H_o: $\alpha_2 = \alpha_3$	F(1,1794) 1.39	F(1,1551) 0.002	F(1,1299) 1.59	F(1,1149) 0.02
	R^2	0.011	0.473	0.008	0.480
	n	1797	1797	1302	1302

[a]LB level fixed effects suppressed

**Significant at the .01 level

*Significant at the .05 level

TABLE IV

The Effects of Size on R&D Intensity

R&D Performers Only

Outliers Removed

Parameter	Variable/ Hypothesis	Regression Coefficient (standard error) All LBs (1)	(2)	Survey LBs (3)	(4)
α_1	Intercept	1.999** (0.075)	a	2.206** (0.095)	a
α_2	BUSALES	-0.002 (0.065)	0.074 (0.070)	-0.024 (0.071)	0.077 (0.074)
α_3	OTHERSALES	0.032* (0.013)	0.016 (0.011)	0.027 (0.016)	0.017 (0.013)
	$H_o:\alpha_2,\alpha_3=0$	F(2,1787) 2.90	F(2,1544) 1.85	F(2,1294) 1.45	F(2,1144) 1.54
	$H_o:\alpha_2=\alpha_3$	F(1,1787) 0.25	F(1,1544) 0.63	F(1,1294) 0.48	F(1,1144) 0.61
	R^2	0.003	0.484	0.002	0.492
	n	1790	1790	1297	1297

[a]LB level fixed effects suppressed
**Significant at the .01 level
*Significant at the .05 level

TABLE V

Tobit Regressions of R&D Intensity on Size

Parameter	Variable/ Hypothesis	Regression Coefficient (standard error)	
		All LBs	Survey LBs
		(1)	(2)
α_1	Intercept	1.141** (0.091)	1.451** (0.118)
α_2	BUSALES	0.126 (0.076)	0.083 (0.104)
α_3	OTHERSALES	0.038** (0.014)	0.026 (0.017)
	$H_o: \alpha_2, \alpha_3 = 0$	$\chi^2(2)$ 11.62**	$\chi^2(2)$ 3.53
	$H_o: \alpha_2 = \alpha_3$	$\chi^2(1)$ 1.21	$\chi^2(1)$ 0.28
	σ	2.778	2.955
	Log-likelihood	-5440	-3938
	n	2487	1714

[a]LB level fixed effects suppressed
**Significant at the .01 level
*Significant at the .05 level

TABLE VI

The Effects of Size and Industry Characteristics on R & D Intensity

Parameter	Variable/ Hypothesis	Regression Coefficient (Standard Error) Tobit (1)	OLS (2)	GLS (3)
α_1	INTERCEPT	-7.572** (1.264)	-8.348** (1.362)	-3.240** (0.980)
α_2	BUSALES	0.163* (0.071)	0.074 (0.063)	-0.024 (0.049)
α_3	OTHERSALES	0.017 (0.014)	0.018 (0.014)	0.041** (0.012)
α_4	SCIENCEBASE	0.267 (0.139)	0.358** (0.126)	0.232** (0.071)
α_5	GOVTECH	0.309** (0.068)	0.363** (0.071)	0.182** (0.055)
α_6	MATERIALTECH	-0.110 (0.089)	-0.077 (0.094)	0.087 (0.066)
α_7	EQUIPTECH	-0.446** (0.103)	-0.310** (0.104)	-0.501** (0.066)
α_8	USERTECH	0.571** (0.093)	0.455** (0.090)	0.279** (0.064)
α_9	APPROPRIABILITY	0.535** (0.160)	0.540** (0.154)	0.338** (0.116)
α_{10}	IMLAG	0.100* (0.041)	0.102* (0.042)	0.060* (0.031)
α_{11}	PELAS	-0.282** (0.080)	-0.301** (0.059)	-0.165** (0.036)
α_{12}	INCELAS	1.471** (0.158)	1.450** (0.149)	0.794** (0.121)
α_{13}	DGROWTH	0.171 (0.096)	0.198* (0.084)	0.074 (0.046)
α_{14}	NEWPLANT	0.051** (0.007)	0.059** (0.008)	0.030** (0.006)

TABLE VI CONTINUED

Variable/ Hypothesis	Regression Coefficient (Standard Error) Tobit (1)	OLS (2)	GLS (3)
H_0: $\alpha_2, \alpha_3 = 0$	$\chi(2)$ 7.62*	F(2,1283) 1.73	$\chi(2)$ 5.67*
H_0: $\alpha_2 = \alpha_3$	$\chi(1)$ 3.95*	F(1,1283) 0.70	$\chi(1)$ 1.56
H_0: Opportunity=0 ($\alpha_4, \alpha_5, \alpha_6, \alpha_7, \alpha_8 = 0$)	$\chi(5)$ 99.76**	F(5,1283) 18.12**	$\chi(5)$ 22.51**
H_0: Appropriability=0 ($\alpha_9, \alpha_{10} = 0$)	$\chi(2)$ 18.79**	F(2,1283) 9.77**	$\chi(2)$ 6.45**
H_0: Demand = 0 ($\alpha_{11}, \alpha_{12}, \alpha_{13} = 0$)	$\chi(3)$ 93.85**	F(3,1283) 35.90**	$\chi(3)$ 15.55**
R^2		0.236	
n	1714	1297	1297

*Significant at the .05 confidence level.
**Significant at the .01 confidence level.

TABLE VII

The Effects of Size and Industry Characteristics on R&D Intensity in Selected 2-Digit Industries

R&D Performers Only
(Adjusted for Heteroscedasticity)

Parameter	Variable/ Hypothesis	Regression Coefficient (standard error) SIC 20 (Food)	SIC 28 (Chemicals)	SIC 35 (Machinery)	SIC 36 (Electrical)
α_1	Intercept	1.145 (3.536)	-24.436** (6.461)	-17.293** (5.037)	-5.135 (7.469)
α_2	BUSALES	-0.430* (0.179)	-0.033 (0.293)	0.738** (0.280)	1.374 (0.911)
α_3	OTHERSALES	0.019 (0.029)	0.013 (0.007)	0.024 (0.019)	0.029 (0.017)
α_4	SCIENCEBASE	-0.261 (0.239)	0.637 (0.704)	1.183** (0.453)	0.672 (0.755)
α_5	GOVTECH	0.020 (0.114)	1.226** (0.324)	0.959** (0.316)	-0.234 (0.226)
α_6	MATERIALTECH	0.136 (0.131)	1.010** (0.363)	0.987** (0.284)	-1.144* (0.494)
α_7	EQUIPTECH	0.097 (0.091)	-0.821* (0.394)	-0.896** (0.241)	1.467* (0.650)
α_8	USERTECH	-0.091 (0.129)	1.958** (0.384)	0.120 (0.253)	1.098** (0.324)
α_9	APPROPRIABILITY	-0.107 (0.368)	0.199 (1.277)	0.786 (0.529)	-0.086 (0.576)
α_{10}	IMLAG	0.053 (0.043)	0.371** (0.120)	-0.182 (0.145)	-0.533** (0.148)
α_{11}	PELAS	-0.191 (0.257)	1.978 (1.101)	-0.511 (0.385)	-1.176 (0.910)
α_{12}	INCELAS	0.678 (0.426)	2.643** (0.878)	2.197** (0.523)	1.110 (1.236)
α_{13}	DGROWTH	0.113 (0.084)	-2.453** (0.834)	-0.316 (0.342)	0.767 (0.771)
α_{14}	NEWPLANT	0.012 (0.009)	0.156** (0.042)	0.096** (0.023)	-0.003 (0.043)
	$H_o:\alpha_2,\alpha_3=0$	$\chi^2(2)$ 3.59	$\chi^2(2)$ 1.88	$\chi^2(2)$ 5.73	$\chi^2(2)$ 2.21

TABLE VII
continued

$H_o: \alpha_2 = \alpha_3$	$\chi^2(1)$ 6.52*	$\chi^2(1)$ 0.025	$\chi^2(1)$ 6.21*	$\chi^2(1)$ 2.19
H_o: Opportunity=0 ($\alpha_4, \alpha_5, \alpha_6, \alpha_7, \alpha_8 = 0$)	$\chi^2(5)$ 1.02	$\chi^2(5)$ 12.02*	$\chi^2(5)$ 7.96*	$\chi^2(5)$ 14.46*
H_o: Appropriability=0 ($\alpha_9, \alpha_{10} = 0$)	$\chi^2(2)$ 0.79	$\chi^2(2)$ 8.70*	$\chi^2(2)$ 1.62	$\chi^2(2)$ 6.51*
H_o: Demand=0 ($\alpha_{11}, \alpha_{12}, \alpha_{13} = 0$)	$\chi^2(3)$ 2.90	$\chi^2(3)$ 12.45**	$\chi^2(3)$ 6.33	$\chi^2(3)$ 0.68
R^2 (OLS)	0.076	0.369	0.440	0.309
n	142	254	217	115

**Significant at the .01 confidence level
*Significant at the .05 confidence level

TABLE VIII

Comparison of Percent Contributions to Explained Variance in R&D Intensity Measured Industry Characteristics v. Fixed Industry Effects

	Sample				
	All Industries	SIC 20	SIC 28	SIC 35	SIC 36
(1) Percent of variance explained by size measures	0.2	1.5	0.4	6.6	0.2
(2) Additional variance explained by measured industry characteristics (d.f.)	23.4 (11)	6.1 (11)	36.5 (11)	37.4 (11)	30.7 (11)
(3) Additional variance explained by fixed industry effects (d.f.)	49.0 (151)	12.1 (21)	46.9 (16)	44.8 (24)	35.8 (16)
(4)(2)÷(3)	0.48	0.50	0.78	0.83	0.86