Innovation, Market Share, and Market Value

Bronwyn H. Hall[1] Katrin Vopel[2]

June 1997

[1] University of California at Berkeley, Oxford University, and the National Bureau of Economic Research. The first draft of this paper was written during a visit to Nuffield College, and their hospitality is gratefully acknowledged.

[2] Diplom-candidat, University of Mannheim, and visiting researcher, University of California at Berkeley, August 1995-February 1996.

Abstract

Recently, Blundell, Griffith, and Van Reenen (1995) have argued that the fact that the stock market valuation of innovative output is higher when a firm has large market share implies that the "strategic preemption" effect is more important than the Schumpeterian effect in explaining the importance of large firms in innovation. Using a newly constructed dataset on approximately 1000 US manufacturing firms from 1987 to 1991 for which we have a measure of market share, we document the fact that the market value of innovative activity as measured by R&D expenditures is higher for firms with a higher market share in their industry in the United States as well. However, the relationship is highly nonlinear and may also depend on firm size. We explore the implications of our findings for models of competition in innovation (June 1997).

1 Introduction

Since the influential articles of Nelson (1958) and Arrow (1962), who argued that individual firms are unable to fully appropriate the output of their innovative activity, many applied economists have focused their attention on measuring the extent to which this possibility actually results in market failure in the production of innovations. A variety of approaches have been used to investigate the appropriability or lack of appropriability of R&D and other investments in innovation. For example, an important goal of surveys by Mansfield (1967) a group of (former) Yale economists (Klevorick, Levin, Nelson, and Winter 1988, 1989), and the successor survey by Cohen, Levin, and ?(1995?) was to obtain information on the perceived imitation costs and appropriability conditions in a variety of industries. Other approaches seek to measure the gap between the private and social returns to R&D at an industry or economy-wide level in order to evaluate the magnitude of the externality problem (see Griliches 1992 and Hall 1996 for surveys of this type of evidence). The conclusion of both surveys and the econometric literature is that appropriability is neither perfect nor is it absent. There are clearly private returns to R&D that accrue to the individuals and firms that perform it, and there are also substantial costs of imitation to the follower of an innovating firm. Although imitation costs can be fairly high (up to 50-70 percent of the original innovation cost), which mitigates against inappropriability, they are nowhere near 100 percent in most cases, implying that in some cases an imitator has higher returns available than an innovator for any given innovation.

Besides the obvious but frequently imperfect strategies of patenting innovations or using trade secret protection, one way modern industrial firms raise the imitation costs of their rivals is by developing special skills in a particular type of innovation.

Other things equal, one expects low appropriability or appropriability difficulties in settings where there exist a number of competing firms whose competence level is such that they might easily imitate any promising new idea discovered by one of their number and where patents, trade secrets, and lead times do not confer complete protection on innovating firms. Obviously, other things are not equal: firms in high appropriability industries will invest to the point where their net returns match those of firms in low appropriability industries, so that a comparison of marginal returns will not reveal the difference. However, we still expect that *average* returns will be somewhat higher for firms facing better appropriability conditions.

Appropriability of the output of innovative activity and the creation of rents from innovative activity are not the same thing, but they will be correlated, especially in the presence of uncertainty. In a completely certain world, we expect that firms will undertake investments in innovation to the point where the marginal return to such investment equals the cost of capital. Appropriability conditions enter this calculus to the extent that they affect the number of investment projects that satisfy the cutoff criterion, and thus, in principle, the average return from these investments. Introducing uncertainty tends to make the returns to innovation skew to the right (especially in view of limited liability), which will introduce correlation between rents and appropriability conditions in practice.

This paper represents another look at the profitability-innovation-market structure nexus that has been widely studied at the industry level in the past. Using the market value of a firm as an indicator of profitability and returns to R&D investment, we ask whether the price (value) applied by the market to that investment varies in any systematic way with the size or market dominance of the firm undertaking the investment. Again, the average-marginal distinction is useful: although marginal rates of return should be equalized across industries and firms (assuming similar risk portfolios), average returns ought to be higher if the firm faces a larger market over which to sell the results of its R&D, or if it operates in an industry with a large number of potentially profitable projects.

Recently, Blundell, Griffith, and Van Reenen (1995) have argued that the fact that the stock market valuation of innovative output is higher when a firm has a large market share implies that the "strategic preemption" effect is more important than the Schumpeterican effect in explaining the importance of large firms in innovation. Our aim in exploring the role of appropriability and market share in explaining the returns to R&D is intended to shed light on this issue also. First we document the precise form of the relationship in United States, as opposed to United Kingdom, data. Next we explore it in more detail: how does it vary across industries? How is it related to firm size and industry-level concentration, and to the appropriability indicators of Klevorick et al? Finally, we offer some thoughts on making the distinction between the strategic preemption and "deep pockets" explanations for the finding that larger size and larger market share lead to a higher valuation for R&D.

Our work is also related to the large literature that relates market structure, profitability, and innovation at the industry level (see Cohen and Levin (1984) for a survey of this literature). Because we focus on the firm as the unit of observation rather than the industry, we will be able to shed a different sort of light on the well-documented relationship between concentration, industry profits, and R&D performance. From the results presented here, it appears that this relationship is driven by the larger firms in an industry, without much spillover to the smaller firms. This presents an interesting avenue of exploration for future work.

2 The Value Equation and the Pricing of R&D Assets

The value of a firm's assets in the market place is the price at which the claims to the cash flows from those assets trade. Tobin's Q, the ratio of the market value of the assets to their book value, is commonly used as a shorthand summary of the market price of the assets. In a cross-sectional equilibrium, we expect the price of the firm's assets (properly measured) to be approximately unity, because deviations from unity suggest either that investment be undertaken to expand the asset base (Q is above one, and the cost of investment is lower than the return to that investment) or to shrink the asset base (the same argument in reverse). As is well-known, departures from equilibrium are endemic in the data, and arise for a whole range of reasons, such as large adjustment costs (both up and down), tax considerations, and fixed costs.

This paper considers yet another departure of market from book value, that due to the rents created by R&D investments. Under the assumption that past R&D investments create intangible assets that yield profits into the future, and that these profits are capitalized by the stock market into the price of the firm's stock, it is possible to use the stock price to quantify the returns to these innovative investments. Previous work that has applied this methodology to R&D investment includes Griliches (1981), Cockburn and Griliches (1988), Jaffe (1986), and Hall (1988, 1993a,b). Most of these authors have found sizable premia for R&D investment, corresponding to a capitalization rate of approximately 4 or 5, but see Hall (1993a,b) for evidence that these premia have varied considerably over time and across industry.

The theoretical underpinnings of such an exercise are derived from a dynamic optimizing program for a firm undertaking investments in ordinary capital and innovation. Using the methods of Hayashi and Inoue (1991) for firms with more than one type of capital and an additively separable capital aggregator, it is possible to show that the market value of such a firm can be written as follows:[1]

$$\begin{aligned} V(A_{it}, K_{it}) &= p_t^I A_{it} + E_t \sum_{s=1}^{\infty} \beta^{s-t} [\Pi_\phi - \lambda(c_I, c_R)] A_{i,t+s} \\ &\quad + p_t^R K_{it} + E_t \sum_{s=1}^{\infty} \beta^{s-t} [\Pi_\phi - \lambda(c_I, c_R)] \gamma K_{i,t+s} \end{aligned} \tag{1}$$

Π_ϕ is the average marginal product of the capital aggregate Φ, λ is a shadow cost of capital for the capital aggregate (a function of the two capital costs c_I and c_R), and the p's are the price of investment in plant and equipment (I) and research and development (R). Our measures of capital are in current prices, and thus already include the prices; that is, they are equal to $p_t^I A_{it}$ (tangible assets) and $p_t^R K_{it}$ (intangible assets). Equation 1says that the market value of a firm with capital A and R&D capital K is the sum of four terms, two that are simply the current book value of the capital and two that describe the rents to be earned in the future by a firm with this capital. Market equilibrium (Tobin's Q equal to unity) implies that these latter terms are zero in expectation; that is, that the average marginal product of future investments $\Pi\phi$ will be on average equal to its cost λ.

In fact, cross-sectional estimates of Tobin's Q based on manufacturing data have deviated from unity for extended periods of time: during the first two-thirds of the 1980s, for example, they were well below one (although there was still a premium for R&D capital), while during the 1990s, they have moved well above one. Much of this shift has been associated with the

[1] The capital aggregator in this case is $\Phi(A_{it}, K_{it}) = A_{it} + \gamma K_{it}$, where γ is a premium or discount for the R&D stock K_{it} (the relative marginal product of K vs A). γ may also reflect the fact that K_{it} is mismeasured in some way (using the wrong depreciation rate, etc.). See Appendix A of Hall (1993b) for details.

restructuring of firms in industries with an older technological basis (Hall 1993b, Hall 1997). In addition, there continues to be evidence of considerable rent (in the form of excess returns) to R&D in some (but not all) industries. This paper investigates a factor that may help to explain the existence of supranormal rents to both capital and R&D capital, namely, the ability to price above full (long run incremental) marginal cost. If firms in an industry are just covering average costs (including R&D), additional R&D will not earn supranormal returns in equlibrium, even if they face somewhat inelastic demand due to differentiated products. However, if they have some market power beyond that due to fixed costs (that is, if they can sustain supranormal profits), then additional R&D spending may be worth more to larger firms or firms with larger market shares. We use both firm size (measured by assets) and the firm's share of the market in its two-three digit industry as a proxies for the possible presence of market power; we interact these variables with R&D spending to explore whether the market value of a dollar of R&D spending increases with market share or market size. Our basic econometric specification of equation 1 is developed in the following way:

$$V(A_{it}, K_{it}) = q_t[A_{it} + \alpha_A M_{it} A_{it} + \gamma K_{it} + \alpha_K M_{it} \gamma K_{it}] \tag{2}$$

where M_{it} is the market share of the ith firm, the prices of investment p^I and p^R have been absorbed into A and K, and we have allowed for disequilibrium in the overall market by including a multiplier q_t that varies over time but not across firms. Following prior work in this area, we divide equation 2 by the tangible assets A and then take the logarithm, using the approximation $\log(1+\varepsilon) \approx \varepsilon$ to simplify:

$$\log V_{it} = \log q_t + \log A_{it} + \alpha_A M_{it} + \gamma(1 + \alpha_K M_{it}) \frac{K_{it}}{A_{it}} \tag{3}$$

Equation 3 specifies a regression with time dummies ($\log q_t$) that track the overall market movements, and regressors equal to the log of tangible assets, the market share, the ratio of R&D capital to assets, and the interaction between market share and this ratio. Note that we have allowed for a free coefficient of $\log A$ in estimation, although the theory predicts that it should be exactly one in a properly specified regression. In practice, we find estimates of approximately 0.90-0.93 with very small standard errors, and imposing unity appears to bias the other coefficients downward. The most plausible explanation would seem to lie in some kind of diminishing returns or negative relationship between expected future growth and size in our sample.[2] If this is true, the finding could be viewed as a consequence of our assumption of parameter constancy across the entire size distribution of firms. Our sample is based on firms that are listed on public stock exchanges or traded over the counter, and we do indeed expect that the population of smaller firms in our sample is different from that of larger firms: in the United States manufacturing sector, most large firms are publicly traded, but smaller

[2] This is in addition to the obvious possibility that there is downward measurement error bias from our imperfect measure of A, of course.

firms tend to be those that expect to grow and want access to public capital markets. We will explore this difference later in the paper.

3 Data and Market Definition

Our data come from several sources: Standard and Poor's Compustat Annual Industrial, OTC, and Research data files (firm-level data, approximately 3000 firms for 1959-1991, unbalanced): Standard and Poor's Compustat Business Segment file (business segment-level data for approximately 500 firms, 1987-1992); 1982 and 1987 Census of Manufactures and 1988-1991 Annual Survey of Manufacturing (4-digit industry-level data, 1982, 1987-1991); and the Yale survey dataset AMAZ (131-IDS-level data, merged to the Census of Manufactures and ASM for 1977 and 1982). We combined data from all these sources and created an unbalanced panel of firms with data from 1982 to 1991 (including data on their primary industry at the 131-firm level) in the manner described below.

The central problem in conducting an investigation into the effects of industry conditions on the performance of individual large manufacturing firms is the matching of firms to industries. In general, assigning these firms to a single 4-digit SIC industry is impossible because these firms are usually engaged in more than one such industry in a significant way. Like so many other studies, ours struggles with this problem and ultimately finds a less than complete satisfactory, but workable, solution.. We begin with the 131-sector manufacturing industry breakdown originally created by Scherer for the analysis of the Federal Trade Commission data in the seventies. This classification system was also used in a somewhat modified form by the Yale survey (Levin et al 1987) to analyze their results. It has the advantage that it has a somewhat technological basis (SIC industries are aggregated when they are based on similar technologies and tend to be found in the same firms (e.g., all dairy products, all plastic products except films and sheets, and so forth). A second advantage is that using this system will enable us to match our data to the Yale survey data (or to an updated version of that survey) if we wish to obtain measures of appropriability and technological opportunity.

We have modified the IDS classification to conform to the 1987 4-digit industrial classification of the Census of Manufactures, combined some industries, and created a few new ones (especially in the computing and electronics areas). In all cases our focus was on creating industries that would plausibly contain firms that could compete on the technological side, which means that we tended to focus on supply side substitution when aggregating, although without completely ignoring the markets that the firms face (e.g., refrigerating and heating equipment, IDS 119 and 126, is separated by the ultimate consumer of the product). We also added firms and industries from outside manufacturing if they were particularly likely to be integrated into manufacturing and to perform significant amounts of R&D. This affected the petroleum industry, where we included firms in SICs 1311 and 1389, and the communication equipment industry, where we added firms in SICs 4810, 4811, and 4813. A complete list of industries and the 4-digit classes they contain, together with their aggregation to the 2-digit level, is shown in Table 1 of the appendix.[3]

After creating the industry classification (called IDS), which is at the lowest level of aggregation that allows firms to be assigned more or less uniquely to a single industry, we assigned the firms from Compustat using their primary 4-digit SIC code. For very large firms on which we also had business segment data (approximately 500), we actually used their sales in a particular business segment when computing their market share, and weighted up their market shares in different industries to obtain a single market share for the market value regression (which is at the firm level). Market shares were defined as the ratio of firm (or segment) sales to the total value of shipments in the IDS industry classification, aggregated from the 1987 Census of Manufacturing figures at the 4-digit level, Obviously, this will produce numbers that are not internally consistent, given the slightly inaccurate procedure of assigning whole firms to industries, but we believe that this is preferable to using a denominator that is based on aggregation of the Compustat sales figures. In fact, our examination of a few key industries suggests that the market share numbers are generally not that far off. We have deleted the few observations for which they are completely implausible.

Figure 1 shows the frequency distribution of our market share variable; as expected, the distribution is highly skewed, with only about 300 of the observations (approximately 60 of the firms) having market shares greater than 10 percent. Figure **??** plots the average market share at the two-digit level versus the 1987 Herfindahl index for that industry (constructed as a shipments-weighted average of the Herfindahl at the lower level of aggregation). It is clear from this figure that the two measure slightly different quantities: it is possible for an industry to be concentrated (high Herfindahl) and still have a large number of very small firms (low average market share), as in the case of the aircraft and parts industry (17). In this case, it is probably that the assumption of a homogeneous industry is problematical. On the other hand, and industry can be only moderately concentrated, but contain firms that have fairly high average market shares (food & tobacco, petroleum, and primary metal products). Confirming the extreme skewness of the market share distribution, Table 1 shows that the average market share in these data is 4.3 percent, while the median is 0.9 percent. One quarter of the firms have market shares above 3.9 percent.

The rest of the data we use is more straightforward to construct, and is described more completely in Hall (1990). The sample is United States R&D-performing manufacturing firms traded on the New York Stock Exchange, the American Stock Exchange, or Over-the-Counter during the 1987 to 1991 period, with up to 5 years of history (back to 1982). For this paper we use the market value of corporate assets (equity, debt, preferred stock, and other liabilities) and the inflation-adjusted book value of tangible assets (plant and equipment, inventories, and other assets) to construct a measure of Tobin's Q. In addition, we use the sales (revenue), the

[3] We welcome suggestions for improvement of this classification system, which is by no means perfect at the present time.

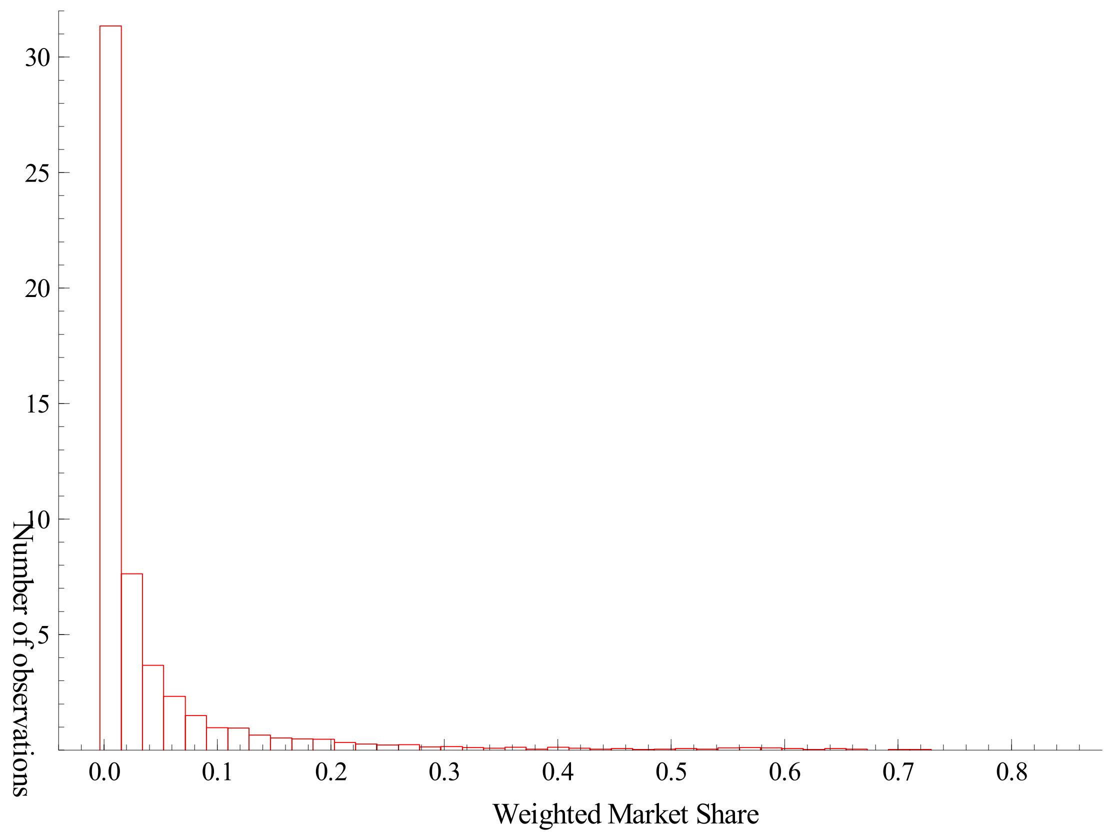

Figure 1: Histogram of weighted market share

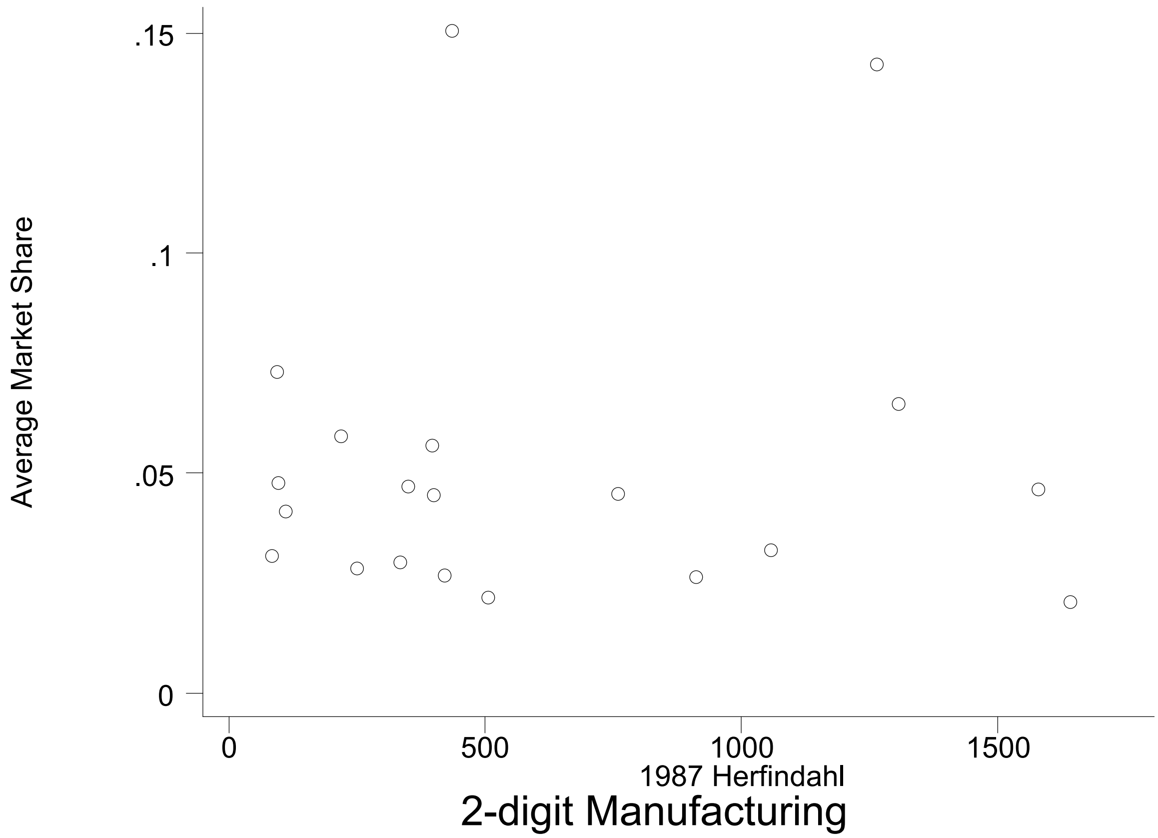

Figure 2: Market share versus Herfindahl

capital expenditures, the flow of R&D spending, and an R&D stock measure constructed from the firm's history of R&D spending using the perpetual inventory method with a depreciation rate of 15 percent. Summary statistics for all our variables are shown in Table 1. We trimmed Tobin's Q, the R&D-assets ratio, the investment-assets ratio, and the market share variable for outliers (the minima and maxima after trimming are also shown in Table 1).

4 Empirical Evidence

In Table 1, the median Tobin's Q is well above unity, which is to be expected since all of these firms are R&D-doers and therefore can be expected to have sizable intangible assets that are not captured by this measure. The average ratio of current R&D to tangible assets is approximately

10 percent, and the distribution is fairly skewed. Innovative activity, as proxied by the R&D stock, is a major piece of the explanation for the fact that Tobin's Q is well above one for these firms. Evidence of this fact is that a simple correction to Tobin's Q (adding the R&D capital to the assets in the denominator) yielded the results in the row labeled "Corrected Tobin's Q": The median premium on the assets of the firms is now 15 percent rather than 52 percent, and the dispersion has also been reduced considerably (the interquartile ranges). Although our measure of the R&D stock is a very rough approximation to the intangible "knowledge" capital that the market presumably values, it is clearly related to something that generates returns for the firm.

An issue that confronts anyone working with panel data is the possible presence of unobservables in the relationship being estimated that are correlated with the variables of interest. In our case, this would correspond to left-out variables in the market value equation that are correlated with either the market share or R&D intensity. The well-known method of differencing to correct estimates for bias from permanent unobservable differences across firms is very unattractive in our case for two reasons. First, both of the right hand side variables of interest (R&D and market share) are rather stable over time, and differencing them reduces the variability associated with their "true" values considerably (see Griliches and Hausman 1986 for discussion of the errors in variables problem in panel data).

Second, and more importantly, we do not believe that "correlated effects" bias is likely to be of great importance in estimating the relationship in equation 3; most of the reasons why there exist "permanent" differences across firms in the market value relationship can be attributed to R&D and/or market share, and we would like to measure these effects rather than simply differencing them away. For example, firms within the same industry may differ permanently from each other to the extent that they serve a niche market or produce higher quality products. If this fact generates higher market value and simultaneously higher R&D, we want to associate this effect with the R&D spending; it would be incorrect to difference in order to remove this correlation.[4] For this reason, we emphasize results in this paper that are based on ordinary least squares estimates of the relationship in equation 3, although we have pursued a variety of experiments that use initial conditions for some of the right hand side variables as partial controls for a "fixed effect." In contrast to Blundell et al (1996), we found these variables to be statistically insignificant or of small economic consequence, in general, and including them had no effect on the other coefficient estimates.

Table 2 presents the basic regression. We use both the current flow of R&D (columns 1, 3, 5, and 6) and the beginning-of-year stock of R&D (columns 2 and 4) as indicators of the innovative activity of the firm. Market share by itself is clearly positively associated with market value;

[4] We can think of one case where a third variable might cause "spurious" correlation between R&D and market value: we know that R&D intensive firms have lower levels of debt, and if our measure of market value includes a measure of the market value of debt that is biased on average, this will induce a correlation between market value of debt that is not of interest. Although this could be true, it is unlikely to be anywhere nearly as large as the direct relation between R&D and market value, and we expect the bias from this source to be small.

the effect is small but significant in percentage terms. An increase in market share equal to its standard deviation (9 percent) is associated with an increase in market value of approximately 5 percent. Regressions not shown confirm that this result is essentially orthogonal to the R&D effects; when market share is omitted, the R&D coefficient in the first column rises to 1.50 with the same standard error. In columns 3 and 4 of this table, we include the interaction between market share and R&D; using either the flow or stock of R&D, the market value premium associated with larger market share is not affected by the R&D intensity of the firm. Column 5 provides evidence that these results are largely unaffected by the inclusion of 21 2-digit industry dummies (the industries are given in the Appendix); that is, they are primarily due to the characteristics of individual firms rather than to the industries in which they are located.

As we have already emphasized, the market share variable is extremely skewed, and it is unlikely that it enters in the simple linear way indicated in equation 3. One piece of evidence on this question is the last column of Table 2, which presents results for the approximately 40 percent of our sample that had data on sales in individual lines of business. These are larger firms (median assets approximately 400 million dollars vs. 143 million dollars for the whole sample), and we also expect that the market share variable is better measured for this sample (and slightly larger, with a median of about two percent). The results for this sample are indeed quite different, with essentially no raw market share effect, but a sizable market share-R&D interaction. At the median market share for these firms of two percent, the R&D coefficient is higher by 0.3 than the base value of 1.95 for firms with negligible market shares. At a large market share of 10 percent, the R&D coefficient increases by about 1.5 which translates into a market value premium of about 5 percent at the median R&D to assets ratio for these firms, which is 0.33.

Table 3 takes a different approach to measuring these valuation effects. Recognizing that our market share is both measured with considerable error and likely to enter the relationship in a nonlinear way, we explore the results of estimation using categorical variables for tiny (MS<1%), small (1%<MS<4%), medium (4%<MS<8%), and large (MS>8%) market shares. The first two columns indicate that the relationship between market value and market share is monotonic, but probably not linear; there is some hint that effects are larger for larger market shares (see Klette and Griliches 1997 for a quality ladder model that predicts a monotonic nonlinear relationship of this kind). The next two columns show that there is an interaction between large market share and high R&D intensities, but mainly for firms with a large stock of past R&D expenditures and a very large market share. Such firms are worth 24 percent more on average, and have a much higher premium than others on their stock of R&D (although the overall R&D stock coefficient is still substantially lower than would be predicted by a model where such investment was valued at parity with ordinary investment).

The final two columns in Table 3 present the results of an investigation into whether the market share effects are simply due to firm size. The results are fairly clear-cut: market share itself is a better predictor of market value than size (once we control for the obvious linear relationship between V and A), but the interaction effect may indeed be due to the fact that large firms have a larger market over which to spread the results of their R&D. There is a slight hint that market share helps in exploiting the results of past R&D, other things equal, but the stock market's expectation of the results from current R&D spending is clearly linked to the size of the firm. A tiny firm with a tiny market share that does the average amount of R&D is worth about 13 percent more than one with no R&D. A large firm with large market share that does the average amount of R&D is worth about 54 percent more than one with no R&D. These effects are large, and definitely focused at the high end of the market share distribution.

5 Interpretation

At the outset of this paper, we argued that although a competitive market with a zero-profit free entry equilibrium might imply that the marginal return to an R&D dollar be the same across all firms, the fact that the R&D investment has a large fixed cost component means that average returns across firms will vary. The data seem to concur. What does this tell us about the deeper question of whether this advantage to firms with large market share arises for Schumpeterian reasons (the cost of financing R&D is lower for large firms, and therefore they find it more profitable) or because of the Gilbert-Newberry pre-emption effect (as long as a new entrant would cause industry profits to fall, firms with large existing market shares in an industry find it more profitable than others to innovate)? Our tentative finding is that in equilibrium, very large firms expect higher profits per average R&D dollar invested, but that market share itself adds only a little to these profits, although it does increase the value of the firm overall. This would seem to lean in the direction of the Schumpeterian explanation, but we will need further exploration of the relationship to reach definitive conclusions.

Our planned future investigations include industry variation in this relationship, the addition of industry-level market structure variables to explore the predictions of models like Dasgupta and Stiglitz (1980) and Levin and Reiss (1984), and estimation of the effects of market structure and market share on R&D investment itself.

6 References

Arrow, Kenneth J. 1962. "The Economic Implications of Learning by Doing," *Review of Economic Studies* 19 (June): 155-173.

Cockburn, Iain, and Zvi Griliches. 1988. "Industry Effects and Measurement of Spillover Effects of R&D Investment," *American Economic Review* 78 (May): 419-23.

Cohen, Wesley M., and Richard C. Levin. 1984. "Empirical Studies of Innovation and Market Structure," in R. Schmalensee and R. D. Willig (eds.), *Handbook of Industrial Organization,* Volume II: 1059-1107. Amsterdam: Elsevier-Science.

Blundell, Richard, Rachel Griffith, and John van Reenen. 1995. "Market Dominance, Market Value, and Innovation in a Panel of British Manufacturing Firms," London: Institute for Fiscal Studies Working Paper No. 95-**????**.

Dasgupta, Partha, and Joseph Stiglitz. 1980. "Industrial Structure and the Nature of Innovative Activity," *Economic Journal* 90 (June): 266-93.

Economic Classification Policy Committee. 993. Issues Paper No. 1, "Conceptual Issues," *Federal Register* (March 31): 16991-17000.

Executive Office of the President, Office of Management and Budget. 1987. *Standard Industrial Classification Manual 1987*, Springfield, Virginia: Technical Information Service.

Gilbert, Richard J., and David M. G. Newberry. 1982. "Preemptive Patenting and the Persistence of Monopoly," *American Economic Review* 72 (No. 3): 514-526.

Griliches, Zvi, Bronwyn H. Hall, and Ariel Pakes. 1991. "R&D, Patents, and Market Value Revisited: Is There a Second (Technological Opportunity) Factor?," *Economics of Innovation and New Technology* 1: 183-202.

Griliches, Zvi. 1994. "Productivity, R&D, and the Data Constraint," *American Economic Review* 84 (No. 1): 1-23.

Griliches, Zvi. 1992. "The Search for R&D Spillovers," *Scandinavian Journal of Economics* 94: 529-548.

Griliches, Zvi, and Jerry A. Hausman. 1986. "Errors in Variables in Panel Data," *Journal of Econometrics ????.*

Hall, Bronwyn H. 1996. "The Private and Social Returns to R&D: What Have We Learned?," in Smith, Bruce L. R., and Claude Barfield (eds.), *Technology, R&D, and the Economy,* Washington, DC: The Brookings Institution and the American Enterprise Institute.

__________. 1993a. "The Stock Market Valuation of R&D Investment During the 1980s," *American Economic Review* 83 (May): 259-264.

__________. 1993b. "New Evidence on the Impacts of R&D," *Brookings Papers on Economic Activity* (Microeconomics): 289-343.

__________. 1990. "The Manufacturing Sector Master File: 1959-1987," Cambridge, Mass.: National Bureau of Economic Research Working Paper No. 3366.

Hayashi, Fumio. 1982. "Tobin's Marginal q and Average q: A Neoclassical Interpretation," *Econometrica* 50 (No. 1): 213-224.

Hayashi, Fumio, and Tonru Inoue. 1991. "The Relation between Firm Growth and q with Multiple Capital Goods: Theory and Evidence from Panel Data on Japanese Firms," *Econometrica* 59 (No. 3): 731-753.

Jaffe, Adam B. 1986. "Technological Opportunity and Spillovers of R&D: Evidence from Firms' Patents, Profits, and Market Value," *American Economic Review* 76 (No. 5): 984-1001.

Lee, T., and L. L. Wilde. 1980. "Market Structure and Innovation: A Reformulation," *Quarterly Journal of Economics* 94: 429-436.

Levin, Richard C., Alvin Klevorick, Richard R. Nelson, and Sidney G. Winter. 1987. "Appropriating the Returns to Industrial R&D," *Brookings Papers on Economic Activity* 3: 785-

832.

Levin, Richard C., and Peter C. Reiss. 1984. "Tests of a Schumpeterian Model of R&D and Market Structure," in Griliches, Zvi (ed.), *R&D, Patents, and Productivity,* Chicago: University of Chicago Press.

Levin, Richard C. 1988. "Appropriability, R&D Spending, and Technological Performance," *American Economic Review* 86 (May): 424-428.

Loury, Glenn. 1979. "Adjustment Costs and the Theory of Supply," *Quarterly Journal of Political Economy* 93: 395-410.

Lucas, Robert E. 1967. "Adjustment Costs and the Theory of Supply," *Journal of Political Economy* 75 (No. 4): 321-343.

Mansfield, Edwin. 1987. " ?????,".

Martin, Stephen. 1988. *Industrial Economic Analysis and Public Policy,* New York: MacMillan and Co.

Mohnen, Pierre. 1994. "The Econometric Approach to R&D Externalities," Montreal: Universitė du Quebec a Montreal Working Paper No. 9408.

Nelson, Richard R. 1959. "The Simple Economics of Basic Research," *Journal of Political Economy* 67: 297-306.

Nelson, Richard R., and Sidney G. Winter. 1982. *An Evolutionary Theory of Economic Change.* Cambridge, Mass: ??????.

Restoy, Fernando, and Michael Rockinger. 1994. "On Stock Market Returns and Returns on Investment," *The Journal of Finance* XLIX (June): 543-565.

Romer, David. 1996. *Advanced Macroeconomics.* New York: McGraw-Hill Co.

Romer, Paul. 1990. "Endogenous Technological Change," *Journal of Political Economy* 96 (October): S71-S102.

Reinganum, Jennifer F. 1983. "Uncertain Innovation and the Persistence of Monopoly," *American Economic Review* 73: 61-66.

__________. 1989. "The Timing of Innovation: Research, Development, and Diffusion," in *The Handbook of Industrial Organization,* New York: Elsevier Science Publishers, Vol. I: 175-204.

Salinger, Michael. 1984. "Tobin's q, Unionization, and the Concentration-Profit Relationship," *Rand Journal of Economics* 15 (Summer): 159-170.

Solow, Robert M. 1956. "A Contribution to the Theory of Economic Growth," *Quarterly Journal of Economics* 70 (February): 65-94.

Tobin, James. 1969. "A General Equilibrium Approach to Monetary Theory," *Journal of Money, Credit, and Banking* 1 (February): 15-29.

Wildasin, David E. 1984. "The q Theory of Investment with Many Capital Goods," *American Economic Review* 74 (No. 1): 203-210.

Table 1
Descriptive Statistics
3932 Observations on 887 Firms (1987-1991)

Variable	Mean	Median	Standard deviation	IQ Range 1Q	3Q	Minimum	Maximum
Market value ($M)**	236.75	176.27	1.99	52.56	903.93	0.83	201,592
Tangible assets ($M)**	144.60	103.75	2.04	33.46	572.78	0.46	97,149
Sales ($M)**	266.40	200.34	1.93	64.72	1017.39	1.75	124,991
Tobin's q** (mkt value to assets ratio)	1.64	1.52	0.62	1.08	2.37	0.18	9.91
Tobin's q corrected** (mkt value to assets+R&D)	1.19	1.48	0.63	0.81	1.75	0.08	8.59
Investment-assets ratio(%)	11.10%	9.29%	8.11%	5.81%	14.10%	0.10%	94.16%
R&D-assets ratio(%)	9.38%	5.35%	11.14%	2.18%	12.44%	0.07%	94.65%
R&D stock-assets ratio(%)	42.90%	26.94%	48.00%	12.19%	56.48%	0.61%	423.70%
Weighted market shares (%)	4.34%	0.93%	9.28%	0.25%	3.86%	0.01%	97.09%
4-Firm concentration ratio (%)*	37.01%	33.72%	15.46%	28.17%	48.70%	9.00%	88.84%
Herfindahl index*	675.1	506.8	497.2	391.4	911.7	45.0	2600.4

*These variables for 887 observations in 1987 only.
**The geometric mean and s.d. of the log are shown for these variables.

Table 2

Market Value Regressions: 1987-1991
3932 observations (1558 with segment data)
Dependent Variable: Log of Market Value

Independent variable	R&D Measure					
	Flow	Stock	Flow	Stock	Flow with ind dums	Flow segment firms
Log assets	0.939 (0.006)	0.922 (0.006)	0.938 (0.006)	0.923 (0.006)	0.927 (0.006)	0.959 (0.008)
R&D-assets ratio	1.49 (0.10)	0.14 (0.03)	1.52 (0.13)	0.11 (0.03)	1.53 (0.11)	1.95 (0.36)
Market share	0.51 (0.11)	0.68 (0.11)	0.60 (0.13)	0.49 (0.16)	0.53 (0.13)	-.26 (0.21)
Market share*R&D-assets ratio			-.90 (0.85)	0.51 (0.34)	0.05 (0.91)	14.9 (4.1)
Standard error	0.576	0.594	0.576	0.594	0.529	0.501
R-squared	0.917	0.911	0.917	0.911	0.93	0.947
LM (heteroskedasticity)	47.9 (.000)	46.6 (.000)	46.8 (.000)	46.6 (.000)	78.9 (.000)	8.8 (.003)
Durbin-Watson	0.846 (.000)	0.844 (.000)	0.845 (.000)	0.846 (.000)	0.898 (.000)	0.796 (.000)
Ramsey's RESET	12.4 (.000)	9.0 (.003)	11.2 (.001)	12.3 (.000)	11.5 (.001)	1.2 (.277)

All equations include a full set of year dummies.

Standard errors in parentheses are heteroskedastic-consistent estimates.

Segment firms are firms where data on sales by business segment was used in constructing the market share variable.

21 industry dummies at the 2/3 digit level were included in the regression in column (5) (see Appendix A for details).

Diagnostic tests for heteroskedasticity, serial correlation, and nonlinearity are shown with p-values in parentheses.

Table 3

Market Value Regressions: 1987-1991
3932 observations (887 Firms)
Dependent Variable: Log of Market Value

Independent variable	R&D Measure Flow	Stock	Flow	Stock	Flow with ind dums	Flow segment firms
Log assets	0.914 (0.007)	0.892 (0.007)	0.913 (0.007)	0.894 (0.007)	0.896 (0.013)	0.891 (0.013)
R&D-assets ratio	1.43 (0.10)	0.11 (0.03)	1.55 (0.13)	0.11 (0.03)	1.42 (0.15)	0.11 (0.34)
0.01<MS<0.04 (952 obs.)	0.09 (0.03)	0.11 (0.03)	0.15 (0.03)	0.14 (0.03)	0.19 (0.03)	0.17 (0.04)
0.04<MS<0.08 (400 obs.)	0.20 (0.04)	0.25 (0.04)	0.23 (0.04)	0.23 (0.04)	0.28 (0.04)	0.26 (0.05)
0.08<MS<1.0 (555 obs.)	0.28 (0.04)	0.35 (0.04)	0.27 (0.04)	0.23 (0.05)	0.33 (0.05)	0.26 (0.05)
30M<assets<100M (1038 obs.)					-0.06 (0.04)	-0.01 (0.04)
100M<assets<500M (950 obs.)					-0.07 (0.05)	-0.05 (0.05)
500M<assets (1040 obs.)					-0.07 (0.07)	-0.02 (0.08)
Small MS * (R/A)			-0.63 (0.23)	-0.09 (0.05)	-1.08 (0.23)	-0.19 (0.06)
Medium MS * (R/A)			-0.28 (0.33)	0.03 (0.08)	-1.07 (0.30)	-0.12 (0.11)
Large MS * (R/A)			0.18 (0.28)	0.32 (0.09)	-0.48 (0.32)	0.20 (0.11)
Small size * (R/A)					-0.06 (0.26)	-0.13 (0.06)
Medium size * (R/A)					0.90 (0.25)	0.13 (0.07)
Large size * (R/A)					1.85 (0.33)	0.28 (0.10)
Standard error	0.573	0.591	0.573	0.590	0.568	0.587
R-squared	0.918	0.912	0.918	0.913	0.919	0.914
LM (heteroskedasticity)	42.9 (.000)	52.2 (.000)	51.7 (.000)	57.3 (.000)	57.2 (.000)	58.7 (.003)
Durbin-Watson	0.857 (.000)	0.857 (.000)	0.860 (.000)	0.862 (.000)	0.869 (.000)	0.867 (.000)
Ramsey's RESET	16.1 (.000)	14.8 (.000)	17.9 (.000)	22.5 (.000)	16.9 (.000)	21.8 (.000)

All equations include a full set of year dummies.
Standard errors in parentheses are heteroskedastic-consistent estimates.
The omitted categories are tiny market share (less then 1 percent) and tiny size (assets less than 30 million dollars).

Table A1
Industry Codes: IND-IDS-SIC Correspondence

Chandler Segment	IND Industry (Quasi 2-digit)	IDS	Old (S-L) IDS	IDS, SIC Description	SIC Codes (1987)
4 Low-tech	01 Food & tobacco	1	1	Meat products	2010 2011 2013 2015 2016
	01 Food & tobacco	4	3,4	Dairy products	2020 2021 2022 2023 2024 2026
	01 Food & tobacco	6	5,6	Canned & frozen foods	2030-2032 3037 2038 2053 3091 3092
	01 Food & tobacco	7	7	Processed fruits & vegetables	2033 2034 2035 2068 2096
	01 Food & tobacco	8	8	Breakfast cereals	2043
	01 Food & tobacco	10	10	Animal feed	2047 2048
	01 Food & tobacco	11	11	Grain mill products	2040 2041 2044 2045
	01 Food & tobacco	12	12	Wet corn milling	2046
	01 Food & tobacco	13	13	Bakery products	2050 2051 2052
	01 Food & tobacco	14	14,15,16	Sugar chocolate & cocoa prods.	2060-2067
	01 Food & tobacco	18	18	Fats & oils	207x
	01 Food & tobacco	19	19	Malt & malt beverages, alcoholic bev.	2082 2083 2084 2085
	01 Food & tobacco	21	21	Soft drinks & flavourings	2080 2086 2087
	01 Food & tobacco	22	22	Miscellaneous preproduced food	2090 2095 2098 2099
	01 Food & tobacco	23	23	Tobacco products	21xx
4 Low-tech	02 Textiles, apparel & footwear	24	--	Textile mill products	22xx excl. 2270 2273
	02 Textiles, apparel & footwear	27	--	Rugs	2270 2273
	02 Textiles, apparel & footwear	34	--	Apparel	23xx 3965
	02 Textiles, apparel & footwear	62	--	Footwear, rubber & leather	3021 314x
	02 Textiles, apparel & footwear	163	--	Leather & leather products	310x-313x 315x 316x 317x 319x 3961
4 Low-tech	03 Lumber & wood products	25	25	Logging & sawmills	241x 242x
	03 Lumber & wood products	26	26	Millwork, veneer & plywood	243x 2450 2451 2452
	03 Lumber & wood products	33	--	Wood products	244x 249x
4 Low-tech	04 Furniture	28	--	Household furniture	251x
	04 Furniture	29	29	Office furniture	252x
	04 Furniture	30	30	Shelving, lockers, office & store fixtures	253x 254x 259x
4 Low-tech	05 Paper & paper products	31	31	Pulp, paper & paperboard mills	261x 262x 263x
	05 Paper & paper products	32	32, 35, 36	Industrial paper & paper products	2600 264x 265x 266x
	05 Paper & paper products	39	--	Converted paper - household use	267x
4 Low-tech	06 Printing & publishing	37	37	Commercial printing	275x 2796
	06 Printing & publishing	38	--	Printing & publishing	27xx excl. 275x 2796
2 Stable tech	07 Chemical products	40	39, 40, 41	Industrial inorganic chemicals	281x
(Long horizon)	07 Chemical products	42	42, 43, 44	Plastic materials & resins	282x
	07 Chemical products	48	48	Paints & allied products	285x
	07 Chemical products	49	49	Industrial organic chemicals	286x
	07 Chemical products	50	50, 51	Fertilizer	287x
	07 Chemical products	52	52	Explosives & misc. chemicals	289x
2 Stable tech	08 Petroleum refining & prods	51	--	Asphalt, roofing & misc coal/oil prods	2950 2951 2952 2990 2992 2999
(Long horizon)	08 Petroleum refining & prods	53	53	Petroleum & refining	291x 1311 1389
3 Stable tech	09 Plastics & rubber prods	54	54	Tires & innertubes	301x
(Short horizon)	09 Plastics & rubber prods	55	55	Plastic products	307x 3080 3084-3089
	09 Plastics & rubber prods	56	--	Unsupported plastics, films &sheets	3081 3082 3083
	09 Plastics & rubber prods	164	--	Packing & sealing dev. & fab. rubber nec	3050 3051 3052 3053 3060 3061 3069
3 Stable tech	10 Stone, clay & glass	57	57	Glass & glass products	321x 322x 323x
(Short horizon)	10 Stone, clay & glass	58	58	Cement	324x
	10 Stone, clay & glass	59	59	Structural clay products	325x
	10 Stone, clay & glass	60	60	Pottery & related products	326x
	10 Stone, clay & glass	61	61, 62	Concrete, gypsum & related prods	327x
	10 Stone, clay & glass	63	63, 64, 65	Abrasive asbestos & mineral wool prods	329x
2 Stable tech	11 Primary metal products	66	66	Steelworks, rolling & finishing mills	331x
(Long horizon)	11 Primary metal products	67	67	Iron & steel foundries	332x
	11 Primary metal products	70	--	Primary metal products	339x
	11 Primary metal products	71	71	Prim aluminum smltg, reg, roll, &draw	3334 3353 3354 3355

	11 Primary metal products	72	68,69,70,72	Primary smeltg & refing (non-ferrous)	3330 3331 3332 3333 3339
	11 Primary metal products	73	73	Secondary smeltg & refing (non-fer.)	334x
	11 Primary metal products	74	74	Rolling, drawing, & extruding of nonferr.	3350 3351 3356
	11 Primary metal products	75	75	Drawing & insulating of nonfer. wires	3357
	11 Primary metal products	76	76	Nonferrous metal casting	336x
3 Stable tech	12 Fabricated metal products	77	77	Metal cans & containers	3411 3412
(Short horizon)	12 Fabricated metal products	78	78, 79	Cutlery & hand tools	342x
	12 Fabricated metal products	80	80	Heating equipment & plumbing fix.	3430 3431 3432 3433 3437 3467
	12 Fabricated metal products	81	81, 82, 83	Fabricated structural metal	344x
	12 Fabricated metal products	84	84	Screw machine products, bolts, nuts	345x
	12 Fabricated metal products	85	85	Metal forgings, plating & coating	346x 347x
	12 Fabricated metal products	86	--	Wire springs & misc. metal prods.	3495-3499
	12 Fabricated metal products	89	89	Ordnance & accessories	348x
	12 Fabricated metal products	90	90	Valves & pipe fittings	3490 3491 3492 3493 3494
2 Stable tech	13 Machinery & engines	91	91, 92	Turbines, generators, & combustion eng.	351x
(Long horizon)	13 Machinery & engines	93	93	Lawn, garden & farm mach. & equip.	3523 3524
	13 Machinery & engines	95	95, 96	Const. & mining mach. & equip.	3530 3531 3532
	13 Machinery & engines	97	97	Oilfield machinery	3533 3534
	13 Machinery & engines	99	99	Conveyors, ind. trucks&cranes, monorails	3535 3536 3537
	13 Machinery & engines	102	102, 103	Mach. tools, metalworking eq. & acc.	354x excl. 3548
	13 Machinery & engines	104	104	Special industrial machinery	3550 3559
	13 Machinery & engines	105	105	Food prods & packaging machinery	3556 3565
	13 Machinery & engines	106	106	Textile machinery	3552
	13 Machinery & engines	108	108	Wood & paper industry machinery	3553 3554
	13 Machinery & engines	109	109	Printing trades machinery & equip.	3555
	13 Machinery & engines	110	110	Pumps & pumping equip.	3561 3586 3594
	13 Machinery & engines	111	111	Ball & roller bearings	3562
	13 Machinery & engines	112	112, 113	Compressors, exhaust., & ventilation fans	3563 3564 3634
	13 Machinery & engines	113	--	General industrial machinery	3560 3568 3569 359x
	13 Machinery & engines	114	114	Ind. high drives, changers & gears	3566
	13 Machinery & engines	115	115	Industrial process furnace ovens	3567 3558
	13 Machinery & engines	118	118	Scales & balances excl. laboratory	3596
	13 Machinery & engines	123	--	General office machines	3579
1 High-tech	14 Computers & comp. equip.	116	116	Electronic computing equipment	3570-3573 3575 3576 3577
	14 Computers & comp. equip.	117	--	Calculating machines excl. comp.	3578
1 High-tech	15 Electrical machinery	119	119	Refrigerating & heating equip. (comml)	3580-3582 3585 3589 3596
	15 Electrical machinery	120	120	Power distribution & transformers	3612
	15 Electrical machinery	121	121	Switchgear & switchboard apparatus	3613
	15 Electrical machinery	122	122	Motors, generators & industrial controls	3600 3620 3621 3622 3625
	15 Electrical machinery	124	--	Electronic & electric coils & connectors	3524 3677
	15 Electrical machinery	126	126	Household refrigerators & freezers	3630 3631 3632 3633 3635 3639
	15 Electrical machinery	128	128	Lighting fixtures & equipment	3640 3641 36425 3646 3647 3648
	15 Electrical machinery	134	134	Primary & storage batteries	3691 3692 3693
	15 Electrical machinery	135	135	Engine elctrical equipment & misc	3694 3699
	15 Electrical machinery	137	--	Electronic & electric connections	3643 3644 3678
1 High-tech	16 Electronic inst. & comm. eq.	125	--	Electronic signaling & alarm systems	3669
	16 Electronic inst. & comm. eq.	127	--	Radio & TV broadcasting sets	3663
	16 Electronic inst. & comm. eq.	129	129	Radio & TV receiving sets	3651
	16 Electronic inst. & comm. eq.	130	130	Records, magnetic, &optical recording	3652 3690 3695
	16 Electronic inst. & comm. eq.	131	--	Communication equipment	3661 3662 3669 4810 4812 4813
	16 Electronic inst. & comm. eq.	132	132	Electron tubes	3671
	16 Electronic inst. & comm. eq.	133	133	Semiconductors & printed circuit boards	3672 3674 3675 3676
	16 Electronic inst. & comm. eq.	138	--	Electronic components, computer acc.	3670 3679
	16 Electronic inst. & comm. eq.	147	147	Engineering scientific instruments	381x
	16 Electronic inst. & comm. eq.	148	148	Measuring & controlling devices	382x
1 High-tech	17 Transportation equipment	141	141, 142	Aircraft parts & engines	3720 3721 3724 3728
	17 Transportation equipment	143	143	Ship & boat building & repairing	373x 3795
	17 Transportation equipment	144	144	Railroad equipment	374x
	17 Transportation equipment	145	145	Complete guided missiles, aerospace	376x
2 Stable tech	18 Motor vehicles	136	136	Motor vehicles	3711 3713 3715 3799

(Long horizon)	18 Motor vehicles	140	--	Motor homes	3716 3792
	18 Motor vehicles	146	--	Motorcycles & bicycles	3751 3790
1 High-tech	19 Optical & medical instruments	149	149	Optical instruments & lenses	3827
	19 Optical & medical instruments	150	150	Dental equipment & supplies	3843
	19 Optical & medical instruments	151	151	Surg. & med. inst., appliances, & supplies	3840 3841 3842
	19 Optical & medical instruments	152	--	X-ray apparatus	3844
	19 Optical & medical instruments	153	153	Photographic equipment & supplies	3861
	19 Optical & medical instruments	154	-	Electromedical apparatus	3845
1 High-tech	20 Pharmaceuticals	45	45	Pharmaceuticals	283x
	20 Pharmaceuticals	155	--	Opthalmic goods	3851
4 Low-tech	21 Misc. manufacturing	156	--	Musical instruments	3931
	21 Misc. manufacturing	157	157	Sporting & athletic goods	3949
	21 Misc. manufacturing	158	158	Dolls, games & toys	3942 3944
	21 Misc. manufacturing	159	159	Pens, pencils, & other office & artists mat.	395x
	21 Misc. manufacturing	160	--	Misc. manufacturing industries	399x
	21 Misc. manufacturing	162	--	Jewelry & watches	3873 3910 3911 3914 3915 396x
3 Stable tech	22 Soap & toiletries	46	46	Perfumes & toilet prods.	2844
(Short horizon)	22 Soap & toiletries	47	47	Soaps & cleaning products	2840-2843
3 Stable tech (SH)	23 Auto parts	139	139	Motor vehicle parts & accessories	3714

Chandler segment: 4 industry segments from Al Chandler (Business History Review, Summer 1994).

IND: Corresponds roughly to the old ARDSIC (Bound et al) but with soap and auto parts broken out for Chandler's segments.

IDS: Hall-Vopel industries, based on the old Scherer-Levin classification (used in Levin-Reiss and Yale survey stuff).

IDS (old) : correspondence to Scherer-Levin

SIC: 4-digit sic, using 1987 codes, but roughly corresponding to those in use by Compustat, although not all will be populated.