Size, Leverage, Concentration, and R&D Investment in Generating Growth Opportunities

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We show that a firm's ability to reap growth opportunities from R&D investments depends on its size, leverage, and the industry concentration. While the direct effects of these factors are significant, the size-leverage interaction reveals further important insights. Large firms' advantages over small firms disappear as their leverage increases. Specifically, small firms with high leverage reap the greatest growth opportunities. Our results provide explanations for inconsistent findings observed when size and leverage are considered independently in existing studies on value and stock return relevance of R&D investment. We also highlight firm-specific factors that guide investors' valuation of R&D.

I. Introduction

The extent to which R&D investments affect stock performance is determined by investor beliefs and expectations that are informed by factors such as the R&D expenditure to market value of equity ratio, debt ratio, planned R&D increases, and growth opportunities (Szewczyk, Tsetsekos, and Zantout 1996; Zantout 1997; Chan, Lakonishok, and Sougiannis 2001). This interdisciplinary study[1] develops some insights into this expectation formation by investigating how three important characteristics salient to the investor,

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1. This interdisciplinary study includes studies in accounting, corporate finance, economics, industrial organization, and strategic management.

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namely, firm size, financial leverage, and industry concentration, affect the degree and type of influence R&D investment exerts on the growth opportunities of firms. Schumpeter (1952) and Arrow (2000) find that greater access to financing sources allows larger firms to be more innovative. Schumpeter (1934) alludes to the fact that innovation cannot be funded by returns from a firm’s normal operating cycle but must depend on credit, and Arrow (2000) notes that the availability of the alternative funding sources depends on firm size. In addition, Williamson (1988) notes that the optimal financing sources are restricted since the intangible nature of assets created by R&D investments calls for an appropriate governance structure to reduce transaction costs and to control managerial opportunistic behavior. Thus firm size and financial leverage are not two independent firm variables, but rather they interact to determine the value of R&D investment. Furthermore, Schumpeter (1952) highlights the important contextual role that industry structure plays in the innovative endeavor when he observes that firms in monopolistic competition produce more innovation as opposed to those in the perfectly competitive market.

Our study differs from existing literature in several ways. First, we examine the interaction effects of firm characteristics (firm size and financial leverage) and an industry characteristic (industry concentration) on the impact that R&D investment has on the growth opportunities of a firm. Existing literature, on the other hand, has treated these firm and industry characteristics as independent effects, thus failing to capture the interaction effects that naturally arise from the arguments put forth by Schumpeter (1934), Williamson (1988), and Arrow (2000). Second, while other studies of the impact of R&D on firm value employ ex post measures such as returns or stock price, we choose to examine the effectiveness of R&D investment through the use of an ex ante measure, namely, a firm’s growth opportunities. Ex post measures of firm value or performance can mask the real impact of R&D since they tend to be affected by the firm’s endogenous characteristics and market forces in the intervening period. The use of an ex ante measure in the form of growth opportunities is appropriate since R&D investment is a form of intangible investment that contributes to the long-term growth of the firm (Chan et al. 2001; Chambers, Jennings, and Thompson 2002). The measure of growth opportunities is a better ex ante measurement of the market perception of the value creation of R&D investment.

Our study makes three contributions. First, we provide evidence to show the positive impact of R&D investment on the growth opportunities of a firm. Second, we provide empirical evidence on the direction and intensity of the collective interaction effects of firm size, financial leverage, and industry concentration on the R&D investment–growth opportunity relationship. Third, we articulate the possible theories that may explain the direction and intensity of these collective interaction effects.

Our study strongly supports the conclusion that R&D investment has a positive impact on firms’ growth opportunities, with this impact amplified by large size and diluted by high industry concentration. Furthermore, analysis of the firm size, financial leverage, and industry concentration interactions shows that the advantages of firm size are moderated by the levels of financial leverage but not by industry concentration. That is, R&D investments are positively associated with growth opportunities as firm size increases when financial leverage is low but are negatively associated when financial leverage is high; industry concentration appears not to be important.

The findings on the interaction effects are interesting for two reasons. First, they contradict our preconceived economic notions that firm size and industry concentration drive firm growth. We find strong evidence that the comparative advantage of large firms over small firms in reaping growth opportunities from R&D investment is conditional on the firm's level of financial leverage. This result may be explained by the insights from transaction cost analysis that suggests that funding decision affects the governance of a firm. That this effect on firm governance is dissimilar across large and small firms could account for the inconclusive and even contradictory results on the appropriability advantage of R&D investments in large firms observed in a number of prior studies that fail to consider the size-leverage interaction (see, e.g., Kamien and Schwartz [1982] and Cohen and Klepper [1996] and contrast with Acs and Audretsch [1988], among others). Second, the findings of this study allow investors, management, creditors, and economic policy makers to understand the reasons for the optimal combination of firm size, financial leverage, and industry concentration, and investment in R&D that will maximize growth opportunities.

In Sections II and III, we review the literature, discuss the economic rationale that drives our study, outline the research methodology, and provide a description of the sample and the computation of the R&D capital. Sections IV and V present the analysis on the independent and two-way interaction effects of firm size, financial leverage, and industry concentration on R&D investment in generating growth opportunities, respectively, and Section VI concludes the study.

II. Literature Review and Theory Development

The value of a firm is in essence measured by the present value of its future cash flows. This is given by the generic valuation equation

$$V_0 = \sum_{t=1}^{\infty} \frac{CF_t}{(1 + r)^t} \qquad (1)$$

where V_0 is the value of a firm at $t = 0$, CF_t is the cash flow at time t, and r is the appropriate discount rate. In this study, we use growth opportunities as an ex ante measure of a firm's ability to generate cash flow from its assets. Contributions to firm value occur at three levels. Contributions at the first level come from relatively easy to value tangible assets in place such as land, building, and equipment. At the next level of complexity, contributions come from merger and acquisition activities. Though these may be more difficult to value, the presence of similar firms and relative valuations facilitate the valuation process. At another level, contribution can come from intangible assets such as brand names and intellectual property developed through advertising and R&D, respectively.[2] However, contributions from this level are difficult to value since further investments may be necessary to exploit the intellectual property and such investments are likely to create firm-specific intangible assets of little value to outsiders (Balakrishnan and Fox 1993; O'Brien 2003). In summary, growth opportunities are affected by investments in tangible assets, mergers and acquisitions, and intangible assets.

Besides assets, Lang, Ofek, and Stulz (1996) and McGahan (1999a, 1999b) conclude that the growth opportunities of a firm are also determined by its endogenous firm characteristics of size and financial leverage, as well as external industry structure factors such as the level of concentration. The dependency of growth opportunities on a firm's investments, its endogenous characteristics, and industry structure can be summarized as follows:

$$\text{GO} = f\,[\text{Investment(TA, M\&A, ITA), SIZE, LEVERAGE, CONC}], \tag{2}$$

where GO, the growth opportunities of a firm, is a function of the three types of investments, the size of the firm (SIZE), its financial leverage (LEVERAGE), and the level of concentration in the industry in which it operates (CONC). The three types of investments, tangible assets (TA), mergers and acquisitions (M&A), and intangible assets (ITA), which include brand name, advertising, and R&D, important though they are to growth opportunities, will not be examined in full in this study. This study concentrates on the impact of R&D on the growth opportunities of a firm, and hence, the following section develops economic theories on how firm size, financial leverage, and industry concentration affect the effectiveness of R&D in generating growth opportunities.[3] We then discuss how the interactions of firm size, financial leverage, and industry concentration moderate the relationship between a firm's R&D investment and its growth opportunities.

A. Firm Size and R&D's Impact on Growth Opportunities

A large body of literature in the field of industrial organization and economics has been devoted to interpreting and testing two popular hypotheses ex-

2. Martin (2002) provides a summary of some of the valuation models that relate R&D investment to the valuation of a firm. Our study assumes this linkage and seeks to test the various conditions in which R&D investment is most effective in increasing the value of a firm.

3. We are aware that investments in tangible assets, mergers and acquisitions, brand names, and advertising are important determinants of the growth opportunities of a firm. A complete model inclusive of these three determinants will be the subject of future study. This paper focuses on a reduced form: the R&D effect on growth opportunities given two endogenous characteristics of the firm and one characteristic of the industry in which it operates.

pounded by Schumpeter (1952) on innovation. The two hypotheses are as follows:

a. Large firms are disproportionately more innovative than small firms.
b. Large firms can exploit the results of innovation better than small firms.

These hypotheses raise two questions about the firm size–R&D investment relationship. The first is whether economies of scale exist for R&D. The evidence from previous studies that have examined the direct output from R&D investment suggests that there are no economies of scale in R&D, but, rather, the law of diminishing returns seems to hold (Acs and Audretsch 1988). Acs, Audretsch, and Feldman (1994) observe that small firms' ability to benefit from R&D spillover makes them relatively more innovative, whereas Parker (1978) points out that control and bureaucracy problems within large firms hamper their R&D efficiency. Thus there appears to be no conclusive evidence that large firms are more innovative than small firms.

The second question is whether firm size plays any role in a firm's ability to appropriate the results of R&D investment. Chan, Martin, and Kensinger (1990) and Chauvin and Hirschey (1993) and find that the positive effect of R&D investment on firm value is strongest for the largest firms. Levin et al. (1987) argue that firms consider investment in complementary sales and service efforts as highly effective means for the appropriation of product innovation. Since large firms are more likely to have control of and access to these assets than small firms, they can be more effective in reaping the results of their R&D investments. Therefore, although large firms may be less productive in undertaking R&D at the margin, they are more effective in appropriating the results of the R&D output.[4] Thus we hypothesize that the appropriability advantages of larger firms result in their superior ability to create growth opportunities from their R&D investment compared to smaller firms.

B. Financial Leverage and R&D's Impact on Growth Opportunities

The effect on debt financing of R&D investments has been the subject of numerous studies (Szewczyk et al. 1996; Zantout 1997; Vincente-Lorente 2001; O'Brien 2003). The results are mixed, with some finding that debt has a positive effect on R&D investment's ability to create value for the firm and others finding a negative effect or no effect at all. This is not surprising since financial leverage influences managers' investment behaviors in two contrasting manners: positively, through playing a disciplinary role, and negatively, through the presence of agency cost and information asymmetry problems. These contrasting influences confound the effect of leverage. On one hand, the disciplinary role of debt acts as a positive influence on managerial behavior

4. A more protracted line of argument for the advantages of large firms benefiting from R&D includes internal funding capabilities, larger tax shields to cover expenses, brand recognition for large companies (Kamien and Schwartz 1982), sales and marketing advantages (Levin et al. 1987), complementarities, and ready demand, among others.

by reining in managerial discretion and driving managers to invest in projects with positive net present value (NPV). Thus R&D projects undertaken under a high debt ratio regime are expected to add positive value to the firm. This expectation by investors is borne out by the event studies of Szewczyk et al. (1996) and Zantout (1997), where significant positive relationships between abnormal stock returns and announcements of planned increases in R&D expenditures are observed only in firms with a relatively high debt ratio (Zantout and Tsetsekos 1994).

On the other hand, agency cost and information asymmetry problems are likely to negatively influence the ability of a high-leverage firm to appropriate benefits from its R&D investments. Agency cost problems arise when the interests of the debt holders (principal) and managers (agent) cannot be aligned in an R&D investment situation. In such cases, underinvestment and asset substitution detrimental to debt holders can occur more easily in R&D projects than in other capital projects. Knowing the possibility of such behaviors, debt holders would demand a premium that raises the cost of the debt, thus reducing the value of the R&D investment. In addition, information asymmetry reduces the attractiveness of R&D projects to outside investors (debt holders) when managers withhold information to maintain confidentiality for competitive reasons. These outside investors will overestimate the project risk when they have little basis for predicting the outcomes of such projects. Hence, agency cost and information asymmetry problems render debt financing of R&D projects relatively more expensive and less preferred than other options. For example, Bhagat and Welch (1995) observe a negative association between the debt ratio of firms and R&D investment effect on the value of firms. In another example, Kamien and Schwartz (1982) posit that investors will value a firm's R&D effects positively when they use their own funds for their R&D efforts.[5]

In addition to the above two opposing theories on how financial leverage influences managers' investment behaviors, there is a significant branch of literature on transaction cost economics that examines how the types of investment made by managers affect the capital structure of a firm.[6] Williamson (1988, 567) noted that the choice of project financing "depends principally on the characteristics of the assets." Titman and Wessels (1988, 17) put it in another way, by postulating that "debt levels are negatively related to the 'uniqueness' of a firm's line of business." This is based on the tenet that governance[7] structures must be crafted to "economize on bounded rationality while simultaneously safeguarding the transaction in question against the hazards of opportunism" (Williamson 1988, 569). Investment in R&D poses one

5. Investors in firms undertaking R&D face two problems: difficulty in monitoring the manager's action in R&D and the information asymmetry problem, whereby the managers have more information pertaining to the value of the project and variance of the returns than investors.

6. We thank an anonymous referee for bringing this new insight to our attention.

7. In the transaction cost economics literature, governance relates to the policing mechanism of the contractual relationships between parties to a firm.

such challenge because it results in firm-specific assets that "cannot be costlessly deployed to other uses" (Balakrishnan and Fox 1993, 3). The end result is that such firm-specific assets cannot be used effectively as collateral for borrowings (O'Brien 2003). Hence, strategic management studies have concluded that firms with higher degrees of firm-specific assets (such as investment in R&D) are found to have less debts since equity financing is optimal for assets whose values can be appropriated only by such firms (Williamson 1988; Balakrishnan and Fox 1993; Vincente-Lorente 2001; O'Brien 2003).

Thus we hypothesize that although financial leverage and investment in R&D are negatively related, leverage will play an ambiguous role in influencing a firm's ability to appropriate benefits of R&D investment in generating growth opportunities as a result of the interaction between the positive effects of its disciplinary role and the negative effects of agency cost and information asymmetry problems. The final impact of financial leverage and investment in R&D on growth opportunities may depend on firm size (Acs and Isberg 1996) or the industry structure the firm operates in.

C. Industry Concentration and R&D's Impact on Growth Opportunities

In addition to the above endogenous factors affecting the value obtainable from R&D investments, we consider a third salient exogenous factor: industry concentration. Contrary to Schumpeter's (1952) suggestion that market power provides the condition for earning abnormal profits from innovation, a number of studies find that high industry concentration, which would suggest high market power, has, in fact, a negative moderating effect on the generation of value by R&D investments (Grabowski and Mueller 1978; Connolly and Hirschey 1984). There exist two plausible reasons for this counterintuitive observation. First, increased intraindustry rivalry driven by the visibility of competitors' actions in high-concentration industries forces firms to adopt similar levels of R&D investments irrespective of the expected returns, in order to appear to be on the cutting edge and to "keep up with the Joneses" (Grabowski and Mueller 1978; Connolly and Hirschey 1984).[8] Second, new product and process leakages (Mansfield 1985) are also greater in high-concentration industries, thus leading to the inability of firms to fully capture value from their innovations.

However, Doukas and Switzer (1992) find that announcements of unexpected increases in R&D expenditure lead to positive abnormal stock returns in the short term only if the announcing firm is in a high-concentration industry. They confirm the Schumpeterian postulation that firms in perfectly competitive markets perform poorly in innovation compared to those operating in more concentrated markets, and that investors appear to attribute market concentration as a significant factor in a firm's ability to benefit from its R&D investment.

8. This is a form of herding behavior similar to the spirit of rational behavior proposed in Scharfstein and Stein (1990).

Thus there exists conflicting empirical evidence and economic rationale on the direction of the moderating impact of high industry concentration on the effectiveness of R&D investment in generating growth opportunities.

D. Interactions of Firm and Industry Characteristics on R&D Investment

The initial focus on the independent effect of each of the firm and industry characteristics was broadened to include the interactions of these firm and industry characteristics when it became obvious that such interactions do occur. The effect of industry concentration may be especially salient (McGahan 1999a, 1999b). The strategic interaction among the small number of large firms in a high-concentration industry is likely to lead to competitive matching since the actions of each firm are very visible. Competitive matching may dilute the appropriability advantage large firms obtain from their R&D investments when it leads to the funding of negative NPV projects. Compared to large firms, smaller firms may face a double disadvantage in a high-concentration industry for two reasons. First, the greater relative difference in size between large and small firms in such a high-concentration industry will render the small firm's appropriability advantage weaker than in a more competitive market. Second, small firms face a potential resource drain in the competitive matching race because of their limited size and access to funds.

In addition, industry concentration could also affect the moderating impact of financial leverage. Under high industry concentration conditions, the disciplinary role of high financial leverage may not be perceived as strong enough to prevent firms facing competitive matching pressure from funding negative NPV R&D projects.

What about the interaction between size and leverage? Transaction cost analysis can throw some light on the size-leverage interaction effect. Acs and Isberg (1996) find that even though the intangible nature of innovation assets arising from R&D investment is an important determinant of a firm's capital structure, the firm size effect on capital structure seems to dominate. Large firms that invest in innovation resulting in firm-specific assets that are less acceptable for collateral purposes use less debt. On the contrary, Acs and Isberg (1996) find that small firms actually use more debts to finance their innovations. There exist several explanations for this small-firm effect. First, limited access to equity capital and binding liquidity constraints (Fazzari, Hubbard, and Petersen 1988; Evans and Jovanovic 1989; Holtz-Eakin, Joulfaian, and Rosen 1994) leave debt as the primary financing alternative for small firms that desire to invest in positive NPV investment. Second, small firms facing binding liquidity constraints most likely must source funds from banks for their attractive R&D investments since such firms are unlikely to have access to impersonal centralized debt markets (Fazzari et al. 1988). These small firms can overcome the information asymmetry problems since they can divulge proprietary project information to banks on a confidential basis without the information spilling over to competitors. Third, the small size of the firms facilitates the lenders' task of conducting due diligence and monitoring to ensure that the funds are indeed invested in NPV-enhancing investments. This supposes that small firms are more transparent to lenders than large firms. A final explanation is that since a small firm's R&D investment requirements constitute only a small portion of the lender's total loan portfolio, the financial risk to the lender is relatively low. Acs and Isberg (1991) confirm this fact when they observe that the low funding requirements of small firms allow them to obtain funds from banks, resulting in more personalized banking relationships between the firms and the banks.

Given the above endogenous firm and industry characteristics, we would expect firms to converge to the optimal mix of firm and industry characteristics so as to maximize their growth opportunities. Thus we formulate the following two hypotheses from the above discussion. First, we hypothesize that large firms operating in low-concentration industries with low financial leverage will be in the best position to convert their R&D investment into growth opportunities, since large firms have an appropriability advantage conferred by size. Operating in low-concentration industries frees such firms from competitive matching behavior in R&D investment, and low leverage leaves them with sufficient financial slack to exploit investment opportunities. Second, we hypothesize that small firms operating in low-concentration industries with high financial leverage can maximize growth opportunities from R&D investments. Small firms operating in low-concentration industries without the pressure of competitive matching will embark only on R&D with positive NPV impact. These small firms exercise discipline in their investment choice because binding liquidity constraints force them to borrow from banks, which will advance loans only on projects with positive growth opportunities. Furthermore, small firms will allow the funding banks access to project proprietary information for evaluation and monitoring; thus the banks' willingness to fund these firms' projects is a positive signal of the prospects of the firms.

The above discussion identifies a gap in the literature as to how the firm and industry characteristics will collectively moderate the impact R&D investment has on the growth opportunities of firms. It is important to bridge this gap because the investment decisions of managers, investors, and creditors are affected by their evaluation of how effective firms are in the creation of growth opportunities from R&D investments under differing firm conditions and industry characteristics.

III. Research Design and Description of the Sample

In this section, we present the research design and the data used for the study. Accounting data, covering the period 1979–98,[9] are obtained from COM-

9. Ideally, we would have preferred to cover the period from 1975 onward when the Statement of Financial Accounting Standards no. 2 became effective (Financial Accounting Standards Board 1974). But we were unable to obtain earlier data, from 1975 to 1978, since we do not subscribe to the COMPUSTAT back data.

PUSTAT annual data tapes for both active (CS Active) and research (CS Research) U.S. companies to reduce the possible effects of survivorship bias, and share price data are taken from the Center for Research in Security Prices (CRSP). Only firms with a December 31 fiscal year end are included in order to have a consistent cutoff date and thus higher certainty as to when the financial information of the sample firms were publicly available. This allows us to use the stock price measure at a consistent point in time for all firms in any particular year.[10] The accounting data of year t are matched with stock prices at the end of April of year $t + 1$ to ensure that the annual financial statements of firms for fiscal year t are already available to the public. This method was suggested by Banz and Breen (1986) and Fama and French (1992) to avoid the look-ahead bias.

Our study employs five variables: firm size, financial leverage, industry concentration, growth opportunities, and R&D investment. Firm size is measured by the natural logarithm of a firm's net sales. The proxy for financial leverage is the ratio of book value of long-term debt to book value of total assets at the end of the year. The long-term debt is used because R&D is a long-term investment that is normally financed using long-term financing. Industry concentration is proxied by the percentage of total net sales in a particular industry attributable to the four largest firms (ranked in terms of sales).[11]

Next, growth opportunities are proxied by the ratio market-to-book value of assets (MBASS).[12] Kallapur and Trombley (1999) find that market-to-book ratios such as market-to-book value of assets, market-to-book value of equity, Tobin's q, and the ratio of market value of assets to book value of property, plant, and equipment are most highly correlated with the realized growth of a firm.[13] MBASS is used since it is easy to compute and does not sacrifice accuracy and purpose.

Finally, the amount of capitalized R&D expenditure divided by the firm's book value of total assets at the end of the year is used as the measure of R&D investment in our study. Capitalized R&D investment is used instead of annual R&D expenditure to account for the fact that this investment gen-

10. We are appreciative of the limitation that the omission of non–December 31 fiscal year companies can bias our sample against young technology firms listed on the NASDAQ. Nonetheless, there are a total of 22 industries in our sample according to the two-digit Standard Industrial Classification (SIC).

11. This measure of industry concentration (CR4) is a popular measure in the literature (Connolly and Hirschey 1984; Doukas and Switzer 1992). To be consistent with previous studies for comparison purposes, we have not used the Herfindahl index as a proxy for industry concentration.

12. We have also used the market-to-book value of equity ratio (MBEQU) as the alternative growth opportunities measure, and the results are qualitatively similar.

13. The use of MBASS, MBEQU, and Tobin's q to proxy growth opportunities or firms' future performance has been rigorously applied in many earlier studies (see, e.g., Smith and Watts 1992; Lang et al. 1996; Bharadwaj, Bharadwaj, and Konsynski 1999). The choice of accounting method does affect book value of the assets or equity, which in turn affects the MBASS and MBEQU measures. The simplicity of using MBASS and MBEQU as a measure of growth opportunities outweighs the benefits of constructing more complex measures of growth opportunities.

erates both current and future benefits for the investing firm (Hirschey and Weygandt 1985; Lev and Sougiannis 1996). The erosion of this capital over time due to obsolescence and knowledge leakages to other firms in the industry demands that the capitalized R&D investment be amortized over the duration of the R&D benefits (Griliches 1979). The capitalized R&D investment is computed using the straight line amortization method that is adjusted for inflation as follows:

$$\mathrm{RDI}_{i,t} = \sum_{m=0}^{K-1} \mathrm{RDE}_{i,t-m} \left(1 - \frac{2m+1}{2K}\right)\left(\frac{\mathrm{CPI}_t}{\mathrm{CPI}_{t-m}}\right), \tag{3}$$

where $\mathrm{RDI}_{i,t}$ is the capitalized R&D investment of firm i at the end of year t; $\mathrm{RDE}_{i,t}$ is the R&D expenditure of firm i for year t; K is the estimated duration of the economic life of the R&D; and CPI_t is the average of the consumer price index value in year t. This is consistent with the approach employed by Hirschey and Weygandt (1985) and Grabowski and Mueller (1978). Hirschey and Weygandt suggest that the duration of the economic life of R&D investments is between five and 10 years; Lev and Sougiannis (1996) find that the duration ranges from five to nine years, depending on the industry examined. Since the durations of R&D economic life for all industries are uncertain and nonuniform, we follow previous studies and use five, seven, and nine years so as to minimize the potential problem of inaccuracy in R&D duration estimation, as well as to check for the robustness of the results.[14] In addition, since there are uncertainties about the timing of R&D expenditure, this formula assumes that, on average, R&D expenditure is incurred in the middle of the fiscal year.

All variables in our study, with the exception of industry concentration, are adjusted to control for possible industry-specific effects. We define an industry as containing all firms with the same two-digit primary SIC.[15] Differences across industries that might affect the firm-specific variables of interest include the stage of the industry life cycle and its corresponding industry growth rate, the level of systematic risk, the nature of R&D activities pursued (e.g., basic research vs. applied research), the expected R&D expenditure, and the reasonable level of financial leverage. We control for industry effects by

14. There is a limitation in our study since the R&D for industries such as chemicals and pharmaceuticals may be longer than nine years. In addition, protection for patents and copyrights is normally longer than nine years. However, catering to a time frame of greater than nine years will significantly reduce the sample size, and using different time frames for different industries (Lev and Sougiannis 1996) may introduce a higher degree of subjectivity in the study.

15. The use of the two-digit SIC to define an industry is a crude method because companies within a two-digit SIC industry differ significantly in terms of their use of R&D. However, we argue that any finer classification of the companies into different industries, such as using a four-digit SIC, will make the sample size for each industry too small to obtain reliable statistical estimates.

TABLE 1 Proxies for Each Variable

Variables (Notation)	Proxies
Firm size ($LNSIZE_{i,t}$)	$LNSALE_{i,t}$
Concentration ($CONC_t$)	$(BFSALE_t/TOTSALEIND_t) \times 100\%$
Financial leverage ($LEV_{i,t}$)	$LTDEBT_{i,t}/TOTASS_{i,t}$
Growth opportunities ($GO_{i,t}$)	$MBASS_{i,t} = \{[N_{i,t} \times SP_{i,(t+1),4}] + (TOTASS_{i,t} - BVEQU_{i,t})\} \div TOTASS_{i,t}$
R&D investment ($RD_{i,t}$)	$RDI_{i,t}/TOTASS_{i,t} = (\Sigma_{m=0}^{K-1} RDE_{i,t-m}\{1 - [(2m + 1)/2K]\}(CPI_t/CPI_{t-m})) \div TOTASS_{i,t}$
DumSIZE	Dummy variable will be 1 if the size of the firm is greater than the median of the industry
DumCONC	Dummy variable will be 1 if the firm belongs to a high concentration industry; the median value of all firms in an industry is used as the benchmark.
DumLev	Dummy variable will be 1 if the financial leverage of the firm is greater than the median of the industry
YrDum	Dummy variable for the respective years

Note.—The definition of the variables used in this study are as follows (numbers in parentheses signify the COMPUSTAT data number). $LNSALE_{i,t}$ is the natural logarithm of the net sales of firm i for the period ending December of year t (#12); $BFSALE_t$ is the sum of net sales of the biggest four firms (in terms of net sales) in the industry to which firm i belongs for the period ending December of year t; $TOTSALEIND_t$ is the total net sales of all firms in the same two-digit SIC industry to which firm i belongs for the period ending December of year t; $CONC_t$ is the ratio of the total net sales of the biggest four firms over the total net sales of the industry for year t; $LTDEBT_{i,t}$ is the book value of total long-term debt of firm i at December of year t (#9); $TOTASS_{i,t}$ is the book value of total assets of firm i at December of year t (#6); $LEV_{i,t}$ is the ratio of total long-term debts to total assets of firm i at December of year t; $BVEQU_{i,t}$ is the book value of equity of firm i at December of year t (#60); $N_{i,t}$ is the number of outstanding shares of firm i at December of year t (#25); $SP_{i,(t+1),4}$ is the closing stock price of firm i at the end of April of year $t + 1$; $MBASS_{i,t}$ is the market-to-book value of assets of firm i at December of year t, defined as the sum of market value of equity and book value of debt, divided by book value of total assets (market value of equity is computed as the number of outstanding shares multiplied by stock price; book value of debt is calculated as the book value of total assets minus the book value of equity); $RDI_{i,t}$ is the capitalized R&D investment of firm i at December of year t; $RDE_{i,t}$ is the R&D expenditure of firm i for the period ending December of year t (#46); CPI_t is the average consumer price index value in the year t; K is the estimated average of R&D duration (the estimated average useful life of R&D), namely, the number of years of capitalization of R&D ($K = 5, 7, 9$ years).

using the normalization-by-industry-median method.[16] All firm-specific variables (i.e., growth opportunities, investment in R&D, firm size, and financial leverage) are adjusted by normalizing each firm-year observation by the industry median (i.e., the median for all sample firms with the same two-digit primary SIC code) for the same sample year. Hence a firm's attributes are defined in relation to the industry to which it belongs.

Table 1 presents the formula for the computation of the variables used in our study.

We now discuss the data used in our study. To be included in the sample, firms must have a positive value for total common equity and available data

16. Healy and Palepu (1988) is the first study to use the difference between a firm and industry method rather than industry dummy variables to control for industry effects. We want to remove any possible scale effect and have thus used a normalization method instead. We recognize that a concern in the use of a normalization by industry median method is the introduction of nonlinearity into the relationships between the dependent and independent variables.

for net sales, total assets, long-term debt, number of common shares outstanding, and closing stock price on April of the following year, $t + 1$, as well as R&D expenditure for years $t - (K - 1)$ to t, where $K = 5$, 7, and 9.[17]

Given the above requirements, our initial data sets with R&D duration of five, seven, and nine years have 7,640, 5,765, and 4,353 firm-year observations, respectively. Specifically, these initial data of R&D durations of five, seven, and nine years consist of 20 years of data (1979–98) of which the first five, seven, and nine years are used to construct the value of R&D investment for the year the amortization period first ends (namely, leaving 15, 13, and 11 years of data for testing purposes), respectively.

Further, to prevent problems of outliers, all data points that have extreme values on any of the variables, whether dependent or explanatory, are removed from these preliminary data sets.[18] The final sample consists of 6,227, 4,721, and 3,550 firm-year observations with R&D durations of five, seven, and nine years, respectively. This represents an average of 415, 363, and 322 firms per year for these three R&D durations. The final sample covers a total of 1,048 firms over a 15-year period. The requirement of at least five years of R&D data for the computation of capitalized R&D biased the sample toward larger manufacturing firms.

We also use three alternative values for R&D duration results in three sets of data, each with a different number of observations because of the screening procedure. Table 2 presents the descriptive statistics and the total number of observations for the three sets of firm-specific data used in our study.

Two major observations from the descriptive statistics of the firm-specific data in table 2 are noted. First, the mean of the firm size as measured by net sales is eight to 10 times the median, indicating that the sample is obviously skewed toward larger firms. Second, the descriptive statistics suggest that the use of different durations for the economic life of R&D investments does not result in significantly different values for the sample except for firm size, in which longer R&D durations correspond to larger values for the mean and median of firm size.[19] The Pearson correlations among the industry-adjusted explanatory variables are presented in table 3.

From table 3, it can be seen that several of the explanatory variables are highly correlated (boldface entries in table 3), especially those that involve interactions. The multicollinearity present in our regression is not a problem

17. In order to allow for the adjustment of industry effects, the sample includes only firms in a two-digit primary SIC industry in which there are at least five firms available after passing the prior screening of data availability.

18. An extreme value is defined as any value below the first quartile less 1.5 times the interquartile range or any value greater than the third quartile plus 1.5 times the interquartile range. The outliers are mainly data with extremely high values, and most of the outliers were from MBASS, RDA, and LEV (about 90% of the outliers). For interaction studies, outliers can affect the stability of the estimated coefficient because of significant multicollinearity problems (Greene 1993).

19. This provides some evidence that the lengthening of the R&D duration will introduce survivorship bias to the sample.

TABLE 2 Descriptive Statistics of the Samples for the Period 1980–98

	R&D Duration		
	5 Years	7 Years	9 Years
MBASS:			
Mean	1.631	1.622	1.634
Median	1.408	1.417	1.431
Standard deviation	.009	.010	.012
Minimum	.359	.359	.359
Maximum	6.437	6.887	5.445
RDI:			
Mean	.102	.130	.160
Median	.069	.090	.114
Standard deviation	.001	.002	.002
Minimum	.001	.002	.003
Maximum	.772	.847	1.020
Net sales (US$ millions):			
Mean	4,450.418	5,058.693	5,615.281
Median	424.685	528.743	653.658
Standard deviation	163.349	206.129	256.215
Minimum	.675	.841	.598
Maximum	168,190	168,190	168,190
LEV:			
Mean	.158	.162	.161
Median	.142	.147	.148
Standard deviation	.001	.002	.002
Minimum	.000	.000	.000
Maximum	.734	.648	.648
CONC:			
Mean	.352	.352	.348
Median	.356	.356	.356
Standard deviation	.084	.083	.081
Minimum	.171	.171	.171
Maximum	.616	.607	.602
Observations	6,227	4,721	3,550

Note.—This table presents the descriptive statistics of the following variables used in this study: market-to-book-value-of-assets (MBASS), capitalized R&D investment (RDI), firm sales (NET SALES), firm leverage (LEV), and industry concentration (CONC) measures. Descriptions for all variables can be found in table 1.

since we are interested in the incremental effects of the explanatory variables after controlling for the main effects (namely, firm size, financial leverage, and industry concentration).[20] Since the presence of multicollinearity will set up a bias toward insignificant results, any significant results will provide strong support for our hypotheses.

IV. Analysis of Results: Independent Effects of Firm Size, Financial Leverage, Industry Concentration, and R&D Investment

Table 4 reports the results of the multivariate regression models for the independent effects of industry-adjusted firm size, industry-adjusted financial

20. In almost all regression studies on interaction effects, multicollinearity is always a problem that biases the results against finding a significant coefficient. We decide to accept this limitation rather than use a biased regression estimator such as the Ridge regression estimator proposed by Greene (1993) to correct for the problem of multicollinearity.

TABLE 3 **Pearson Correlation Coefficients**

	RD	RD# LNSIZE	RD# CONC	RD# LEV	LNSIZE	CONC	LEV
RD	1.000	□.132	**.925**	**.554**	□.101	.038	□.179
RD# LNSIZE		1.000	□.083	□.068	**.834**	.032	.036
RD# CONC			1.000	**.520**	□.081	**.348**	□.159
RD# LEV				1.000	□.031†	.037	**.555**
LNSIZE					1.000	□.036	.098
CONC						1.000	□.007†
LEV							1.000

Not e.—This table presents the Pearson correlation coefficients for the data set with the R&D duration of five years, and R&D investment (RD), firm sales (LNSALES), industry concentration (CONC), and firm leverage (LEV) measures. # ’ signifies the interactions between two variables. The statistics are qualitatively similar for seven-year and nine-year durations of R&D investment. All variables are normalized by the industry median except for CONC. Descriptions for all variables can be found in table 1. All coefficient values are significant with 5% significance except those noted.

† Insignificant.

leverage, and industry concentration on the effectiveness of R&D investment in generating growth opportunities. Year dummy variables are included in all regression models to control for possible influences related to economywide conditions. A pooled ordinary least squares regression using the Newey-West (1987) method to correct for heteroskedasticity and autocorrelation of unknown form is employed. The coefficient values for the year dummies are not presented in the table since they are generally insignificant.

Table 4 shows that the results are very consistent across different R&D durations (except for RD^2, which is significant only for R&D duration of five years, and RD# LNSIZE, which is not significant for the R&D duration of five years).

An analysis of the coefficients of the control variables in table 4 shows that firm size and industry concentration are significantly positive whereas financial leverage is significantly negative.

The positive coefficient of firm size is not consistent with that of Evans (1987a, 1987b), who observes that smaller firms tend to grow faster than larger firms. However, our results support the findings of positive firm size effects of Levin et al. (1987), Hall (1993), and Chauvin and Hirschey (1993).

The negative relationship between financial leverage and a firm’s growth opportunities is consistent with the behavior of high-growth firms as theorized by Myers and Majluf (1984). High-growth firms with valuable investment opportunities prefer a position of low leverage to maintain a reserve borrowing capacity (financial slack) for exploiting future positive NPV investment opportunities (Myers and Majluf 1984; Harris and Raviv 1990; Lang et al. 1996). The lack of financial slack causes underinvestment problems since firms would sometimes forgo profitable future investments.

The positive coefficient for concentration implies that higher industry concentration leads to more growth opportunities for firms. This is consistent with the results of Doukas and Switzer (1992), who explain that firms in more concentrated industries are in a better position to translate their market power into growth opportunities.

TABLE 4 **Results for the Independent Effects**

	R&D Duration		
	5 Years	7 Years	9 Years
Constant	.784***	.849***	.859***
	(16.805)	(16.280)	(14.789)
RD	.340***	.298***	.295***
	(8.576)	(6.262)	(5.754)
RD^2	−.020***	−.015	−.014
	(−2.885)	(−1.771)	(−1.502)
RD × LNSIZE	.003	.010***	.014***
	(.854)	(2.448)	(2.994)
RD × LEV	.005	−.002	−.011
	(.613)	(−.238)	(−.961)
RD × CONC	−.686***	−.654***	−.655***
	(−7.625)	(−5.750)	(−5.347)
LNSIZE	.011**	.012**	.013**
	(2.330)	(2.371)	(2.126)
LEV	−.076***	−.074***	−.077***
	(−7.297)	(−6.085)	(−5.425)
CONC	.773***	.736***	.704***
	(7.140)	(5.732)	(4.811)
Annual dummy variables	yes†	yes†	yes†
Adjusted R^2	.053	.056	.067
F-statistics	16.877***	15.066***	15.229***
Observations	6,227	4,721	3,550
Durbin-Watson statistic	1.868	1.877	1.892

Note.—This table presents the results for the independent effects of firm size (LNSIZE), financial leverage (LEV), and industry concentration (CONC) on the effectiveness of R&D investment (RD) in generating growth opportunities (MBASS). The *t*-values are in parentheses. Descriptions for all the variables can be found in table 1. MBASS is defined as

$$a_0 + a_1RD + a_2RD^2 + a_3(RD \times LNSIZE) + a_4(RD \times LEV) + a_5(RD \times CONC)$$

$$+ a_6LNSIZE + a_7LEV + a_8CONC + \sum_{t=1}^{T-1} a_{8+t}YrDum_t + \epsilon_t.$$

** 5% level of significance.
*** 1% level of significance.
† Year dummy variables are used; they are generally insignificant.

Table 4 also shows that R&D investment retains a significant positive impact on a firm's growth opportunities even after one controls for the effects of firm size, financial leverage, and industry concentration. This shows that the impact of R&D investment on a firm's growth opportunities is robust. In addition, the coefficients of the square term of R&D investment are negative, providing some evidence of a nonlinear relationship between R&D investment and growth opportunities (although this negative relationship is significant only for R&D duration of five years).

Examination of the interactions between R&D and firm size (RD × LNSIZE) in table 4 shows a significant positive relationship with growth opportunity, except for an R&D duration of five years. This positive relationship is consistent with Chauvin and Hirschey's (1993) view that larger firms are more effective in generating growth opportunities from their R&D investments because of the appropriability advantage conferred by their size. Furthermore, Cohen and Klepper (1996) observe that larger businesses can spread their R&D expenses over bigger volumes, conferring size advantages in the undertaking of R&D. Hence, the result is in line with investors' expectations that firm size exerts a significant influence on a firm's ability to appropriate value from R&D investment.

Table 4 shows a statistically insignificant coefficient for the interaction between R&D investment and financial leverage (RD# LEV). The lack of a clear indication of the leverage effect is not totally unexpected given the existence of two opposing effects of high financial leverage: the positive debt monitoring effect on the one hand and the negative effects from agency and information asymmetry problems on the other hand. In addition, transaction cost economics suggests that firms with high levels of R&D investment require discretionary power to act. This requirement decreases the likelihood of the use of debts with their incongruent rigid governance structure. This avoidance of debt is demonstrated in our study by the negative correlation between R&D investment and financial leverage shown earlier in table 3. Thus debt alone may not be a discriminating factor in influencing investor expectations about the ability of firms to appropriate value from their R&D investments.

Finally, the significant negative coefficients for the interaction between R&D investment and industry concentration (RD# CONC) in table 4 suggest that while higher industry concentration and higher R&D investment are individually associated with greater growth opportunities, R&D undertaken in a high industry concentration environment is marginally less effective in generating growth opportunities than that undertaken in a low industry concentration environment. This result is consistent with the findings of Grabowski and Mueller (1978) and Connolly and Hirschey (1984) of a negative association between the R&D-concentration interaction and a firm's financial performance. Our finding supports the argument that marginal returns for R&D investment in high-concentration industries diminish more rapidly because of competitive matching prevalent in a high-concentration market (Grabowski and Mueller 1978; Mansfield 1985). Hence, investors would discount the value of a firm's R&D investments in the high-concentration industry since they have little confidence in the firms' ability to extract value from their R&D investments.

V. Analysis of Results: Two-Way Interaction Effects of Firm Size, Financial Leverage, and Industry Concentration with R&D Investment

We use the following three regression models to test for interaction effects.

Model 1 (refer to table 1 for a description of the variables):

$$\begin{aligned} GO = {} & \gamma_0 + \gamma_1 RD + \gamma_2 RD^2 + \gamma_3 (RD \times LNSIZE) \\ & + \gamma_4 (RD \times LNSIZE \times DumLEV) \\ & + \gamma_5 (RD \times LNSIZE \times DumCONC) \\ & + \gamma_6 (RD \times LEV) + \gamma_7 (RD \times CONC) + \gamma_8 LNSIZE \\ & + \gamma_9 LEV + \gamma_{10} CONC + \sum_{t=1}^{T-1} \gamma_{10+t} YrDum_t + \varepsilon_1. \end{aligned} \quad (4)$$

Model 1 tests the effect of firm size under each of the following conditions: high financial leverage firms ($RD \times LNSIZE \times DumLEV$) and high industry concentration ($RD \times LNSIZE \times DumCONC$). Given our above hypotheses on the interaction effects, we expect $\gamma_4 > 0$ and $\gamma_5 > 0$.

Model 2 (refer to table 1 for a description of the variables):

$$\begin{aligned} GO = {} & \pi_0 + \pi_1 RD + \pi_2 RD^2 + \pi_3 (RD \times LNSIZE) \\ & + \pi_4 (RD \times LEV) + \pi_5 (RD \times CONC) \\ & + \pi_6 (RD \times LEV \times DumSIZE) \\ & + \pi_7 (RD \times LEV \times DumCONC) + \pi_8 LNSIZE \\ & + \pi_9 LEV + \pi_{10} CONC + \sum_{t=1}^{T-1} \pi_{10+t} YrDum_t + \varepsilon_3. \end{aligned} \quad (5)$$

Model 2 examines the financial leverage effect under the following conditions: large firm size ($RD \times LEV \times DumSIZE$) and high industry concentration ($RD \times LEV \times DumCONC$).[21] We expect $\pi_6 > 0$ and $\pi_7 > 0$, given our hypotheses.

21. We have not reported the results of the model on the industry concentration effects under different firm size and financial leverage since industry concentration is an exogenous condition that a firm has limited ability to influence. Nonetheless, the results are available from the authors on request.

Model 3 (refer to table 1 for a description of the variables):

$$\begin{aligned} GO = {} & \beta_0 + \beta_1 RD + \beta_2 RD^2 + \beta_3(RD \times LNSIZE) \\ & + \beta_4(RD \times LNSIZE \times DumLEV) \\ & + \beta_5(RD \times LNSIZE \times DumCONC) + \beta_6(RD \times LEV) \\ & + \beta_7(RD \times CONC) + \beta_8(RD \times LEV \times DumSIZE) \\ & + \beta_9(RD \times LEV \times DumCONC) + \beta_{10} LNSIZE + \beta_{11} LEV \\ & + \beta_{12} CONC + \sum_{t=1}^{T-1} \beta_{12+t} YrDum_t + \varepsilon_4. \end{aligned} \tag{6}$$

Finally, model 3 tests the combined interaction effects of the above three variables. On the basis of our hypotheses, we expect $\beta_4 < 0$, $\beta_5 < 0$, $\beta_8 < 0$, and $\beta_9 < 0$.

Table 5 presents the regression results using MBASS as the measure of a firm's growth opportunities.[22]

From table 5, it can be seen that the individual effects of firm size, financial leverage, and industry concentration are significant and consistent with the findings in table 4 for all three R&D durations and the three different models. Similarly, their respective interaction effects with R&D investment are again consistent with the findings in table 4.

With respect to the interactions between firm size and the other two variables, the results in models 1 and 3 show that the coefficients of RD × LNSIZE × DumLEV are negative and significant across all three R&D durations.[23] The advantage large firms possess in creating growth opportunities from R&D investments when financial leverage is low disappears under high financial leverage situations. This result can be explained by a number of factors. Large firms with high leverage lack the financial slack to invest in emerging R&D opportunities. In addition, the market expecting large firms to internally fund attractive R&D projects to capture value from such investments will perceive the presence of high leverage to be a signal that their R&D investments have poor prospects. Finally, an application of transaction cost analysis would suggest that the use of debt gives rise to a rigid rule-based governance structure when a more flexible administrative-based structure is required to exploit R&D opportunities in a dynamic situation (Williamson 1988; Acs and Isberg 1996). Thus inappropriate governance structure will cause such firms to enjoy lower growth opportunities.

22. As per table 4, year dummy variables are used.

23. For example, in model 3 of table 5, when R&D duration is seven years, the coefficient values of RD × LNSIZE and RD × LNSIZE × DumLEV are 0.021 and −0.026, respectively. This means that the coefficient value of RD × LNSIZE for low-leverage firms (DumLEV = 0) is 0.021, whereas the coefficient value of RD × LNSIZE for high-leverage firms (DumLEV = 1) is −0.005 (= 0.021 − 0.026).

TABLE 5 Results for the Two-Way Interactions Effects

	R&D Duration 5 Years			R&D Duration 7 Years			R&D Duration 9 Years		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Constant	.765***	.773***	.763***	.845***	.855***	.844***	.863***	.869***	.863***
	(16.664)	(16.809)	(15.850)	(16.442)	(16.585)	(15.443)	(14.772)	(14.816)	(14.773)
RD	.360***	.330***	.347***	.314***	.282***	.299***	.305***	.288***	.297***
	(10.166)	(8.917)	(8.273)	(7.625)	(6.519)	(5.881)	(6.471)	(5.772)	(5.982)
RD^2	−.022***	−.020***	−.022***	−.018**	−.014	−.018**	−.015	−.014	−.016
	(−3.137)	(−2.848)	(−3.142)	(−2.132)	(−1.751)	(−2.129)	(−1.667)	(−1.454)	(−1.687)
RD# LNSIZE	.011***	.006	.010**	.021***	.014***	.021***	.026***	.019***	.025***
	(3.060)	(1.605)	(2.341)	(5.117)	(3.532)	(4.453)	(5.354)	(4.043)	(5.181)
RD# LNSIZE# DumLEV	−.023***		−.025***	−.025***		−.026***	−.026***		−.026***
	(−6.404)		(−5.926)	(−6.475)		(−5.592)	(−5.586)		(−4.933)
RD# LNSIZE# DumCONC	−.002		−.002	−.006		−.006	−.009		−.009
	(−.435)		(−.363)	(−1.485)		(−1.283)	(−1.782)		(−1.742)
RD# LEV	−.004	.013	−.006	−.012	.010	−.010	−.018	.000	−.017
	(−.542)	(1.500)	(−.538)	(−1.219)	(.970)	(−.802)	(−1.636)	(−.022)	(−1.420)
RD# CONC	−.696***	−.644***	−.665***	−.651***	−.597***	−.604***	−.649***	−.624***	−.627***
	(−9.012)	(−7.788)	(−6.937)	(−7.262)	(−6.134)	(−5.016)	(−6.057)	(−5.284)	(−5.321)

RD# LEV# DumSIZE		□.014	.011		□.023***	.004		□.026***	.002
		(□1.863)	(1.317)		(□2.659)	(.418)		(□2.681)	(.188)
RD# LEV# DumCONC		□.012	□.008		□.015	□.011		□.008	□.005
		(□1.559)	(□ .958)		(□1.663)	(□1.247)		(□.755)	(□.448)
LNSIZE	.013***	.011***	.013***	.014***	.013***	.014***	.016***	.014**	.016***
	(3.177)	(2.556)	(2.923)	(2.966)	(2.569)	(2.781)	(2.853)	(2.402)	(2.837)
LEV	□.068***	□.073***	□.070***	□.068***	□.071***	□.068***	□.072***	□.074***	□.072***
	(□6.729)	(□7.182)	(□6.683)	(□5.777)	(□6.089)	(□5.607)	(□5.266)	(□5.394)	(□5.258)
CONC	.783***	.784***	.788***	.735***	.740***	.738***	.704***	.698***	.703***
	(7.807)	(7.801)	(7.294)	(6.390)	(6.419)	(5.916)	(5.156)	(5.097)	(5.145)
Adjusted R^2	.059†	.054†	.059†	.069†	.058†	.065†	.076†	.069†	.075†
Observations	6,227	6,227	6,227	4,721	4,721	4,721	3,550	3,550	3,550

Not e.—This table presents the results from regressions on the two-way interactions between firm size (LNSIZE), financial leverage (LEV), and industry concentration (CONC) on the effectiveness of R&D investment (RD) in generating growth opportunities (MBASS) using *combined-continuous-dummy-variable* regression models. The *t*-values are in parentheses. Descriptions of all the variables can be found in table 1. The three models are defined in eqq. (4), (5), and (6).

** 5% level of significance.

*** 1% level of significance.

† *F*-statistics significant at the 1% level.

We also find that the coefficients of RD# LNSIZE# DumCONC in models 1 and 3 are negative but insignificant across the three R&D durations. These findings suggest that the positive impact of firm size in increasing effectiveness of R&D investment in generating growth opportunities is not significantly different across low- and high-concentration industries. Hence, the proposition that the positive impact of firm size will be reduced in a high-concentration industry is not supported.

Next, we examine the financial leverage effect on a firm's growth opportunities from its R&D investment under different firm size and industry concentration scenarios (RD# LEV# DumSIZE and RD# LEV# DumCONC). The coefficients of RD# LEV# DumSIZE are not consistent between models 2 and 3, and RD# LEV# DumCONC coefficients are negative but insignificant across the three R&D durations as shown in models 2 and 3 in table 5. Interestingly, the coefficients of RD# LEV# DumSIZE are significant only for R&D durations of seven and nine years in model 2; that is, there are indications that while the level of financial leverage does not affect the effectiveness of smaller firms in appropriating growth opportunities from R&D investment (the coefficient of RD# LEV in models 2 and 3 of table 5 is insignificant), increasing leverage does negatively affect the larger firm's effectiveness for these two R&D durations. This is consistent with the earlier finding that large firms with high financial leverage have their appropriability advantage diluted. What is interesting to note here is that no negative impact is observed on the appropriability of R&D investments for small firms increasing their level of financial leverage, in contrast to the larger firms discussed above. The reason may be that smaller firms suffer from binding liquidity constraints and limited funding sources, and will hence go into debt only to finance positive NPV projects (Fazzari et al. 1988; Evans and Jovanovic 1989; Holtz-Eakin et al. 1994; Acs and Isberg 1996). A high leverage level may thus not be perceived as a negative signal, in contrast to the large firms.

In summary, table 5 yields two interesting observations that offer additional evidence on the importance of the two-way interaction effects between firm size, financial leverage, and industry concentration on the effectiveness of R&D investment in generating growth opportunities that is consistent with our hypotheses. First, the impact of firm size on R&D investment effectiveness in inducing growth opportunities varies between firms with high and low financial leverage. In our study, the positive effect of firm size on the effectiveness of R&D investment in inducing growth opportunities, which indicates the appropriability advantage of large firm size, is less pronounced or even reversed for high financial leverage firms. This finding is economically intuitive since large firms will reap maximum growth opportunities from R&D investment through the appropriability advantage on the condition that they have sufficient financial slack to finance the asset yet to be in place necessary to commercialize their R&D investments. This result is also consistent with the transaction cost analysis view that the types of assets or investments (in this case firm-specific R&D investments) would favor an equity-type funding that results in a governance structure best suited to the maximization of the growth opportunities of a firm through the provision for discretionary management action in the face of uncertain conditions (Williamson 1988; Balakrishnan and Fox 1993; Acs and Isberg 1996; Vincente-Lorente 2001; O'Brien 2003). Second, the results provide some evidence that the effect of financial leverage on R&D investment effectiveness in inducing growth opportunities appears to vary between large and small firms. The negative effect of financial leverage seems to be present only in large firms. Small firms appear to be superior to large firms in deriving growth opportunities from their R&D investments in a high financial leverage environment. This finding is consistent with the economic intuition that small firms will be willing to embark on R&D investment using high financial leverage only if they are productive in using the investment in R&D to generate growth opportunities. In addition, it appears that information asymmetry is not as much a problem for small firms as it is for large firms because of differing sources of funding. The private nature of this funding source allows small firms to disclose more details about their innovation. Furthermore, according to the debt-monitoring hypothesis, high financial leverage may signal that the small firm is undertaking economically more viable projects compared to small firms with lower financial leverage (Zantout 1997). Finally, this result suggests that small firms that face binding liquidity constraints have limited options to grow except by borrowing, and such borrowing is well received by banks and investors in general (Fazzari et al. 1988; Evans and Jovanovic 1989; Holtz-Eakin et al. 1994).

VI. Conclusion

In this paper, we investigate how the interaction effects of two endogenous variables, firm size and financial leverage, together with one exogenous variable, industry concentration, moderate the impact of R&D investment on the growth opportunities of a firm. When only the independent effects of firm size, financial leverage, and industry concentration on the effectiveness of R&D investment in generating growth opportunities are considered, we document a significant positive effect for firm size and a significant negative effect for industry concentration, whereas we find nonsignificant ambiguous results for the independent effect of financial leverage.

Contrary to expected economic rationale about market power arising from large firm size and the importance of financial slack in funding positive NPV projects, our results show the complexity of the firm size–financial leverage interaction. Investors attribute a higher growth opportunity arising from the R&D capital of large firms compared to small firms only when the large firms have low financial leverage. When high financial leverage is present, investors instead expect smaller firms to be able to appropriate value from their R&D capital better than larger firms. Our findings are consistent with the extant literature that the impact of R&D investment in the presence of a firm's two endogenous characteristics on growth opportunities is not straightforward. Hence, we find qualified support for the comparative advantage in reaping growth opportunities from R&D investment by large firms compared to that by small firms. Clearly, the appropriability advantage of large firms is not a universal phenomenon.

Surprisingly too, industry concentration does not play any significant role as a moderating variable in determining the impact of R&D investment on growth opportunity when its interactions with size and financial leverage are examined. The reason is that the positive impact of market power arising from firm size may be offset by the negative effect of the propensity to fund negative NPV projects in a high-concentration market. Hence, investors are not able to discern the high potential projects from duds, leading to their inability to evaluate the value of R&D projects of large firms in high-concentration industries.

To conclude, our study provides new insights into the interaction effects that firm size, financial leverage, and industry concentration have on the effectiveness of R&D investment in generating growth opportunities. It will be interesting and useful to extend this research to test how the relationship between firm size, financial leverage, industry concentration, and the effectiveness of R&D investment in generating growth opportunities will eventually influence the growth of stock prices and thus shareholders' wealth in an ex post setting.

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