A COMPILATION OF ESSAYS IN CORPORATE FINANCE: STUDIES OF THE CHOICE OF EQUITY MARKETS, STRATEGIC INNOVATION, AND RESEARCH AND DEVELOPMENT INVESTMENT

By

Melinda L. Newman

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ABSTRACT

A COMPILATION OF ESSAYS IN CORPORATE FINANCE: STUDIES OF THE CHOICE OF EQUITY MARKETS, STRATEGIC INNOVATION, AND RESEARCH AND DEVELOPMENT INVESTMENT

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This dissertation contains three chapters that address separate issues in the area of corporate finance. The first chapter is an empirical analysis of firms' strategic choice of equity markets. That is, prior studies document a negative stock price reaction to public equity offering announcements, but a positive stock price reaction to private equity offering announcements. These opposing reactions suggest that capital markets believe that the form of equity matters. This issue is explored by comparing the stock price reactions for firms that issue the predicted forms of equity to those who do not and results show that issuing the unanticipated form of equity has adverse implications for firm value. The evidence also indicates that firms deviate to private markets to concentrate ownership and they deviate to public markets to capitalize on investor optimism.

The second chapter presents a theoretical model of an innovator's choice of product quality when imitation is anticipated. Specifically, the innovator's optimal quality choice is compared to that of a pure monopolist to see if and how the threat of imitation alters the innovator's decision. As a result, the model identifies a median range of relative imitation costs over which the innovator chooses a preemptive quality level. Observations from the semiconductor industry are offered as anecdotal support.

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Finally, the third chapter contains an empirical investigation of the differences in investment in research and development both across firms within the same industry and across different industries. Within the existing literature, it is generally agreed that research and development activity varies both within an industry and across different industries. Empirical studies that investigate how firms make their research and development investment decision, however, are limited in number and generally lack consensus in the results.

The purpose of this chapter is to investigate what firm- and industry-specific characteristics influence investment in research and development, and how those influences vary both within and across industries. I find that firm profitability and leverage have significant and varying effects on the research and development investment decision. Statistically significant results are also obtained for the effect of firm size and industry concentration.

Dedicated, with love and gratitude, to Steve and Andy

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I have greatly benefited from the advice and guidance of each of my dissertation committee members: Dr. Naveen Khanna, Dr. Assem Safieddine, Dr. Charles Hadlock, and Dr. Jeff Wooldridge. I especially thank Naveen for serving as my committee chairman and acting as a mentor throughout my completion of the doctoral program. His support and encouragement have been invaluable. All errors within this document remain the sole responsibility of the author.

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INTRODUCTION

This dissertation contains three chapters that address separate issues in the area of corporate finance. The first chapter presents an empirical analysis of firms' strategic choice of equity markets. In particular, prior studies document a significant negative stock price reaction to public equity offering announcements, but a positive stock price reaction to private equity offering announcements. For example, Smith (1986) reports a -3% average abnormal return for public equity announcements while Wruck (1989) and Hertzel and Smith (1993) document average abnormal returns exceeding +4% for private equity announcements.

Given that the market reacts differently to public and private equity announcements suggests that capital markets believe that the form of equity (private or public) matters. If so, conditional on issuing equity, firms that issue the predicted form will have a more favorable stock price reaction to the offering announcement than those that do not. Chapter 1 explores this issue by estimating a probit model of the determinants of the public/private decision to identify firms that are more likely candidates for issuing public/private equity. The stock price reaction of those that issue "against type" is then compared to the stock price reaction of those that issue "with type". The findings are consistent with the argument that issuing the form of equity that is not anticipated by the market has adverse implications for firm value.

Based on these results, the incentives for firms to issue "against type" are then explored. The results indicate that firms deviate to public markets to take advantage of general overall optimism of investors toward public equity markets. On the other hand, it is l

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is less clear why firms with "public issue" characteristics deviate to more costly private markets. Wruck (1989) suggests change in ownership concentration as one motivation for issuing private equity. The results are consistent with Wruck (1989) in that firms issuing the "against type" form of private equity have a much higher ownership concentration than firms issuing the "with type" form of private equity. Finally, the evidence also indicates that issuing "against type" in certain market conditions ("cold" or "hot" periods) has a more pronounced effect.

The second chapter presents a theoretical model of an innovator's choice of product quality when imitation is anticipated. In the context of the relationship between imitation and innovation costs, Pepall and Richards (1994) compare a chosen innovation level with that of a pure monopolist to see if potential imitation alters an innovator's behavior. Among other results, they find that for relatively low imitation/innovation cost ratios, the chosen innovation level is less than that of a pure monopolist's, while a relatively high ratio corresponds to a higher quality choice.

Motivated by Fishman's (1988) model of a sequential takeover bidding process, this chapter re-examines the problem set forth by Pepall and Richards. In particular, Fishman's model provides a rationale for a bidder to make a high premium bid for a targeted firm in order to "preempt" or deter a second bidder from competing. The purpose of this chapter is to allow the innovating firm to exhibit comparable preemptive behavior when challenged by a potential imitator. Consequently, my findings depart from those of Pepall and Richards.

Specifically, while relatively low imitation costs still correspond to a lower quality choice, there is now a "middle" range of cost ratio values for which the innovator chc

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chooses a relatively high quality product. Therefore, there is a median range of cost ratio values over which it may be optimal for the second firm to imitate, but it is "preempted" by the quality choice of the profit-maximizing innovator. Observations from the semiconductor industry are offered as anecdotal support.

Finally, Chapter 3 contains an empirical investigation of the differences in investment in research and development both across firms within the same industry and across different industries. Within the existing literature, it is generally agreed that research and development activity varies both within an industry and across different industries. Empirical studies that investigate how firms make their research and development investment decision, however, are limited in number and generally lack consensus in the results.

The purpose of this chapter is to investigate what firm- and industry-specific characteristics influence investment in research and development, and how those influences vary both within and across industries. Specifically, I first develop a probit model that tests the role of several firm-specific characteristics in the firm's decision to maintain either a high or low commitment to R&D. I then develop a panel data model that jointly tests the influence of the firm-specific characteristics (and an industry-specific characteristic) on the intensity of the firm's R&D investment.

Consistent with existing literature, I generally find a positive relationship between my measures of firm profitability and R&D investment. I depart from the existing literature, however, in my finding that this relationship is not uniformly positive. In addition, my results for firm leverage suggest that debt may play a significant, but varying role in a firm's commitment to R&D investment. Finally, the effect of firm size or

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on R&D intensity is fairly consistent in its significance and its effect is industry-specific. There is also limited evidence of a negative relationship between industry concentration and R&D investment among the top performers within each industry.

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CHAPTER 1

THE STRATEGIC CHOICE OF EQUITY MARKETS: PRIVATE OR PUBLIC[1]

1.1 Introduction

Prior studies document a significant negative stock price reaction to public equity offering announcements, but a positive stock price reaction to private equity offering announcements. For example, Smith (1986) reports a -3% average abnormal return for public equity announcements while Wruck (1989) and Hertzel and Smith (1993) document average abnormal returns exceeding +4% for private equity announcements. The negative stock reaction of the former type of equity offerings has been attributed to the Myers and Majluf (1984) asymmetric information problem. However, Hertzel and Smith (1993) argue that private placements of equity resolve this problem by allowing firms to communicate information to private investors more efficiently than would be possible through public equity offerings. Indeed, Hertzel and Smith (1993) suggest that announcements of private placements should not be associated with negative abnormal returns. To the contrary, they predict a positive stock price reaction if firms use the proceeds to finance positive NPV projects, providing thus an explanation for the reported positive abnormal returns associated with private placements.

Given that the market reacts differently to public and private equity announcements suggests that capital markets believe that the form of equity (private or

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[1] Authorship of this essay is shared with Dr. Assem Safieddine, an Assistant Professor at Michigan State University and a member of my dissertation committee.

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public) matters. If so, conditional on issuing equity, firms that issue the predicted form will have a more favorable stock price reaction to the offering announcement than those that do not. In this chapter, we explore this issue by estimating a probit model of the determinants of the public/private decision to identify firms that are more likely candidates for issuing public/private equity. We find the probability of issuing public equity is higher: the bigger the firm, the stronger its stock price momentum (runup) and the leading economic indicators, and the higher the aggregate volume of equity issues. In contrast, the probability of issuing public equity is smaller for firms that are distressed and that are at risk of being acquired.

We then compare the stock price reaction of those that issue “against type” to the stock price reaction of those that issue “with type”. Our findings indicate that firms issuing the “with type” form of public equity have a less negative stock price reaction than firms issuing “against type”. In addition, firms issuing the “with type” form of private equity have a more positive stock price reaction than those firms issuing “against type”. This is consistent with the argument that issuing the form of equity that is not anticipated by the market has adverse implications for firm value.

Given these results, we investigate the incentives for firms to issue "against type". Because the public equity market offers certain advantages over the private equity market (e.g. all else equal, the public market offers a more liquid, and therefore cheaper, venue for issuing equity than does the private market), it is relatively easy to understand why firms with "private issue" characteristics deviate to public markets. We hypothesize that firms deviate to public markets to take advantage of general overall optimism of investors tow

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toward public equity markets. For example, the number of firms that deviate in "hot" periods is more than four times the number of firms deviating in "cold" periods.

On the other hand, it is less clear why firms with "public issue" characteristics deviate to more costly private markets. Wruck (1989) suggests change in ownership concentration as one motivation for issuing private equity. Our results are consistent with Wruck (1989) in that firms issuing the "against type" form of private equity have a much higher ownership concentration than firms issuing the "with type" form of private equity.

Finally, the evidence also indicates that issuing "against type" in certain market conditions ("cold" or "hot" periods) has a more pronounced effect. Several studies suggest that information asymmetry varies over time and that this variation influences the timing of the securities' offerings. For example, Korajczyk, Lucas and McDonald (1991) report that firms are more likely to issue public equity following an informative earnings report than at any other time. Choe, Masulis and Nanda (1993) provide evidence that firms time public equity issues to coincide with periods of economic expansion. Bayless and Chaplinsky (1996) provide evidence that low volume ("cold") markets for public equity offerings coincide with periods of high information asymmetry.

We hypothesize, based on the arguments of Hertzel and Smith (1993) as well as the market timing theories, that firms in cold periods, i.e., in periods of high information asymmetry, turn to private placements as an alternative source of financing. Anecdotal evidence supports the idea that firms turn to private markets when public markets are "closed" (Fenn, Liang and Prowse, 1995). In addition, if private markets resolve information problems, then private issuers are more likely to be fairly priced and we should observe insignificant stock price reaction.

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On the other hand, based on arguments similar to those of Choe, Masulis and Nanda (1993), firms with more severe information problems (which would otherwise go to private placement markets) have an increased probability of moving into public markets in "hot" periods. In this case, public equity issuers, since they are still subject to information problems, are more likely to be mispriced.

This chapter is organized as follows. Section 1.2 describes the data and reports summary statistics of the issuing firms and their offerings. In Section 1.3, we discuss the four broad categories that might influence the equity market choice and Section 1.4 investigates the equity market choice in a probit model. Section 1.5 includes our univariate results and reports the performance of firms issuing "against type". In Section 1.6, we present summary statistics of ownership concentration of firms making private sales of equity, and in Section 1.7 we report a multivariate analysis. Section 1.8 concludes the chapter.

1.2 Data

Our sample of privately placed common equity is obtained from the *Dow Jones News Retrieval* (DJNR) database. Specifically, using combinations of the key words "private placement", "stock" and "equity", we search the full text of selected articles from the *Wall Street Journal*, *Barron's*, and press releases from the *Dow Jones News Service*. Our sample period covers announcements from the period of January 1, 1980 through December 31, 1993. Observations that include issues of securities other than common equity are excluded.

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Our sample of publicly issued common equity is obtained from the *Securities Data Corporation (SDC) New Issues* database. We restrict this sample to include only issues of industrial firms which have financial data available on CompuStat in the year prior to the issue and stock price data available from the Chicago Center for Research in Security Prices (CRSP) tapes on the issue date. Announcement dates should also be available for sample firms, either in *Lexis/Nexis*, *Dow Jones News Retrieval*, or the *Wall Street Journal Index*. The final sample consists of 1,016 public equity offerings and 283 private equity placements during the 1980-1994 period. The same firm can be included in both public and private issuer groups if the firm issued in both markets during the same period.

In Table A1 of Appendix A, we report the distribution of both private and public common equity offerings by year. There are a substantial number of public offerings in 1983, with nearly 10% of the sample falling in that year. In addition, note that both distributions are rather heavily concentrated in the 1990's, with 42.2% of the public issues occurring from 1990 through 1994 and 58.3% of private placements falling in the period 1990-1993. No private placements are recorded for 1994, as the data was not collected for that year. In Panel A of Table A2, we report summary statistics for issuing firms. The median book value of assets of firms issuing public common equity is $274.87 million, significantly larger than the $14.66 million median book value of assets of firms privately placing equity. Issuers of public equity also have significantly greater sales in the year prior to the issue. The median sales of firms privately placing equity is $9.02 million, compared to median sales of $226.89 million for firms issuing public equity. Panel A also shows that firms issuing public equity raise more funds, on average.

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The gross proceeds of the public offerings has a median of $32.5 million, compared to $3.35 million for firms raising equity through private placements.[2] These figures are similar to the ones reported in Hertzel and Smith (1993). They report median gross proceeds of $ 5.40 million for firms raising funds through private placements and a median of $20.86 for public offerings.

The operating performance in the year prior to the offering of firms privately placing their equity is significantly lower than the performance of firms who issue equity publicly. Our measure of pre-issue firm operating performance is pretax operating cash flow. Pretax operating cash flow is defined as net sales, minus cost of goods sold, minus selling and administrative expenses, but before the deduction of depreciation and amortization expense.[3] Median cash flow scaled by the book value of assets is 0.1102 for public equity issuers and -0.0230 for private placement issuers.[4]

Annual industry-adjusted performance is calculated by subtracting the industry median from the firm value, where the industry median is calculated for all CompuStat

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[2] Public equity issuers raise an average of $59.06 million, which compares to $22.34 million for issuers of private placements. These figures are smaller than the figures reported by Wruck (1989) for two possible reasons: In Wruck (1989), the sample consists of NYSE and AMEX firms only whereas our sample consists of NYSE, AMEX and NASDAQ firms and therefore includes smaller firms. In addition, our sample consists solely of common equity issuers. Wruck's sample includes more than twenty percent preferred and convertible preferred issues. The proceeds raised in preferred stock issues as well as the issuers themselves tend to be larger.

[3] CompuStat data item # 13.

[4] We scale cash flow by the asset value to produce a performance measure comparable across firms and through time. We scale by book value of assets rather than market value because market value impounds valuations of differences in firm and management quality. Using the market value of assets tends to mask true variation in performance by scaling superior (inferior) performance by its higher (lower) capitalized value.

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firms with the same four-digit SIC code.[5] Industry-adjusted cash flow to book value of assets indicates that firms publicly issuing equity significantly outperform their industry while firms privately placing their equity significantly underperform their industries. The median cash flow to sales and industry-adjusted cash flow to sales follow a similar pattern.[6]

The private placement group includes a substantially greater proportion of firms in "financial distress". More than 43% of firms privately placing their equity have negative operating performance in the two years prior to the offering, compared to 10.73% for firms publicly issuing their equity.[7] However, while the median leverage varies slightly between the two groups, it does not appear unusually high in either case. We estimate the percentage of shares issued as the proceeds of the equity issue divided by the firm's book value of assets in the year prior to the issue. As shown in Panel A, the median values are virtually identical for our sample of public and private offerings.

Stock price performance in the year prior to the offering is consistent with the operating performance evidence. We measure raw buy-and-hold returns over an eleven month period from month -12 through month -2 prior to the offering date [D_RUNUP].

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[5] If there are no more than ten firms with the same four-digit SIC code, the median is calculated for all firms falling in the same three-digit SIC code, assuming the three-digit SIC code has more than ten firms. Again, if there are no more than ten firms in the three-digit SIC code category, the median is then determined for all firms with the same two-digit SIC code.

[6] Our finding of poor operating performance prior to private placements of equity is consistent with results documented by Hertzel, et. al. (1999). Using similarly defined ratios of operating income/assets and operating income/sales, (as well as profit margin and return on assets), they find that the sample median values compare poorly to the industry medians in the 4 years preceding a private placement of equity.

[7] Hertzel and Smith report that 20% of their sample of issuers of private placements are in distress. They classify "distress" as a firm with two consecutive years of negative

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Adjusted holding period returns are calculated as $\Sigma(1+R_{it}) - \Sigma(1+R_{jt})$, where R_{it} is the holding period return of an issuing firm and R_{jt} is the holding period return on a matching benchmark portfolio. That is, we match each issuing firm with a portfolio of stocks of the same book-to-market quintile, the same size quintile, and the same momentum quintile as the sample firm in the year prior to the issue.[8] For firms publicly issuing equity, consistent with prior studies, there is a significant stock price runup. These firms outperform the benchmark portfolio, on average by 34.43%. On the other hand, the performance of firms privately placing their equity is not significantly different from the benchmark.[9]

Finally, for public issuers, ANNRET is the two-day return (-1, 0) around the announcement date. For private issuers, ANNRET is the difference between the issuer's and the benchmark's announcement monthly return. As shown in the results, the private placement median of 3.26% is statistically different from the public offering median of -2.03% at a 1% level of significance.[10]

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earnings prior to the placement. We classify firms as being in "distress" if they have two consecutive years of negative operating cash flow prior to the placement.

[8] See Safieddine and Titman (1999); Daniel, Grinblatt, Titman, and Wermers (1997).

[9] Hertzel, et. al. (1999) measure stock price runup for a sample of firms that issue equity privately using month –23 through month –2 prior to the offering date. Using a benchmark portfolio based upon size and book-to-market, they also find a statistically insignificant difference in the average runup of their sample firms and the control firms. When compared to a benchmark matched on size or matched on size and industry, however, the average adjusted stock price runups of 30.06% and 36.73%, respectively, are statistically significant.

[10] For their sample of 401 private placements over the sample period 1983-1992, Krishnamurthy, et. al. (1998) calculate a mean, 2-day abnormal return of 1.54%. However, when the sample is split into private placements made with "affiliated" or "unaffiliated" investors, the former group enjoys an average abnormal return of 2.97% while the latter group's average abnormal return is only 1.15%. The authors argue this

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Panel B of Table A2 shows the distribution of each issue type by the use of the capital raised. Of the 192 private placements for which data is available, nearly half apply the funds towards general corporate operations, 31% to finance acquisitions, and 13.4% to refinance debt. For the 627 public issues considered, 57% use the capital for general purposes of the firm, 38.3% refinance various forms of corporate debt, and only 2.7% finance acquisitions.

In summary, Table A2 shows that the sample firms placing equity privately are fundamentally different from the firms issuing equity publicly. Specifically, the latter firms are typically larger and exhibit a superior level of operating performance. In addition, the proportion of firms making public offerings that are in financial distress is dramatically lower. Finally, while the purposes for which the proceeds are raised do not differ largely from those of private-placement firms, the dollar size of those proceeds is notably larger for the firms offering equity to the public.

1.3 Equity Market Choice

In this section, we investigate an empirical model of equity market choice for our sample firms. If the form of equity matters, then deviating from the "right" form of equity should have implications on the stock price reaction to the announcement of both private and public equity offerings. If this is true, then given information asymmetry and firm characteristics, firms that issue as expected, i.e., issue "with type" should convey more favorable information than those that issue "against type", regardless of whether they are expected to issue public or private equity. We test these hypotheses by

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is evidence that the market perceives participation in the placement by affiliated investors as a positive signal of firm quality.

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estimating a probit model of the equity market choice to identify firms that have the characteristics of public or private equity issuers. This enables us to identify public and private equity issuers that are issuing "against type" or issuing "with type". We then compare the stock price reaction of the "against type" issuers to that of similar firms issuing "with type".

Prior studies document that the form of equity (private or public) may be motivated by information issues, agency problems or simply because of lower issuance costs. The probit model allows for proxies from four broad categories hypothesized to influence the choice between private and public equity markets. These categories include: firm-specific information asymmetry [Myers and Majluf (1984)], market timing or external factors which affect information asymmetry [Lucas and McDonald (1990), Choe, Masulis and Nanda (1993), Bayless and Chaplinsky (1996), and Korajczyk, Lucas and McDonald (1991)], potential gains from a change in ownership structure [Wruck (1989)], and fixed costs of issuance [Fenn, Liang and Prowse (1995), and Eckbo and Masulis (1992)].

1.3.1 Firm-Specific Information Asymmetry

Myers and Majluf (1984) demonstrate that equity issues convey management's belief that the firm is overvalued. Managers of undervalued securities with positive NPV projects will choose not to issue equity if the costs imposed on existing shareholders outweigh the benefits from the new project. Myers and Majluf argue that this underinvestment problem disappears if managers can costlessly convey their private information to the market.

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Hertzel and Smith (1993) suggest that private placements of equity are a way to resolve the Myers and Majluf underinvestment problem because a firm can more efficiently communicate information to private investors. They show that if the Myers and Majluf model is extended to allow private investors to assess firm value at some cost, the underinvestment problem can be mitigated through private equity sales. In these instances, a private placement is a less costly form of finance than a public offering because it allows the firm to invest and to avoid the negative impact on its stock. Private placements are placed at a discount to the current share price to compensate private investors for the cost of obtaining information.

Hertzel and Smith find indirect empirical support for the idea that private placements offer a partial solution to the Myers and Majluf underinvestment problem. They find that variables which proxy for the degree of asymmetric information such as the book-to-market ratio and firm size have significant explanatory power in predicting the discount-adjusted stock price reaction to private equity announcements.

Mackie-Mason (1990) examines the public-private equity market choice of firms. He finds that firms that are subject to more firm-specific information asymmetry are more likely to raise capital in the private markets. For example, firms that are unable to signal reliable cash flows through dividends will be subject to a greater negative stock price effect and thus prefer to avoid public issues. His results show that firms that do not pay dividends are more likely to use private sources of funds.

The evidence in Hertzel and Smith and Mackie-Mason indicates that firms with high information asymmetry are more likely to issue equity in private markets. If so, then if smaller firms suffer from more severe information asymmetry since they have less of a

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of a history and have fewer analysts following them, then smaller firms are more likely to privately place their equity. As a proxy for firm-specific information asymmetry we use log of the book value of assets [LOG (BV)] in the year prior to the offering.[11]

1.3.2 Timing the Equity Offering

There have been several theories suggesting that information asymmetries vary over time, and that firms time their equity offerings to coincide with times when information problems are lower. For example, Korajczyk, Lucas and McDonald (1991) report that firms time their publicly placed equity offerings in periods where information asymmetries are small, e.g., following an informative earnings report.

Choe, Masulis and Nanda (1993) suggest that firms time public equity issues to coincide with periods of economic expansion. In their model, the degree of information asymmetry associated with equity offerings varies with the business cycle. They find that the negative stock price reaction to equity offering announcements is smaller in economic expansions. In periods of expansion, more firms receive projects with positive net present value. This implies that in these periods a greater number of firms will find it optimal to issue equity even in the face of the adverse selection problem. Consequently, the average quality of equity issuers increases, which in turn reduces the negative information conveyed by such an announcement. As a result, Choe, Masulis and Nanda (1993) predict that public equity issues will increase in an expanding economy, simply because information problems are less severe. They find empirically that the negative stock price reaction to equity offering announcements is smaller in economic expansions.

[11] Opler and Titman (1995) also use firm size as a proxy for information asymmetry. We also use the log of the market value of equity and find qualitatively identical results.

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Bayless and Chaplinsky (1996) also argue that firms time their public equity offerings to coincide with "windows of opportunity", i.e., periods with low information asymmetry. However, Bayless and Chaplinsky use the volume of equity issues instead of macroeconomic variables to proxy for periods of low/high information asymmetry. They rank the three month moving average of equity issue volume into quartiles and identify high volume periods ("hot" markets) as those where the equity volume is in the upper quartile for at least three consecutive months. Conversely, low volume issue periods ("cold" markets) are those where issue volume falls in the lower quartile for at least three consecutive months. After controlling for macroeconomic conditions, they find that the stock price reaction to public equity issue announcements in high volume periods is less negative on average than in low volume periods.

Drawing on the arguments of Hertzel and Smith as well as the market timing theories, we consider the possibility that rather than passing up valuable investment opportunities in cold periods, firms turn to private placements as an alternative source of financing. Anecdotal evidence supports the idea that firms turn to private markets when public markets are "closed" (Fenn, Liang and Prowse, 1995). In addition, based on arguments similar to those of Choe, Masulis and Nanda (1993), firms with more severe information problems (which would otherwise go to private placement markets) have increased probability of moving into public markets in "hot" periods.

We hypothesize that in hot periods, since information asymmetry problems are less severe, firms will find it more favorable to issue equity in public rather than in private markets. On the other hand, in cold periods, more firms will find it favorable to go to private markets. Using the calculations described by Bayless and Chaplinsky

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(1996) for our sample period, we include dummy variables for hot [HOT] and cold [COLD] periods in our probit regressions. We also use the logarithmic growth rates in leading economic indicators to control for macroeconomic conditions [GLEAD].

Lucas and McDonald (1990) show that firms are likely to issue public equity following a stock price runup. Mackie-Mason also finds that firms are more likely to raise money in public markets if their stock price has risen. We therefore include a variable for the adjusted holding period return in the year prior to the offering [D_RUNUP]. Ritter (1980) argues that industry price-earnings ratios influence the decision to issue public equity. We use two variables to measure the effect of industry valuations, the median change in either the industry price-earnings ratio or the industry market-to-book ratio from the year prior to the year of the offering.

1.3.3 Gains from Change in Ownership Structure

Wruck (1989) argues that one motivation for private placements of equity is to concentrate ownership. Firms that bring a blockholder on board will benefit from increased monitoring and reduced agency costs. Consistent with the agency hypothesis, she finds that abnormal stock returns at announcements of private placements are positive and are positively related to the increase in ownership concentration of these firms. Consistent with Wruck, Hertzel and Smith (1993) find a positive mean stock price reaction to announcements of private placements and that these abnormal returns are positively related to the fraction of the firm's shares issued. However, they also find that ownership concentration in their sample often falls because many of their transactions involve groups of investors rather than a single investor.

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As an ex ante proxy for firms most likely to benefit from a change in ownership structure and increased monitoring, we identify firms with poor operating performance in the two years prior to the offering. We include in our probit model a dummy variable indicating firms with two consecutive years of negative cash flow prior to the offering [IDIS].

Previous research has also shown that firms can use private placements to change ownership structure as a means of avoiding hostile takeovers. DeAngelo and DeAngelo (1989) find firms frequently place blocks of stock with "friendly" investors after receiving an unsolicited offer. Therefore, we also include a dummy for firms that have received a takeover bid in the year prior to the offering [D_ACQUIRE].

1.3.4 Fixed Costs

Differences in fixed issue costs will also influence the choice between public and private markets. Fenn, Liang and Prowse (1995) suggest that some firms find it cheaper to issue in the private market as opposed to the public market. Although they receive a lower price for their shares in the private market, these firms are not burdened with the large fixed costs (e.g. underwriting fees and registration costs) involved in public market issuance. Eckbo and Masulis (1992) suggest there is an inverse relationship between issue costs and the gross proceeds of the offering. We use the log of the gross proceeds to proxy for the importance of fixed issue costs.

1.4 Probit Model of Choice between Public and Private Equity Markets

The specification of our probit model and the predicted signs are as follows:

Π = f [Log of issuer book value(+),

Dummy for hot periods(+),

Dummy for cold periods(-),

Growth in leading economic indicators(+),

Adjusted pre-issue holding period stock return (+),

Median change in industry market-to-book(+),

Dummy for firms in distress(-),

Dummy for firms with takeover bid(-)

Log of gross proceeds(+)]

In our model, Π takes the value of one for publicly issued equity and zero for privately placed equity. Therefore, a positive coefficient indicates that a firm is more likely to issue equity in public than in the private markets. Table A3 shows that, with the exception of the dummy for cold market periods and the median change in industry market-to-book, the variables in our probit regressions have signs as predicted.

Regression (1) is the main regression that will be used for our tests in Section 1.5. Our proxy for the degree of information asymmetry, the log of book value of assets, has a positive and highly significant coefficient. This supports the idea that smaller firms, which have less of a history and analyst following, are more likely to privately place their equity. The dummy variable for hot periods and the growth in leading economic indicators both have positive coefficients; while the dummy variable for cold periods is also positive, it is insignificant. These findings are generally consistent with the wi

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"windows of opportunity" theories of Bayless and Chaplinsky (1996) and Choe, Masulis and Nanda (1993).

In addition, the difference in runup between issuing firms and the benchmark portfolio has a positive and significant coefficient supporting Lucas and McDonald's (1990) idea that public equity issuers time their equity offerings after the stock price has risen. Finally, the coefficient for the dummy variable IDIS is negative and significant at the 1% level, indicating that firms in distress are more likely to go to private equity markets. The dummy variable D_ACQUIRE has a negative and significant coefficient. This is consistent with evidence that firms who are concerned about a potential raider often place their equity in "friendly" hands through a private placement.

Regressions (2) and (3) present alternative specifications of the model. Regression (2) uses the change in the industry price-earnings ratio rather than the change in the industry market-to-book ratio, and finds this variable is not significant. In regression (3), we add the log of the gross proceeds (LPROCEEDS) as a proxy for fixed issue costs. Jung, Kim and Stulz (1996) argue that regressions that use the amount raised as an explanatory variable can be misleading because these regressions incorporate information not available before announcement of the issue. In our sample, issuer size and the size of the issue are highly correlated, therefore in regression (3), we use LPROCEEDS rather than the log of book value of assets. LPROCEEDS has a positive and significant coefficient, which is consistent with the hypothesis that higher fixed issue costs lead firms to use private markets for smaller issues.[12, 13]

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[12] Regression (3) does not include a proxy for information asymmetry because of the high correlation between proceeds and firm size (the Spearman correlation between log (book value of assets) and log (proceeds) is 0.77, p-value = 0.00). However, when we include firm size and proceeds in the same probit model, only proceeds prove to be

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The pseudo R^2 of all regressions are higher than 52%. This measure of fit is similar to statistics reported by Jung, Kim and Stulz (1996) for their model of the debt/equity choice, which range from 26% to 41%. Our regressions classify correctly more than 83% of the public/private decisions. Jung, Kim and Stulz (1996) correctly classify from 74% to 82% of their observations.

1.5 Stock Price Reaction of Firms Announcing Issues Against Type

In this section, we use the probit model developed in the preceding section to segment the sample into firms that are more likely, given their characteristics, to issue public equity and those that are more likely to issue private equity. We then compare the stock price reaction of those who issue according to the predictions of the classification model ("with type") to those who issue "against type".

Our methodology is similar in spirit to that employed by Stulz et. al. (1996). Stulz et. al. estimate logistic regressions predicting whether firms issue debt or equity. They then classify firms that are predicted to issue debt but in fact issue equity, and firms that are predicted to issue equity but in fact issue debt, as firms that have issued "against type". They then compare the characteristics of these subgroups of misclassified issuers in order to distinguish among theories of the debt/equity choice. From the probit model,

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significant and our classification from this probit model is qualitatively identical. Including size or proceeds in the probit models indicates that we have not captured the independent effects of information asymmetry and fixed costs.

[13] In a similar vain, Krishnamurthy, et. al. (1998) use a logit model and a number of explanatory variables to test the influence of flotation costs, information asymmetry, and the level of monitoring on the choice of the form of equity issue (i.e. private vs. public). While they find strong (and consistent) support for the role of flotation costs, their proxies for the effects of information asymmetry and monitoring are not statistically significant.

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we obtain the predicted probability of each firm going to public or private markets. We then divide our sample of both public and private equity issuers into those who issue "with type' and those who issue "against type" based on the predicted likelihood of issuing private or public equity.

Before drawing comparisons between with- and against-type issuers, we provide summary statistics for the stock price reaction. Specifically, in Table A4, we first provide the announcement returns for the full samples of public equity issues and private placements. We then report the results for sub-samples based upon financial distress, firm size, and equity issue volume.

Consider first the results for firms who issue equity publicly. As previously reported, the mean announcement return for the full sample is a significant -2.49%. When the sample is then divided based upon financial distress, the mean announcement returns remain negative, but there is no significant difference between the sub-samples. Next, Table A4 reports the announcement returns for public equity issuers with book value that is less than $25 million, between $25 and $100 million, and greater than $100 million. While all three sub-samples suffer significantly negative mean announcement returns, issuers that are less than $25 million in asset book value have the largest drop in their stock price (-3.73%). In contrast, issuers with more then $100 million in asset book value incur a significantly lower decline of -1.94%. These results are consistent with the idea that smaller firms suffer from more severe information asymmetry.

Finally, we divide the full sample of public equity issues according to whether the issue was introduced in a "hot", "normal", or "cold" period. These periods are defined based on Bayless and Chaplinsky's classification of equity issue volume. Consistent with

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Bayless and Chaplinsky (1996) and Choe, Masulis and Nanda (1993), public equity issuers in cold periods do worse than public equity issuers in hot periods. The announcement return of public issuers in cold periods has a mean of -4.09%, which compares to -2.12% for the same group in hot periods.

For private equity issuers, the mean announcement return of the full sample is +10.39%. When the sample is then split based upon financial distress, distressed issuers have significantly higher stock price reaction than non-distressed issuers do. The former group enjoys a 15.31% mean return as compared to a 6.61% mean return for the latter group. The results suggest that private investors' willingness to invest in a distressed firm signals to the market positive information regarding the firm's expected future performance.

When the sample of private placements is divided by firm size, issuers with asset book value of less than \$25 million have a mean return of 12.64% as compared to a mean of 5.42% for firms with asset book value exceeding \$100 million. Note that this pattern is in direct contrast to that of the public equity issues cited above. That is, while the market reacts more negatively for relatively small firms compared to their larger counterparts when issuing equity publicly, the market reacts less favorably for larger firms when they instead choose to privately place the issue. Finally, private equity issues in cold periods (mean = 15.37%) have a higher stock price reaction than private equity issues in hot periods (mean = 9.20%), but the difference is not statistically significant.

Table A5 reports the stock price reactions for both public and private equity issuers. Each type is divided into two groups based on predicted probabilities from our estimated probit model. That is, we rank the predicted probabilities obtained from the

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probit model and then divide this ranking into two groups based on the median probability measure. Those observations below the median are classified as expected private issues, while observations above the median are classified as expected public issues. We then compare these predictions to what action is actually taken, and accordingly categorize each observation as issuing "with type" or "against type". Panel A presents the results for the full sample of each type of issue, while Panels B, C, and D show announcement returns during normal, hot, and cold periods, respectively.

In Panel A, we first compare the announcement returns for firms issuing public equity when expected ("with type") to firms issuing public equity when it is unexpected ("against type"). The mean return of –1.80% for the former group is less negative than the –3.40% mean return for the latter group, with the results being statistically different at a 1% level of significance. Similarly, for private placements of equity, firms who issue "with type" enjoy a mean return (11.6%) that is relatively superior to that of firms issuing "against type" (3.80%).

Panel B shows that the return pattern established by the full samples is maintained for both private equity placements and public equity issues during normal periods. That is, for both public and private equity issues, the announcement returns for firms issuing "with type" are relatively superior to those for firms issuing "against type". In Panels C and D, the pattern is again maintained. More importantly, however, the latter two panels show that firms who issue public equity "against type" when information asymmetry is relatively high are penalized relatively more severely than firms issuing public equity "against type" when information asymmetry is relatively low.

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Specifically, Choe, Masulis, and Nanda (1993) and Bayless and Chaplinsky (1996) argue that hot periods are associated with low information asymmetry arising from better-than-average investment opportunities. As shown in Panel C, the mean announcement return for firms issuing public equity "with type" during these periods is -1.80%, while the mean return for firms issuing public equity "against type" is –2.80%.

In contrast, Choe, Masulis and Nanda, and Bayless and Chaplinsky characterize cold periods as periods of high information asymmetry. Panel D shows that during these periods, firms issuing public equity "with type" have a mean announcement return of -1.20%, while firms issuing public equity "against type" have a mean return of –5.20%, for a difference of 4%.

Therefore, while the mean returns for firms issuing public equity "with type" are relatively comparable across hot and cold periods, the mean returns for firms issuing public equity "against type" are lower in periods of high information asymmetry (cold periods) than they are in periods of low information asymmetry (hot periods). In addition, the number of firms that issue public equity "against type" in hot periods is 180, while in cold periods, only 43 firms deviate to the public market. These results are consistent with our hypothesis that firms have an incentive to issue public equity "against type" in order to take advantage of the overall optimism of investors toward public equity markets. Finally, while "with type" private issues also outperform "against type" private issues in both hot and cold periods, little can be said, as the difference is statistically insignificant in both periods.

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1.6 Ownership Concentration of Firms Making Private Sales of Equity Securities

Wruck (1989) argues that firms who concentrate ownership benefit from increased monitoring and reduced agency costs. Consistent with her argument, she finds that a shift to more concentrated holdings by non-management through a private equity issue corresponds with an average abnormal return of 4.9%. Drawing on this idea, we hypothesize that firms may therefore have an incentive to issue private equity "against type". To test this hypothesis, available ownership data is collected from both the proxy statement that precedes and the proxy statement that follows each private placement. Specifically, we record the ownership data for all officers and directors of the firm ("management") and for all parties who beneficially own more than 5% of a firm's outstanding common stock, but who are unaffiliated with the corporation ("non-management").[14,15] Table A6 summarizes our results.

Panel A of Table A6 shows that, on average, total beneficial ownership prior to the issue of private equity is 43.77%. Management owns 29.53% and non-management controls 13.71% of the sample firms' outstanding common stock. Following the private placement, there is a mean (median) decrease is management ownership of 4.52% (1.85%), and a mean (median) increase in non-management ownership of 2.78% (0.00%).

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[14] Proxy statements closest to the date of the private placement are used when available. The maximum time span between any proxy date and private issue date is 2 years.

[15] Footnotes of the proxy statements are used to determine the number and the nature of the shares beneficially owned. That is, allowances are made for the reporting of duplicate shares and if shares are indirectly controlled by an officer or director of the firm, they are considered to be owned by management.

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While total ownership concentration decreases an average of 1.99%, this change is statistically insignificant.[16]

Panels B and C divide our results into sub-samples of private equity placed "with type" and "against type", respectively. The results for private equity issued "with type" are similar to those noted above, while the more interesting results for private equity issued "against type" are concentrated among non-management. The change in non-management ownership is 5.32% for "against type" private issues: more than twice the 2.26% change for "with type" private issues. These results are consistent with our hypothesis. There appears to be an incentive for firms to issue private equity "against type" in order to concentrate ownership, and therefore, improve monitoring and reduce agency problems.

1.7 Regression Analysis of Announcement Returns

As presented in Tables A4 and A5, our univariate results suggest that the capital markets believe the form of equity (public or private) matters. In this section, we further explore this issue by estimating a linear regression model of announcement returns for both public and private equity issues. In particular, the specification of our model is as follows:

ANNRET = F [PROB, IDIS, HOT, COLD, D_RUNUP, LOG(BOOK VALUE OF ASSETS), MARKET-TO-BOOK VALUE, PSHARES, AND D_LEV]

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[16] While consistent in sign, these results vary somewhat from those of Wruck(1989). She finds mean, pre-issue ownership levels of 30.7%, 13.1%, and 15.6% for total, management, and non-management holdings, respectively. In addition, the corresponding mean changes in ownership concentration following the private placement of equity are 7.7%, -2.26%, and 4.65%. The difference in the magnitude of the results may arise from the basic differences in our samples. See Footnote #1.

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When estimating the model for public issues, ANNRET is the two-day return (-1, 0) around the announcement date; for private issues, it is the difference between the issuer's and the benchmark portfolio's monthly announcement return. PROB is the dummy variable for the predicted probability of the issue as determined by our estimated probit model. It assumes a value of zero for issues that are "with type" and one for issues that are "against type". IDIS, the dummy variable for financial distress, takes a value of one if the issuing firm has a negative cash flow in the two years prior to the offering, and is zero otherwise. Similarly, the dummy variables HOT and COLD assume a value of one if the issuing period is hot or cold, respectively, and zero otherwise.

As argued by Masulis and Korwar (1986), the runup in the adjusted pre-issue holding-period return [D_RUNUP] is included because it may be used by the market in predicting equity issue announcements, and therefore, may influence the subsequent announcement return. Specifically, in their analysis of seasoned public equity offerings, they contend that a higher pre-announcement runup is associated with an increased likelihood of an offering announcement, and therefore, a smaller negative announcement return.[17] The log of the issuing firm's book value of assets is included as a measure of firm size, while the issuing firm's market-to-book value is an ex-ante measure of the issuing firm's expected future performance.

[17] Masulis and Korwar (1986) make allowances, however, for the case of a relatively large price runup among a sample of stocks where most experience some increase in pre-announcement price. In this case, they argue that the comparatively large runup may predict a decreased likelihood of an offering announcement. Because the runup is associated with a decrease in leverage, the firm may wish to avoid a further decrease in the leverage ratio brought about by selling additional stock. In this case, the pre-announcement runup would be associated with a relatively larger negative announcement return.

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Again, based upon the argument of Masulis and Korwar (1986), we include the percentage change in the number of shares of common stock outstanding (PSHARES) in the regression model. PSHARES proxies for the resulting decrease in management's fractional ownership of shares, and therefore, captures the fall in firm value predicted by both Jensen and Meckling (1976) and Leland and Pyle (1977). Finally, D_LEV measures the change in the issuing firm's total debt from the year prior to the year of the equity offering. It is included in the model to capture both the direct effect of a change in capital structure on announcement returns (as argued by Asquith and Mullins (1986)), and its role as a signal for correlated changes in the issuing firm's future earnings (as argued by Masulis and Korwar (1986)). Note, however, that once the effect of the size of the issue is captured, neither Asquith and Mullins nor Masulis and Korwar found this variable to be significant.

In Table A7, we present the cross-sectional results for the model of public equity offerings. In Model 1, we consider only the effect of the firm issuing public equity "against type" and find the coefficient to be both significant and of the expected sign (-0.0154). In Model 2, we add the remaining dummy variables and D_RUNUP to the regression. While none of these additional variables has a significant effect, both the value and significance of the "against type" variable is virtually unaltered.

In Model 3, the addition of the variable for firm size results in a positive, slightly significant coefficient of 0.0019. Consistent with our results in Table A4, the larger the size of the firm issuing equity publicly, the less negative the resulting announcement return. Note that while the significance of PROB is lower than in Model 1 and Model 2, it rem

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it remains statistically significant at a 5% level. Finally, in Model 4, the coefficient on PROB (-0.0133) is again significant at a 1% level, as is the coefficient on PSHARES (-0.0430). The latter result is also consistent with the argument of Masulis and Korwar (1986): the higher the percentage of shares issued, the lower the fractional ownership of management, and therefore, the lower the announcement return. Table A8 presents the same set of regression models for our sample of private placement issues. However, because of the lack of significance in the results, interpreting the data would be tenuous.

1.8 Summary

We investigate whether the form of equity matters and find that it does. First, we identify attributes that correspond to a firm's tendency to issue equity publicly or privately. Based upon these characteristics, we then find the firms issuing "with type" have a more favorable stock price reaction than firms that issue "against type", regardless of which form of equity they are expected to issue. Given this result, we consider the incentives that induce firms to issue "against type". We find that firms deviate to public markets to take advantage of investors' optimism, and they deviate to private markets to increase ownership concentration and reduce agency problems. Finally, we find that issuing "against type" under certain market conditions (i.e. "hot" or "cold" periods) has a more pronounced effect.

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CHAPTER 2

INNOVATION AND IMITATION: A THEORETICAL MODEL OF PREEMPTION

2.1 Introduction

In addressing the relationship between innovation and market structure, early writings [Loury (1979), Lee and Wilde (1980), and Dasgupta and Stiglitz (1980)] assumed perfect patent protection, and therefore the absence of imitation due to its prohibitive cost. Because of practical concern over apparent weaknesses in patent policy, however, more recent work has focused on the potential effects of costly imitation on innovative activity.

Specifically, Mansfield, Schwartz, and Wagner (1981) reported that in a sample of 48 new products, the average ratio of imitation cost to innovation cost was 0.65. In addition, of the 43 patented innovations examined, 60% were legally imitated within four years of their introduction. Moreover, a 1988 study by Levin, et al. produced similar results, with the majority of surveyed firms citing the "ability of competitors to 'invent around' ...patents" as the most significant constraint on the legislative protection. Therefore, while both papers conclude that patents serve to increase imitation costs to varying degrees, neither finds these costs to be prohibitive.

In acknowledgment of such empirical findings, Reinganum (1981) considers how diffusion of a given innovation can occur through firms' strategic behavior in the presence of imitation. While this model assumes a firm prefers to be the innovator rather than an imitator, Dasgupta (1988) relaxes this restriction in his model of patent races and waiting

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waiting games. Katz and Shapiro (1987) also consider the competition to put a given innovation into practice when the possibility of "postdevelopment dissemination" is present. However, they focus on the specific rivalry between an industry "leader" and "follower" in order to draw conclusions regarding who will innovate and when.

Finally, Pepall and Richards (1994) depart from the previous literature's assumption of an exogenously imposed innovation by exploring a firm's choice of product quality when the possibility of imitation by later rival entrants is anticipated. In the context of the relationship between imitation and innovation costs, they then compare the chosen innovation level with that of a pure monopolist to see if potential imitation alters the innovator's behavior. Among other results, they find that for relatively low imitation/innovation cost ratios (λ), the chosen innovation level is less than that of a pure monopolist's, while a relatively high λ corresponds to a higher quality choice.

Motivated by Fishman's (1988) model of a sequential takeover bidding process, this chapter re-examines the problem set forth by Pepall and Richards (PR). In particular, Fishman's model provides a rationale for a bidder to make a high premium bid for a targeted firm in order to "preempt" or deter a second bidder from competing. The purpose of this chapter is to allow the innovating firm to exhibit comparable preemptive behavior when challenged by a potential imitator. Consequently, my findings depart from PR's Schumpeterian-like results.[18]

[18] The basic point of Schumpeter's 1943 thesis, as summarized by Jean Tirole in *The Theory of Industrial Organization* (1994), is that because of innovation's status as a "public good", the creation of monopolies is a necessary evil to induce firms' to invest in R&D. Therefore, we would expect that, ceteris paribus, the easier (or cheaper) it is to imitate a new product or process technology, the less the incentive to invest in developing the innovation.

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Specifically, while relatively low imitation costs still correspond to a lower quality choice, there is now a "middle" range of λ values for which the innovator chooses a relatively high quality product. Once λ exceeds this range, the firm then reverts to a quality level lower than that chosen by a pure monopolist.[19] Therefore, there is a median range of cost ratio values over which it may be optimal for the second firm to imitate, but it is "preempted" by the quality choice of the profit-maximizing innovator.

The chapter proceeds as follows. In Section 2.2, the model and its assumptions are presented. I first derive and interpret the results assuming the innovator makes its quality choice under conditions of demand certainty. This restriction is then relaxed and the analysis repeated. Section 2.3 relates the model's theoretical implications to empirical observations from the semiconductor industry. Section 2.4 concludes the chapter by offering possible extensions of the research.

2.2 The Model

Consider a new product that embodies a quality characteristic, *z*.[20] While consumers agree that increases in *z* enhance the product, they disagree as to the value of increments in *z*. In particular, consumer preferences are generated by the following utility function, where *z* is assumed to be costlessly identified:

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[19] That is, when the innovator chooses its quality level under conditions of demand uncertainty. When demand is certain and imitation costs are relatively high, the innovator chooses a quality level *equivalent to* the pure monopolist's. The derivation of these results is left to section 2.2 of the chapter.

[20] Let *z* be broadly defined. For example, *z* may encompass not only the bundling of several characteristics within one product, but also the differentiation of an entire product line.

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$$U = \begin{cases} z\theta - p & \text{if the consumer buys one unit of a good with quality } z \text{ at price } p \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

$\theta \in R_+$ is a taste parameter that varies over consumers and therefore indexes consumer type. Specifically, θ indexes taste for quality: the higher its value, the greater is the consumer's willingness to pay for a high-quality product. Assume that θ is continuously and uniformly distributed over $[0,\beta]$, where β is the strongest taste for quality in the consumer population.

Demand for a new good of quality *z* and selling for price *p* will be equal to the number of consumers whose θ satisfies $z\theta \geq p$, or $\theta \geq p/z$. Therefore, the demand function may be written as: $Q(z) = 1 - p/(z\beta)$, which yields the following inverse demand function:

$$P(Q,z) = (1 - Q)\, z\beta \quad (2)$$

For simplicity, assume that marginal production costs, *c*, are equal to 0. However, there is a sunk cost of innovation, $K(z) > 0$, where it is assumed that $K'(z) > 0$; $K''(z) > 0$. In addition, if the innovation is imitated, assume the imitating firm will duplicate the chosen quality level, and will incur imitation costs of $\lambda K(z)$, where λ is a known factor of proportionality, $0 < \lambda < 1$.[21] Therefore, note that as innovation costs increase, so will imitation costs.

[21] If the imitating firm is permitted to choose a quality level different from that chosen by the innovator, then price-quality tradeoffs arise. Such issues are beyond the scope of this chapter.

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2.2.1 Demand Certainty

The model will develop in the following two-stage sequence:

Time 1	**Time 2**
·Innovating firm chooses quality z and incurs $K(z)$; ·enjoys monopoly profits ·β is known and constant	·Imitating firm enters market if profitable; ·produces z and incurs $\lambda K(z)$; ·Firms compete in quantities in Stackelberg equilibrium

Let Firm 1 and Firm 2 indicate the innovator and imitator, respectively. Both firms are risk-neutral, profit maximizers. Upon making its respective production decision (i.e. Firm 1 chooses quality, z, and Firm 2 decides whether or not to imitate), and incurring any associated sunk cost, each firm initiates production of the good. Therefore, because Firm 1 will enter the market at Time 1 (if it is profitable to do so), the innovator will enjoy monopoly profits for at least one period prior to potential competition from Firm 2.

If the imitator decides to enter at Time 2, the firms then compete under conditions of a Stackelberg equilibrium. Upon solving the model, the optimal choice of z is then compared to that of a pure monopolist in order to determine if potential competition alters the innovator's decision, and if so, in what way. Finally, note that a constant β known at Time 1 indicates that both firms operate under conditions of demand certainty, while the discount rate, r, is assumed equal to zero for simplicity.

In order to solve for the innovator's profit-maximizing choice of quality, z, consider first the activity at Time 2. If the firms compete in quantities, the Stackelberg assumption implies the following equilibrium price, equilibrium quantities, and single-period pr

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period profit value functions for a given level of quality, z', where the subscripts correspond to the assigned firm numbers: (*Proof: see Appendix B*)

Proposition 1:

$$p = (1/4)z'\beta; \quad q_1 = 1/2; \qquad q_2 = 1/4 \tag{3a}$$

$$\pi_1 = (1/8)z'\beta - K(z') \tag{3b}$$

$$\pi_2 = (1/16)z'\beta - \lambda K(z') \tag{3c}$$

Note that Firm 2 will imitate iff $\pi_2 = (1/16)z'\beta - \lambda K(z') > 0$. Therefore, if $\pi_2 = (1/16)\, z'\beta - \lambda K(z') \leq 0$, Firm 2 will choose not to imitate and Firm 1 will earn the following single-period monopoly profit at Time 2: (*Proof: see Appendix B)*

Corollary 1a:

$$\pi_m = (1/4)\, z'\beta - K(z') \tag{4}$$

At Time 1, the innovator's problem is then to choose a quality, z, that maximizes the firm's two-period profit given the imitator's anticipated decision at Time 2. In order to solve this problem in a tractable manner, assume a quadratic cost function: $K(z) = \alpha z^2;\ \alpha > 0$. From Corollary 1, we see that Firm 1 will garner monopoly revenues of $(1/4)z\beta$ in the first period. Therefore, by combining these revenues from Time 1 with the appropriate revenues from Time 2, and subtracting the sunk innovation cost, the innovator's problem may be stated as follows:

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Proposition 2:

With No Imitation at Time 2: $$\underset{z}{\text{Maximize}}\ (1/2)z\beta - \alpha z^2 \tag{5a}$$

$$\text{subject to:}\quad z \geq 0$$
$$(1/16)\,z\beta - \lambda\alpha z^2 \leq 0$$

With Imitation at Time 2: $$\underset{z}{\text{Maximize}}\ (3/8)z\beta - \alpha z^2 \tag{5b}$$

$$\text{subject to:}\quad z \geq 0$$
$$(1/16)\,z\beta - \lambda\alpha z^2 \geq 0$$

Solving the above optimization problems with inequality constraints then leads to the following choices of *z*, the innovator's profit value function associated with each, and the range of relative imitation costs over which each is valid: (*Proof: see Appendix B)*

Corollary 2a:

When no imitation occurs:

$z_{m1} = \beta/(4\alpha)$; $\pi_{m1} = \beta^2/(16\alpha)$; $1/4 < \lambda < 1$

$z_{m2} = \beta/(16\lambda\alpha)$; $\pi_{m2} = \beta^2[8\lambda - 1]/[256\lambda^2\alpha]$; $1/8 < \lambda \leq 1/4$

When imitation occurs:

$z_{im} = (3\beta)/(16\alpha)$; $\pi_{1im} = (9\beta^2)/(256\alpha)$; $0 < \lambda < 1/3$

Note that π_{m1} and π_{m2} indicate the respective profit value functions of the innovator when no imitation occurs, while π_{1im} denotes the innovator's profit value function when imitation does occur. By comparing the innovator's applicable profit value functions over the various ranges of λ, the following conclusions may be drawn:

Corollary 2b:

(1) For $0.00 < \lambda \leq 0.125$: $\pi_{1im} > 0 > \pi_{m2}$;
Firm 1 chooses $z_{im} = (3\beta)/(16\alpha)$;
Firm 2's profit value function:
$\pi_{2im} = [(3\beta^2)(1-3\lambda)]/(256\alpha) > 0$

(2) For $0.125 < \lambda < 0.15$: $\pi_{1im} > \pi_{m2}$;
Firm 1 chooses $z_{im} = (3\beta)/(16\alpha)$;
Firm 2's profit value function:
$\pi_{2im} = [(3\beta^2)(1-3\lambda)]/(256\alpha) > 0$

(3a) For $0.15 < \lambda \leq 0.25$: $\pi_{m2} > \pi_{1im}$;
Firm 1 chooses $z_{m2} = \beta/(16\lambda\alpha)$;
Firm 2's profit value function:
$\pi_2 = 0$

(3b) For $0.25 < \lambda < 1.00$: $\pi_{m1} > \pi_{1im}$;
Firm 1 chooses $z_{m1} = \beta/(4\alpha)$;
Firm 2's profit value function:
$\pi_2 = [\beta^2/(64\alpha)]*[1-4\lambda] < 0$

In order to determine if and how potential imitation affects the profit-maximizing behavior of the innovating firm, consider the innovator's two-period problem if it were a pure monopolist:

$$\underset{z}{\text{Maximize}}\ (1/2)z\beta - \alpha z^2$$

$$\text{FOC:} \qquad (1/2)\beta - 2\alpha z = 0$$

$$z_m = \beta/(4\alpha);\ \pi_m = \beta^2/(16\alpha) \tag{6}$$

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Therefore, Corollary 3 shows that when $0.25 < \lambda < 1.00$, Firm 1 chooses a quality level equivalent to that of a pure monopolist, and the imitator's profits are negative. Also, note that z_{im} is always less than z_m, and $z_{im} < z_{m2}$ over the interval $0.00 < \lambda < .333$; thus, Firm 1 chooses a relatively low quality level in (1) and (2), and the imitator's profits are positive. Finally, note that over the interval $0.150 < \lambda < 0.250$, z_{m2} is greater than z_m, which indicates that Firm 1 chooses a high quality level relative to the pure monopolist. The choice of z_{m2} causes Firm 2's profits to just equal 0, and therefore preempts the imitator from competing in (3a). The results are summarized in Theorem 1.

Theorem 1: The model's Nash equilibrium consists of two outcomes: the innovator's optimal quality choice and the imitator's decision of whether or not to imitate. Comparing these outcomes to the quality choice of a pure monopolist, the Nash equilibrium solutions are characterized below. For completeness, the profit value functions relevant to each solution are also given.

(a) For $0.00 < \lambda < 0.15$:

The innovator chooses a relatively low quality level, $z_{im} = 3\beta/(16\alpha)$ and imitation occurs.

$\pi_{1im} = (9\beta^2)/(256\alpha)$; $\pi_{2im} = [(3\beta^2)(1-3\lambda)]/(256\alpha)$

(b) For $0.15 < \lambda \leq 0.25$:

The innovator chooses a relatively high quality level, $z_{m2} = \beta/(16\lambda\alpha)$ and imitation is preempted.

$\pi_{m2} = \beta^2[8\lambda - 1]/[256\lambda^2\alpha]$

(c) For $0.25 < \lambda < 1.00$:

The innovator chooses the same quality level as a pure monopolist $z_{m1} = \beta/(4\alpha)$ and imitation does not occur.

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Therefore, for very low levels of imitation costs, it is not optimal for the innovator to incur the higher cost associated with choosing a preemptive level of quality, and imitation occurs. However, for mid-range values of λ, such activity is beneficial to Firm 1. Specifically, note that as λ increases over this range, the quality choice necessary for preemption decreases ($\delta z_{m2}/\delta\lambda<0$) and the innovator's profits increase ($\delta\pi_{m2}/\delta\lambda>0$). Once relative imitation costs reach a higher level, the innovator is no longer threatened by potential imitation and may revert to a chosen quality level comparable to that of a pure monopolist.[22] Finally, note that for all ranges of λ, higher costs of innovation (α) have a negative effect on the optimal quality choice and firm profits [$\delta z/\delta\alpha<0$; $\delta\pi_1/\delta\alpha<0$; $\delta\pi_2/\delta\alpha<0$], while a higher β has a positive effect, as expected [$\delta z/\delta\beta>0$; $\delta\pi_1/\delta\beta>0$; $\delta\pi_2/\delta\beta>0$].

2.2.2 Demand Uncertainty

Time 1	**Time 2**
·Innovating firm chooses quality z and incurs $K(z)$; ·enjoys monopoly profits	·β is revealed ·Imitating firm enters market if profitable; ·produces z and incurs $\lambda K(z)$; ·Firms compete in quantities in Stackelberg equilibrium

[22] Note that while this latter case corresponds to a rather small minimum value of $\lambda = .25$, introduction of demand uncertainty in section 2.2 ameliorates the result's severity. Moreover, empirical observations from the semiconductor industry suggest that relative imitation costs are routinely low. Further consideration of this particular issue is left to section 2.3 of the chapter.

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Recall that β is an indicator of the strongest taste for quality in the market; as β increases, the number of persons willing to purchase a product of quality z at price p increases, and the demand curve rotates outward. In order to model the innovator's problem under conditions of demand uncertainty, I assume the value of β is unknown at Time 1. After β is revealed at Time 2, Firm 2 will again use this information to decide if imitation of the chosen quality z' will be profitable. Although Firm 1 chooses the level of product quality under conditions of demand uncertainty, assume it knows that β is distributed uniformly over [0,1].

Note that competition in quantities under the assumption of a Stackelberg equilibrium will again yield the single period profit function for Firm 2 found in equation (3c). In addition, if it is known that Firm 2 will refrain from imitation, Firm 1 will enjoy the two-period, pure monopoly profits found in (5a), while the presence of imitation will yield the innovator the two-period profit function of (5b). Again, assume $K(z) = \alpha z^2$, $\alpha > 0$.

Let β^* be the maximum taste for quality at which Firm 2 earns no profit. That is, β^* solves the following:

$$(1/16)\, z\beta - \lambda\alpha z^2 = 0$$

$$\beta^*(z) = 16\lambda\alpha z \qquad (7)$$

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Consequently, for $\beta \leq \beta^*$, insufficient demand will prevent Firm 2 from competing.[23] As a result, Firm 1 may always choose a quality level, z^*, that will deter imitation over all possible states of demand by setting $\beta^* = 1$. This yields:

$$z^* = 1/(16\lambda\alpha) \tag{8}$$

and Firm 1 will enjoy the corresponding expected profit level of:

$$\begin{aligned}
E(\pi^*) &= \int_0^1 (1/2)z^*\beta \, d\beta \; - \alpha z^{*2} \\
&= (1/4)z^*\beta^2 \Big|_0^1 - \alpha z^{*2} \\
&= 1/(64\lambda\alpha) - 1/(256\lambda^2\alpha)
\end{aligned}$$

$$E(\pi^*) = (4\lambda - 1)/(256\lambda^2\alpha) \tag{9}$$

It is important to note that $E(\pi^*) > 0$ iff $\lambda > 1/4$. That is, at relative imitation costs below this level, the costs of deterring imitation outweigh the monopoly revenues. Therefore a preemptive move is detrimental to the innovator when imitation is relatively inexpensive.

Alternatively, Firm 1 could risk the occurrence of imitation, in which case the innovator's problem will be to find the z that solves the following:

$$\text{Maximize } E(\pi_{im}) = \int_0^{\beta^*} (1/2)z\beta \, d\beta + \int_{\beta}^{1} (3/8)z\beta \, d\beta \; - \alpha z^2 \tag{10}$$

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[23] Note that the higher is λ, the higher β^* must be in order for Firm 2 to break even.

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Solving the above optimization equation yields the following two results, the innovator's corresponding profit value functions, and the range of λ over which each solution is valid: (*Proof: see Appendix B*)

Proposition 3:

$$z_{im1} = [1 + \sqrt{(1-9\lambda^2)}\,]/(48\lambda^2\alpha); \qquad (11a)$$
$$E(\pi_{im1}) = [27\lambda^2 - 2 + (18\lambda^2 - 2)\sqrt{(1-9\lambda^2)}\,]/(6912\lambda^4\alpha);$$
$$1/3 < \lambda < 1$$

$$z_{im2} = [1 - \sqrt{(1-9\lambda^2)}\,]/(48\lambda^2\alpha); \qquad (11b)$$
$$E(\pi_{im2}) = [27\lambda^2 - 2 + (2 - 18\lambda^2)\sqrt{(1-9\lambda^2)}\,]/(6912\lambda^4\alpha);$$
$$0 < \lambda < 1/3$$

Consider first the range of λ values over which z_{im1} holds ($1/3 < \lambda < 1$). By inspection, $E(\pi_{im1})$ will be a complex number due to the presence of $\sqrt{(1-9\lambda^2)}$ in the numerator. Therefore, because the profit function is economically invalid, z_{im1} is not a feasible solution. As a result, when $1/3 < \lambda < 1$, Firm 1 will choose the quality level $z^* = 1/(16\lambda\alpha)$. Alternatively, when $0 < \lambda < 1/3$, Firm 1 will then choose between z_{im2} and z^* in order to maximize its expected profits. Recall that $E(\pi^*) \leq 0$ when $\lambda \leq 1/4$, while it can be shown that $E(\pi_{im2}) > 0$; therefore the innovator will choose quality level z_{im2} over this range. Because $E(\pi^*)$ and $E(\pi_{im2})$ are difficult to relate directly, Figure BF1 in Appendix B offers a numerical comparison over the range $1/3 > \lambda > 1/4$, where $\alpha = 1$ for simplicity.

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Combining Figure BF1 with the results noted above, $E(\pi_{im2})$ dominates $E(\pi^*)$ over the range $1/3 > \lambda > 0$ (while at $\lambda = 1/3$, the two are equivalent). Therefore, the profit-maximizing innovator will choose $z_{im2} = [1 - \sqrt{(1 - 9\lambda^2)}]/(48\lambda^2\alpha)$ over this range. Corollary (3a) summarizes the results:

Corollary 3a:

(1) For $0.00 < \lambda < 0.33$:

$$E(\pi_{im2}) > E(\pi^*);$$

Firm 1 chooses $z_{im2} = [1 - \sqrt{(1 - 9\lambda^2)}]/(48\lambda^2\alpha);$

$$\pi_2 = [3\beta\lambda(1-\sqrt{1 - 9\lambda^2})-2+9\lambda^2+2\sqrt{1 - 9\lambda^2}]/(2304\lambda^3\alpha)$$

where π_2 denotes Firm 2's profit function. Note that the value of π_2 will depend upon the level of β. That is, as $\beta \rightarrow 1$, $\pi_2 > 0$ over a growing portion of the range, and imitation will occur. However, as $\beta \rightarrow 0$, $\pi_2 < 0$ over a growing portion of the range, and imitation will be foregone due to insufficient demand.

(2) For $0.33 < \lambda < 1.00$:

$$E(\pi^*) > 0;$$

Firm 1 chooses $z^* = 1/(16\lambda\alpha);$

$$\pi_2 = 0$$

In order to interpret these results, let us again use the quality choice of a pure monopolist as a benchmark for comparison. Specifically, a pure monopolist will choose z_m to maximize its profit function as follows:

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$$\text{Maximize} \int_0^1 (1/2)z\beta\, d\beta - \alpha z^2 = (1/4)z\beta^2\Big|_0^1 - \alpha z^2$$

$$\text{FOC:} \qquad 1/4 - 2\alpha z = 0$$

$$z_m = 1/(8\alpha) \qquad E(\pi_m) = 1/(64\alpha) \qquad (12)$$

As shown in the numerical comparison of z_{im2} and z_m in Figure BF2 of Appendix B, the former is less than the latter when $0 < \lambda < .29$, while the reverse relationship holds over the range $.29 < \lambda < .33$. In addition, by directly comparing z^* to z_m, we see that $z^* > z_m$ when $0 < \lambda < 1/2$, while the opposite is true when $1/2 < \lambda < 1$. Theorem 2 summarizes the results:

Theorem 2: The profit maximizing behavior of the two firms leads to the outcomes noted below. The innovator's quality choice is again compared to the quality choice of a pure monopolist in order to draw conclusions regarding how the potential threat of imitation alters the innovator's decision. For completeness, the profit value functions relevant to each solution are also given.

(a) $0.00 < \lambda < 0.29$:

The innovator chooses a relatively low quality level,
$z_{im2} = [1 - \sqrt{(1 - 9\lambda^2)}]/(48\lambda^2\alpha)$;
Imitation (as dependent upon β) may occur.
$E(\pi_{im2}) = [27\lambda^2 - 2 + (2-18\lambda^2)\sqrt{(1 - 9\lambda^2)}]/(6912\lambda^4\alpha)$;
$\pi_2 = [3\beta\lambda(1-\sqrt{1 - 9\lambda^2}) - 2 + 9\lambda^2 + 2\sqrt{1 - 9\lambda^2}]/(2304\lambda^2\alpha)$

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(b) $0.29 < \lambda < 0.33$:

The innovator still chooses the quality level

$z_{im2} = [1 - \sqrt{(1-9\lambda^2)}\,]/(48\lambda^2\alpha)$, however it is relatively higher than that chosen by the pure monopolist over this range of λ values.

Imitation (as dependent upon β) may occur.

$E(\pi_{im2}) = [27\lambda^2 - 2 + (2-18\lambda^2)\sqrt{(1-9\lambda^2)}\,]/(6912\lambda^4\alpha)$;

$\pi_2 = [3\beta\lambda(1-\sqrt{1-9\lambda^2}\,)-2+9\lambda^2+2\sqrt{1-9\lambda^2}\,]/(2304\lambda^2\alpha$

(c) $0.33 < \lambda < 0.50$:

The innovator chooses a relatively high quality level,

$z^* = 1/(16\lambda\alpha)$ and imitation is preempted.

$E(\pi^*) = (4\lambda - 1)/(256\lambda^2\alpha)$

(d) $0.50 < \lambda < 1.00$:

The innovator again chooses the quality level

$z^* = 1/(16\lambda\alpha)$, however it is relatively lower than that chosen by the pure monopolist over this range of λ values.

Imitation does not occur.

$E(\pi^*) = (4\lambda - 1)/(256\lambda^2\alpha)$

As with the analysis under demand certainty, there is again a median range of λ values for which the innovator chooses a preemptive level of quality. Recall, however, that in the prior case the innovator chose a quality level equivalent to that of a pure monopolist over the highest range of relative cost ratios. In contrast, the present analysis leads the innovator to a relatively lower quality choice when faced with the highest levels of λ.

In fact, Firm 1's quality choice and expected profits are equivalent to those of a pure monopolist when $\lambda = 1/2$. However, note that $\delta z^*/\delta\lambda < 0$ for all relevant λ, while

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$\delta E(\pi^*)/\delta\lambda < 0$ for $1/2 < \lambda < 1$. Consequently, the innovator's expected profits are everywhere dominated by the pure monopolist's as λ increases $[(4\lambda-1)/(256\lambda^2\alpha) < 1/(64\alpha)$ *for* $1/2 < \lambda < 1]$. In effect, because the innovator anticipates imitation when demand is sufficiently strong, its optimal quality choice is less than that of the pure monopolist. Moreover, because the innovator cannot adjust its quality choice at Time 2 when demand and the imitation decision are revealed, its profitability suffers. In fact, note that the higher is λ (and therefore the less likely imitation is to occur), the greater is the relative deficiency.

2.3 Empirical Evidence

In the early 1980's, second-sourcing, or the contractual production of an innovator's technology by other firms, was a commonplace practice among participants in the domestic semiconductor industry. Indeed, the custom was considered critical in quickly establishing a product as the market standard and therefore played a pivotal role in the industry's expansive growth. Specifically, the fabrication of U.S.-designed chips, particularly microprocessors, was often licensed to production-savvy Japanese firms, although some domestic firms specialized in second-source production as well. For example, Hitachi's second-source agreement with Motorola helped the firm become one of the world's largest semiconductor manufacturers, while Advanced Micro Devices (AMD) came into existence as a domestic, second-source producer for Intel.

However, in light of steadily-increasing microprocessor demand, and upon realizing that second-sourced products were often *cheaper than and superior in quality to* the original technology, innovating firms severely curtailed second-sourcing in the mid-

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1980's. In particular, Intel's 1987 break of its technology exchange agreement with AMD was considered a radical departure from the standard industry practice. After watching its second-sourcing provision contribute to the rapid descent of its 80286 microprocessor to a low-priced commodity, the industry leader unilaterally ended the practice with the introduction of its 80386 chip. Credited with delivering Intel from a $183 million loss in 1986 to a $453 million profit in 1988, the innovator's move was then mimicked by other industry leaders.

In particular, Motorola restricted second-sourcing of its 80880 microprocessor, and eliminated the practice with the introduction of its 32-bit 68020 microprocessor. Similarly, National Semiconductor Corporation ended the second-sourcing of its 32-bit microprocessor in the late 1980's, while Texas Instruments (TI) shifted its focus away from the intense price competition of the commodity market towards the development of proprietary products. As a result, in 1994, "differentiated products" were credited for 50% of TI's sales, up from less than 30% in 1989.[24]

Recall that this surge of effort to effectively increase imitation costs grew from the ability of the second source to improve upon the original technology at a relatively lower cost. Yet even with the elimination of these second-sourcing arrangements, *and* the existence of legislative protection for innovations, such imitative behavior persists today. To gain further insight, consider the primary arbiter of innovative activity in the semiconductor industry: The 1984 Semiconductor Chip Protection Act (SCCPA).

In the early 1980's, the cost of developing a complex microprocessor chip was approximately $1m - $4m, while "reverse engineering" of the chip design could produce

[24] *Standard & Poor's Industry Surveys*, 1994. pp. E17-19.

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an exact duplicate for as little as $50,000 - $100,000.[25] Although chip "cloners" still had to bear the substantial costs associated with fabrication, the significant reduction in R&D allowed them to introduce their product at a substantially lower price and subsequently garner market share. Consequently, "legitimate" chipmakers faced potential losses from piracy in the tens of millions of dollars.[26] In response, the SCCPA was created to compensate for the shortcomings in patent, copyright, and trade secret laws' applicability to the industry's products. However, even today, the relatively vague language of the SCCPA leaves several issues to future judicial resolution.

First, the act provides for "legitimate reverse engineering", which is deemed essential to the evolution of semiconductor technology. That is, while "piratical copying" is prohibited, reverse engineering that disseminates standard chip design information (thereby conserving time and resources that would otherwise be invested in duplicative research) is encouraged.

Second, the act protects "original" designs by activating infringement proceedings against "substantially similar" products. For instance, reverse engineering efforts that include a protected work in the new chip will evade liability provided the new chip is "original". Obviously, such wording begs for clearer definition as well as a point of

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[25]"Reverse engineering" refers to the reconstruction of a given chip's design. Through a series of relatively easy steps, both the chip's architecture and the manufacturing techniques needed to create it may be reassembled. Estimates of relative costs from the reverse engineering of semiconductors have been as low as one-one thousandth of the innovator's investment. *Federal Reserve Bank of San Francisco Economic Review*, 1987, p. 44.

[26]In fact, with increasing technological sophistication, the current stakes are much higher: the cost of developing and fabricating a new product is estimated to be more than $1 billion. *Electronic-Engineering Times*, (July 25, 1994).

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reference. Is "originality" to be judged expansively, based on the level of knowledge present in the industry, or is it relative to the creator of the design in question?

Finally, in contrast to patent enforcement, there currently is no specialized court designated to hear actions brought under the SCCPA. In addition, with major portions of the act in need of judicial clarification, conflicting decisions are likely to occur as cases wind though the appellate maze. Thus, while the average semiconductor product life cycle is 1 - 2 years, legal resolution of a dispute is estimated to take 4 - 5 years.

As a specific example of the weakness in legislative protection, reconsider the initial move made by Intel away from second-sourcing. Despite the termination of its second-source provision, AMD effectively broke Intel's monopoly hold on the "386" market when it shipped in excess of $250 million of its "AM386" microprocessor in 1991. Although the product was originally reverse engineered, its speed was enhanced and it consumed less power. Consequently, it was "generally agreed that by leaving gaps in its product line, Intel allowed AMD to grab a larger share of the market than would have otherwise been the case".[27] Capitalizing on this interpretation, AMD subsequently introduced a cloned version of Intel's 486 microprocessor in 1992.

However, in direct response to AMD's reverse engineering of the firm's 386 chip, Intel introduced 30 versions of its next-generation 386SL and 486 chips in 1992. Featuring different speeds, power consumption, and packaging, the firm vowed never again to leave "gaps in its product line". Furthermore, the firm has resolved to double the performance of its microprocessors each year, with one innovation cannibalizing the next. As a result, in 1994, Intel offered a wide variety of Pentium models as the

[27] *Standard & Poor's Industry Surveys*, 1992. p. E24.

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successor to the 486 chip. In addition, its next-generation microprocessor, the "P6", is currently nearing introduction, while development of the "P7" is simultaneously underway.

Similarly, both Motorola and Texas Instruments have aggressively pursued differentiation of their product lines: the former introduced multiple versions of its Power/PC in alliance with IBM; the latter has branched into digital signal processors and linear mixed-signal devices. Moreover, National Semiconductor Corporation is in the final stages of a 5-year business plan aimed to shift its focus from commodity chips to the development of proprietary products.

In terms of the theoretical model, the relatively low development costs associated with reverse engineering and the weaknesses of the SCCPA suggest that relative imitation costs in the semiconductor industry are not prohibitive. Therefore, it appears reasonable to view both the termination of second-sourcing agreements and the aggressive product development by industry leaders as preemptive moves against potential imitators. While the latter move is clearly an increase in quality, z, as defined by the model, recall that z is also the only variable by which the innovator can affect imitation costs. Therefore, the increase in imitation (and innovation) costs that arise from the termination of second-sourcing agreements are also captured by the variable, and may therefore be interpreted as a preemptive action. Clearly, the evidence is anecdotal. However, it does encourage the need for further research.

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2.4 Summary

In addition to the need for further empirical work regarding the behavior of innovators when threatened by potential imitation, three theoretical extensions of the research come to mind. First, allowing β to be unknown in both stages would enhance the current model's flexibility, while inclusion of social welfare analysis may give insight into its normative implications. Second, introduction of a third stage would greatly enrich the model. In particular, rather than exogenously imposing an "innovator" and an "imitator", the first stage would permit the two firms to compete in the innovation, while allowing for the possibility of waiting to imitate at Time 2. Finally, the incorporation of product "cannibalization" and "leapfrogging" into this more general model format may prove to be other viable extensions.

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CHAPTER 3

THE NATURE OF RESEARCH AND DEVELOPMENT INVESTMENT: AN EMPIRICAL STUDY OF DIFFERENCES WITHIN AND ACROSS INDUSTRIES

3.1 Introduction

To date, empirical work that investigates the impact of firm- and industry-specific characteristics on the firm's research and development investment decision is relatively limited. For example, a body of work exists that addresses the relationship between firm profitability and R&D activity. However, in their thorough review of the literature, Kamien and Schwartz (1982) note that "the empirical evidence that either [firm] liquidity or profitability are conducive to innovative effort or output appears slim".[28] Although additional studies have been conducted since that time, the empirical results remain fairly tenuous.[29] Similarly, while numerous studies have tested the relationship between firm size and R&D activity, the results are mixed.[30] Finally, empirical tests of the impact of leverage on research and development are extremely limited as well.[31]

Although there is a general lack of consensus among the empirical results, there is agreement throughout the literature that R&D activity varies both across and within industries. In general, however, empirical studies either do not allow for distinct industry influences (Acs and Audretsch, 1988; Hall, 1995), confine the data to a single industry

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[28] *Market Structure and Innovation* (Cambridge: Cambridge University Press, 1982); p.98

[29] See Bernstein and Nadiri (1988), Himmelberg and Peterson (1994), and Hall (1992, 1995, 1998)

[30] See Kamien and Schwartz (1982) and Scherer (1984) for reviews of the literature

[31] See Bernstein and Nadiri (1988) and Hall (1992).

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(Grabowski & Baxter, 1973) or fail to find a statistically significant industry effect (Link & Neufeld, 1986).[32]

The purpose of this chapter is to investigate how firms make their research and development investment decision, and how that decision may vary both across different industries and within the same industry. Specifically, I first develop a probit model that tests the role of several firm-specific characteristics in the firm's decision to maintain either a high or low commitment to R&D. I then develop a panel data model that jointly tests the influence of the firm-specific characteristics (and an industry-specific characteristic) on the intensity of the firm's R&D investment.

While the panel data model is first run on the full sample of firms, I then run the model separately for each sample industry, as defined by the corresponding 2-digit standard industrial classification (SIC). In addition, I refine my industry definition to the 3-digit SIC level, and then re-run the test for a select number of these classifications. In order to evaluate how the effect of the firm-specific characteristics on the level of R&D investment varies across firms within the same industry, I divide each 2-digit SIC based on key firm variables. I then compare the panel data results for the top third of each industry sample to those for the bottom third of each industry.

Although the empirical literature that specifically investigates the effect of firm profitability on R&D investment is thin, there is a general consensus among the results that this effect is positive.[33] In addition, there is a well-developed body of literature that

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[32] An exception is the study by Cohen and Klepper (1992), in which they identify a positively skewed, unimodal distribution of R&D intensity within the majority of the sample 2-digit standard industrial classifications.

[33] See Grabowski (1968), Grabowski and Baxter (1973), Himmelberg and Peterson (1994), and Hall (1992, 1998).

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examines the sensitivity of firms' capital investment to internally generated cash flows (e.g. see Fazzari, Hubbard, and Peterson (1988) and Kaplan and Zingales (1997)). A common point within this literature, as well, is that the investment-cash flow relationship is positive.

Consistent with both of these literatures, I generally find a positive relationship between my measures of firm profitability and R&D investment. I depart from the existing literature, however, in my finding that this relationship is not uniformly positive. For example, I find that the least profitable firms within both the Electronic and Other Electric Equipment industry (SIC 36) and the Instruments and Related Products industry (SIC 38) show a negative relationship between profitability and R&D. This suggests that in certain cases, the availability of internally generated funds has an impact on the level of firm investment.

In addition, my results for firm leverage suggest that debt may play a significant, but varying role in a firm's commitment to R&D investment. For example, I find the relationship between leverage and R&D investment to be positive for the relatively R&D-intensive Drugs industry. This is consistent with earlier work by Brander and Lewis (1986) and Maksimovic (1988), in which higher leverage commits managers to more aggressive investment decisions. In the relatively less R&D-intensive Soap, Cleaners, and Toilet Goods industry, however, the relationship is negative. This is consistent with the work by both Chevalier and Scharfstein (1996) and Dasgupta and Titman (1998) which documents a negative relationship between leverage and investment.

For both the full data sample and the SIC 36 sub-sample, I also find that among the least profitable firms, both profitability and leverage have negative impacts on the lev

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level of R&D activity. This suggests that in certain instances, less profitable firms may be more capitally constrained in external markets. Finally, the effect of firm size on R&D intensity is fairly consistent in its significance and its effect is industry-specific. There is also limited evidence of a negative relationship between industry concentration and R&D investment among the top performers within each industry.

The remainder of the chapter is organized as follows. Section 3.2 describes the formation of the data set and provides summary statistics for both the full sample and each industry sub-sample. Section 3.3 highlights the firm-specific characteristics employed in the model specifications. Section 3.4 and Section 3.5 review the empirical results for the probit model and panel data model, respectively. Section 3.6 concludes the chapter.

3.2 Characteristics of the Data Sample

3.2.1 Formation of the Data Set

To form the sample data set, I begin with all firms in both the *Active* and *Research Files* of *Compustat PC Plus* for the sample period 1978 – 1997. The majority (63.8%) of the available R&D expenditure data points is concentrated among manufacturing firms, which fall into the general Standard Industrial Classifications (SIC) of 2000 and 3000. Of these firms, 77.1% of the R&D observations are concentrated in five, 2-digit SICs. Therefore, as shown in Table 1 below, this study focuses on firms falling in the following 2-digit SICs:

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Table 1
2-Digit Standard Industrial Classifications

SIC	Classification
28	Chemicals & Allied Products
35	Industrial Machinery & Equipment
36	Electronic & Other Electric Equipment
37	Transportation Equipment
38	Instruments & Related Products

Because it is generally agreed that research and development is a long-term investment, I then pursue a balanced panel of data by selecting the firms within the above categories that report R&D expenditure in each year of the sample period 1978 – 1997. Consequently, my final sample consists of 324 "established" firms, each with 20 years of R&D data, or a total of 6,480 sample firm years. As shown in Table C1 of Appendix C, this sample accounts for the majority of the data available for all firms falling in the above-noted 2-digit classifications.

Specifically, my established firms are responsible for nearly 64% of all R&D expenditure reported within the chosen SICs over the entire sample period. Similarly, my sample firms account for nearly 61% of total sales revenue, and 62% of total asset book value. When grouped by 2-digit SIC, the percentages are comparable for SIC 28, 36, and 38. For SIC 35, the figures are slightly lower, with the established firms responsible for approximately 50% of R&D expenditure, 45% of sales revenue, and 46% of total asset book value. In contrast the figures for SIC 37 are relatively higher, accounting for roughly 81%, 70%, and 71% of each respective category.

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3.2.2 Summary Statistics

3.2.2a Full Sample and 2-Digit Standard Industrial Classifications

Panels A and B of Table C2 contain summary statistics for the sample of established firms and for the corresponding 2-digit SIC industries, respectively. Specifically, the mean and standard deviation of R&D expenditure, sales revenue, R&D intensity, and total asset book value are reported.[34] Because accounting data is typically skewed in nature, median values are also reported and are focused upon. In preparation for the empirical tests of the chapter, I also include a measure of firm profitability, which is defined as the ratio of firm operating cash flow (adjusted for R&D expenditure)/sales revenue.[35] Finally, Panel A and Panel B show the total number of sample firm years used in the calculation of each measure. All figures, with the exception of R&D intensity and profitability, are reported in millions of dollars.

For each variable, the Industrial Machinery and Equipment industry (SIC 35) and the Electronic and Other Electric Equipment industry (SIC 36) each account for roughly 26-27% of the total number of firm years available in my sample of established firms. Likewise, the Chemicals and Allied Products industry (SIC 28) and the Instruments and Related Products industry (SIC 38) each account for approximately 20% of the total sample points. In contrast, the Transportation Equipment industry (SIC 37), constitutes a much smaller 7% of the data sample.

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[34] R&D intensity is defined as the ratio of a firm's R&D expenditure (Compustat Annual Data Item #A46)/Sales revenue (Compustat Annual Data Item #A12).

[35] My measure of operating cash flow is defined by Compustat to be Operating Income Before Depreciation (Compustat Annual Data Item #A13) and is equal to Net Sales less Cost of Goods Sold and Selling, General, and Administrative Expenses before deducting Depreciation, Depletion, and Amortization. To this figure, I add R&D expenditure to arrive at my "adjusted operating cash flow" measure.

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While the median level of R&D expenditure for the entire sample is $7.4 million, Panel A shows that when the sample is divided into 2-digit SICs, the median values vary widely. For example, SIC 37 has a median value of $68.7m in R&D expenditure, while SIC 28 has a median value of $23.8m. SIC 36 and SIC 38, however, have median values of only $4.1m and $4.7m, respectively. With respect to sales revenue, SIC 37 and SIC 28 again rank at the top with median values of $3,196m and $1,003m, respectively. SIC 36 and SIC 38 again rank at the bottom, each with median sales revenue of approximately $100m. Median values of total asset book value show a similar pattern.

In contrast, SIC 36 and SIC 38 rank at the top in terms of median R&D intensity, with ratios of 0.057 and 0.046, respectively. This suggests that, although firms in SIC 36 and SIC 38 are relatively smaller in terms of size and level of R&D expenditure, they are devoting a relatively larger portion of their resources to research and development.[36] Finally, SIC 28 and SIC 38 also have the highest median profitability measures of 0.186 and 0.172, respectively, while SIC 37 ranks at the bottom with median profitability of 0.134.

Panel B of Table C2 displays the same summary statistics for each 2-digit SIC as a whole. In terms of median R&D expenditure, sales revenue, and total asset book value, the industries display a pattern fairly consistent with that of the sample of established firms. That is, when comparing across industries, SIC 37 and SIC 28 rank at or near the top, while SIC 36 and SIC 38 consistently rank at the bottom. Note, however, that there

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[36] This inverse relationship between level R&D expenditure and R&D intensity is consistent with other empirical literature. For example, for the top 20 firms in terms of R&D expenditure, Chauvin & Hirschey (1993) show a sample average expenditure of $2.1 billion and an average intensity of 6.4%. In contrast, for the top 20 firms in terms of R&D intensity, they have a sample average R&D expenditure of $32.2 million and a corresponding intensity of 41.6%.

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is relatively less variation in medians across the different industries than there is across the categories of sample firms. With respect to industry median R&D intensity and median profitability, the patterns are again fairly consistent with the established firms, with SIC 38 ranking at the top and SIC 37 at the bottom.

When comparing each group of established firms to their corresponding industry, I see that all are significantly larger in terms of median sales revenue and total asset book value. For example, in SIC 38, the established firms' median sales revenue is only $101.7m, but in comparison to the industry's median value of $16.2m, it is relatively large. With respect to R&D expenditure, the established firms again have a relatively higher median in comparison to their respective industries. In SIC 28, the median expenditure for the established firms is $23.8m, as opposed to the industry's median outlay of $4.7m. For SIC 36, the medians are $4.1m and $1.7m, respectively.

When comparing median R&D intensity, however, the measures for the sample firms and their respective industries are generally more comparable. The exceptions are SIC 35 and SIC 28, where the industry median intensities (0.047 and 0.066, respectively) substantially outweigh the established firms' corresponding medians (0.029 and 0.032, respectively). Therefore, for these two classifications in particular, it appears that while the established firms are relatively larger and invest more in R&D, they devote proportionately less to research and development than their respective industries.

Finally, when comparing the median profitability measures to the corresponding industry measures, we see that in every 2-digit SIC classification, the sample median exceeds that of the industry. This suggests that, at the median, the sample of established firms are more profitable than their corresponding industries.

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3.2.2b 3-Digit Standard Industrial Classifications

As a supplement to Panel A and Panel B of Table C2, Table C3 reports summary statistics for the data sample and the corresponding industries, but refines the industry definition to a 3-digit SIC level.[37] As expected, disaggregating the data again shows a wide variation in the variables' median values across the sample firms. For example, within SIC 28, consider the Drugs industry (SIC 283) and the Soap, Cleaners, and Toilet Goods industry (SIC 284).

For the Drugs industry, the pivotal role played by research and development is apparent. First, the median value of R&D expenditure for the sample registers a relatively high $95.3m. Second, while the sample firms are relatively large in terms of median revenue ($1,802m), book value ($1,999m), and profitability (0.299), they have a significantly higher median R&D intensity of 0.081 as well.

In contrast, the median commitment to R&D expenditure for the sample firms within the Soap, Cleaners, and Toilet Goods industry is a relatively low $17.3m. Moreover, while these firms are relatively smaller than the other sample classifications in terms of median revenue ($597.6m), total asset book value ($422.2m), and profitability (0.143), their median R&D intensity of 0.023 ranks among the lowest within the SIC 28 classification as well.

It is worth noting that while SIC 283 contributes the largest number of data points (N=380) to the SIC 28 sample, this represents only a small percentage of the more than 3,000 data points available from the industry as a whole. Moreover, while the median

[37] See Appendix D for a description of each 3-digit Standard Industrial Classification (SIC).

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R&D intensity of 0.081 dominates the other 3-digit sample medians, it is just a hint of the relative intensity of the industry's R&D, as reflected in the industry median of 0.232. For SIC 284, however, the sample firms are representative of the industry in terms of median R&D intensity. In addition, the sample for SIC 284 accounts for nearly 36% of the industry's available research and development data points.

Within SIC 35, the Computer and Office Equipment sample (SIC 357) has a relatively low median level of $3.8m in R&D expenditure, but the highest median R&D intensity of 0.072 and the highest median profitability margin of 0.176. In SIC 356 (the General Industrial Machinery industry), investment in research and development appears to be relatively insignificant, as shown by the median R&D expenditure level of $1.8m, and an R&D intensity measure of 0.02.

For both classifications, the sample firms are representative of their corresponding industries in terms of both median R&D expenditure and median R&D intensity. Approximately 50% of the available R&D data within SIC 356 (N=972) is accounted for by the sample firms, but only 12% of the R&D data within SIC 357 (N=3,633) is represented by the sample.

In SIC 36, the Communication Equipment industry sample (SIC 366) and the Electronic Components and Accessories industry sample (SIC 367) both post a mere $3m in median R&D expenditure. In addition, both classifications rank equally low among the sample in terms of median size. In terms of profitability, however, the median measures of 0.172 and 0.169 for SIC 366 and SIC 367, respectively, are among the highest. The same holds true for the median R&D intensities of 0.063 (for SIC 366) and 0.049 (for SIC 367). Finally, both sample classifications are relatively larger than their correspo

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corresponding industries in terms of median size, but are fairly comparable in terms of both median profitability and commitment to R&D. The sample of firms represent approximately 21% and 30% of the available R&D data points for SIC 366 and SIC 367, respectively.

In SIC 37, the sample of firms from the Motor Vehicles and Equipment industry (SIC 371) appears to be driving the median results for all the variables within the 2-digit SIC. It's median R&D expenditure ($1,142m), sales revenue ($36,284m) and total asset book value ($23,713) far exceed not only the median measures of all the other sample medians, but also the median measures for the Motor Vehicles and Equipment industry as a whole. The sample firms' median R&D intensity of 0.030 also exceeds the industry median of 0.016. While representing only 18% of the research and development data points within SIC 371, the sample is clearly the most dominant of the firms within the industry.

Within SIC 38, the Search and Navigation Equipment industry (SIC 381), the Measuring and Controlling Devices industry (SIC 382) and the Medical Instruments and Supplies industry (SIC 384) contribute the majority of data points to the sample. At the median, the SIC 381 sample is generally comprised of larger firms that are relatively less R&D intensive and relatively less profitable than the sample firms of SIC 382 and SIC 384. In each classification, the sample firms are relatively larger than their corresponding industries in terms of median sales revenue, total asset book value, and R&D expenditure, but they are relatively comparable in terms of median R&D intensity. Finally, the sample represents approximately 35%, 25%, and 11% of the available R&D data points for SIC 381, SIC 382, and SIC 384, respectively.

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3.2.2c Summary

In summary, I have chosen five 2-digit standard industrial classifications that account for the majority of research and development during the period 1978 – 1997. Within those industries, I have focused on a sample of firms that account for a relatively significant proportion of that research and development, and who are consistent in their commitment to R&D.

At the median, the sample is relatively larger than the corresponding 2-digit SIC industries in terms of levels of R&D expenditure, sales revenue, profitability, and total asset book value. In contrast, the sample's median R&D intensity ratios are either comparable to or relatively lower than are those of the corresponding industries. Finally, the nature of R&D expenditure, both as a level measure and as a proportion of sales, varies across the sample of 2-digit Standard Industrial Classifications.

When the sample is refined to 3-digit Standard Industrial Classifications, the sample firms are generally among the larger firms within their industries in terms of median size and R&D expenditure, but are representative of the industries in terms of profitability and R&D intensity. As with the 2-digit SICs, we see that research and development, both in terms of level expenditure and intensity, again varies widely across the 3-digit classifications.

Finally, among both the 2-digit and 3-digit classifications of the sample, there is a generally positive correspondence between median profitability and median R&D intensity. That is, when the full sample is divided by 2-digit SIC, the classifications that rank among the top (bottom) in terms of median R&D intensity generally also rank among th

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among the top (bottom) in terms of median profitability. The same can be said for the ranking of each 3-digit SIC within its corresponding 2-digit classification. Because the measures are contemporaneous, nothing may be said about the direction of causality within this relationship. I will, however, address the issue in more detail in the following sections of the chapter.

3.3 Firm-Specific and Industry-Specific Characteristics

3.3.1 Firm Profitability

At the time of their survey of the empirical literature addressing the firm's choice of innovative activity, Kamien and Schwartz (1982) credit Grabowski (1968) and Grabowski and Baxter (1973) with having the strongest empirical results documenting the relationship between firm profitability and research and development. In particular, both studies find a positive relationship between a firm's internally generated funds and R&D expenditure. However, both tests are limited in scope and Kamien and Schwartz cite numerous studies that find no conclusive evidence of a relationship between R&D and profitability.[38] The authors argue that the lack of conclusive evidence with respect to the relationship between profitability and R&D may arise from there being a threshold level of profitability.

Himmelberg and Peterson (1994) argue that prior studies' failure to find a statistical relationship between profitability and R&D arises from their focus on primarily large, Fortune 500 firms. They propose that the moral hazard and adverse selection

[38] Grabowski regresses R&D intensity on three variables: measures of cash flow, diversification, and an index of prior research productivity for three industries. The tests of Grabowski and Baxter are limited to eight firms in the chemical industry.

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problems of debt and equity markets, as modeled by Stiglitz and Weiss (1981) and Myers and Majluf (1984), are acute for small, high-tech firms. As a result, the R&D investment of these particular firms relies upon, and is constrained by, internally generated funds.[39] In their panel-data study, Himmelberg and Peterson regress R&D expenditure on the "permanent" component of internal cash flows for a group of small firms and find a significant positive relationship.[40]

In more recent work, Hall (1992, 1998) has used relatively sophisticated econometric techniques to test the effect of firm cash flows on R&D activity, and has also found the relationship to be consistently positive.[41] Note that in each of the studies cited, lagged measures of profitability are employed to alleviate the issue of simultaneity between R&D expenditures and firm cash flow.

In related work, Fazzari, Hubbard, and Peterson (1988) test the sensitivity of firms' capital investment to internally-generated cash flows and find there is a greater sensitivity among firms that are defined to be financially constrained (i.e. to have limited access to external funding due to information asymmetries).[42] Therefore, inasmuch as the

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[39] In addition, this point is supported by a theoretical model proposed by Kamien and Schwartz (1978).

[40] Himmelberg and Peterson's data sample consists of 179 firms with a maximum replacement value of capital stock of $10 million. The firms are drawn from SIC 28, SIC 35, SIC 36, and SIC 38 over the period 1983-1987.

[41] Hall's 1992 study is a panel data test of 1,300 firms over the sample period 1976 - 1987. She estimates a first-differenced form of her model specification using lagged values as instruments for her explanatory variables. Her 1998 study evaluates 204 firms drawn from SIC 28, SIC 35, SIC 36, and SIC 38 over the sample period 1978 - 1989. She estimates a panel data form of a VAR model, again using lagged values as instruments for her explanatory variables.

[42] Additional studies in this large body of literature include: Hoshi, Kashyap, and Scharfstein (1991), Calomiris and Hubbard (1995), Bernanke, Gertler, and Gilchrist (1996), and Kaplan and Zingales (1997). In a departure from the majority of results, Kaplan and Zingales (1997) find that those firms defined to be less financially

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intangible nature of R&D investment constrains a firm's access to external funding, we should expect that firms who commit proportionately more resources to R&D should be more dependent upon internally-generated funds for this investment. Consistent with the findings of Fazzari, Hubbard, and Peterson (1988), we should then expect relatively higher R&D investment-profitability sensitivities in industries with relatively higher R&D intensities. Finally, as is the case with all the above-noted studies, we expect the sign of the R&D investment-profitability relationship to be consistently positive.

3.3.2 Firm Size

Numerous empirical studies have had mixed results with respect to the relationship between R&D activity and firm size.[43] One body of work has found constant returns to scale, while another body argues that R&D activity increases more than proportionately for smaller firms, but diminishes among larger firms. There are, however, two points of commonality among the literature. First, it is widely agreed that the size effect varies across industries. Second, much of the evidence to date on the effect of firm size has not controlled for other factors that may help explain a firm's R&D decision. In the multivariate tests that follow, I attempt to remedy the latter point, but because this is an industry-based study, I expect the sign of the effect of size on R&D to vary accordingly.

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constrained have greater capital investment-cash flow sensitivity. A common thread throughout the literature, however, is that the sign of the investment-cash flow relationship is positive.

[43] See Kamien and Schwartz (1982) and Scherer (1984) for reviews of the literature.

3.3.3 Market Structure

In his 1943 thesis, Schumpeter argues that because innovation is a public good, the creation of monopolies is a necessary evil to induce firms to invest in research and development. Alternatively, once a firm has monopoly power, it may be argued there is less threat from rivals and a lowered incentive to innovate (Arrow, 1962). Similar to the evidence for the effect of firm size, the existing empirical literature shows no consensus with respect to the relationship between market structure and research activity.[44]

3.3.4 Industry-Adjusted Growth

My inclusion of firm growth in the explanatory variables is not directly motivated by existing empirical work, but I believe it is reasonable to assume that a firm's rate of growth relative to the industry in which it competes may be significantly influential. I am, however, unsure of the direction of that influence. It may be the case that a firm that is enjoying a high level of growth relative to its industry is performing well and is willing to commit relatively more resources to research and development. On the other hand, superior performance may dull the firm's competitive edge, and lead to a decrease in R&D. Similarly, a firm experiencing a relatively low growth rate may either commit an increasing amount of funds to R&D in an attempt to improve performance, or it may reduce the commitment of funds in order to meet shorter-term obligations.

[44] See Scherer (1967, 1984) and Kamien and Schwartz (1982).

3.3.5 Leverage

Empirical tests of the impact of leverage on R&D investment are extremely limited. Among this work, however, both Bernstein and Nadiri (1988) and Hall (1992) find that a negative relationship exists. More generally, there is a body of literature that examines the relationship between the choice of capital structure and product market competition. That is, based on the theoretical model introduced by Bulow, Geanakoplos, and Klemperer (1985), firms may be categorized as competing in either "strategic substitutes" or "strategic complements". A firm is said to compete in strategic substitutes (complements) if its marginal profitability decreases (increases) in response to an increase in a rival firm's action.

Under the additional assumption of linear demand and constant marginal cost, quantity competition may be characterized as competition in strategic substitutes and price competition may be characterized as competition in strategic complements. Drawing on this framework, the capital structure/product market competition literature examines the use of debt as a device to commit managers to more or less aggressive behavior in the product market.[45] Specifically, work by Brander and Lewis (1986) and Maksimovic (1988) show that when competition is in quantities (strategic substitutes), higher leverage leads to more aggressive investment decisions. In contrast, studies by Chevalier and Scharfstein (1996) and Dasgupta and Titman (1998) argue that when competition is in prices (strategic complements), leverage and investment are negatively

[45] For additional applications within the strategic substitute/strategic complement framework, see Aggarwal and Samwick (forthcoming, 1999) and Kedia (1996). Both of these studies examine the relationship of managerial compensation contracts and strategic competition. In addition, see Sundaram, John, and John (1996), in which the announcement effects of R&D spending are analyzed separately for firms that compete in either strategic substitutes or strategic complements.

related. I do not attempt to sort my sample based on the nature of strategic competition. However, to the extent that different industries may be characterized as competing in strategic substitutes or strategic complements, I expect the sign of the relationship between leverage and R&D investment to vary accordingly.[46]

3.4 Probit Model of the Choice Between High and Low R&D Intensity

3.4.1 Model Specification

The probit model is specified as follows:

$$\Pi = \alpha + \beta_1 \text{ Industry-Adjusted Profitability}_{i,-1} + \beta_2 \text{ Industry-Adjusted Profitability}_{i,-2} + \beta_3 \text{ Ln(TABV)}_i + \beta_4 [\text{Ln(TABV}_i)]^2 + \beta_5 \text{ Market Share}_i + \beta_6 \text{ Industry-Adjusted Growth}_i + \beta_7 \text{ Leverage}_i + \varepsilon$$

To test the model, the full sample of firms is ranked by R&D intensity within each year of the sample period 1978 – 1997. Firms falling in the top third of the ranking for any given year are defined to be "high-intensity" firms, while those falling in the bottom third of the ranking are "low-intensity" firms.

As shown in Table C4, the median R&D intensity of the two groups is statistically different at a 1% level of significance for each year of the sample.[47] In addition, note that for the 106 firms categorized as high-intensity firms, median R&D intensity grows from a measure of 6.6% in 1980 to 9.4% in 1997, but hovers rather steadily in the 8.5% - 9.5% range for most of the sample period. Similarly, for the 106 firms falling into the low-

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[46] In Kedia's (1996) study, 59% of the sample industries (as defined by 4-digit SIC) that can be categorized by the nature of the strategic interaction compete exclusively in either strategic complements or strategic substitutes.

[47] The years 1978 and 1979 are necessarily omitted because of the use of lagged variables in the corresponding probit model.

intensity ranking, median R&D intensity consistently measures near 1.5% over the entire sample period.

In my probit model, Π takes the value of zero for high-intensity firms and a value of one for low-intensity firms. The value of zero is defined to be the "natural" response. Therefore, a positive coefficient indicates that a firm is more likely to be a high-intensity firm rather than a low-intensity firm. A separate probit model is then run for each year of the sample period 1980 – 1997.

The independent variables used in this specification are defined as follows:

Industry-Adjusted Profitability$_{i\,(-1,-2)}$: The numerator of the profitability ratio is defined to be firm operating cash flow adjusted for research and development expenditure (i.e. Compustat Annual Data Item #A13 + Compustat Annual Data Item #A46). The denominator of the profitability ratio is firm sales revenue (Compustat Annual Data Item #A12). To derive industry-adjusted profitability, I subtract the median ratio for the industry, where "industry" is defined as the primary 3-digit Standard Industrial Classification in which the firm competes.

The 1-year and 2-year lags of this measure are derived for each firm i and each year t (with the exception of 1978 and 1979).[48,49] As previously noted, lagged values are employed to alleviate the issue of simultaneity between R&D investment and firm

[48] As a robustness check, I also included the 3-year lag in both the probit and panel data tests. The estimated coefficient generally lacked statistical significance, however, so the variable is excluded from my tests.

[49] My use of the 1-year and 2-year lags is fairly consistent with existing empirical studies. Grabowski & Baxter (1973) use a 1-year lag only. Himmelberg & Peterson (1988) use all available lags, but their sample period of 1983 - 1987 necessarily limits the

profitability. In addition, I do not consider reverse causality between R&D and profitability to be an overriding concern in my empirical analysis because of the gestation period between an outlay of R&D and the beginning of an associated revenue stream.

Ln(TABV$_i$): The natural log of the book value of total assets (Compustat Annual Data Item #A6) for each firm i and each year t in the data sample is used as a proxy for firm size.

Market Share$_i$: Market share is the ratio of firm i sales revenue to industry sales revenue for each year t of the data sample period. "Industry" is defined as the 3-digit SIC in which the firm competes, and industry sales revenue is the sum of sales revenue (Compustat Annual Data Item #A12) for every firm with the same primary 3-digit SIC for each year t of the sample period.

Industry-Adjusted Growth: Firm i's growth is measured as the 2-year percentage change in sales revenue, or as (sales revenue$_{i,t}$ – sales revenue$_{i,t-2}$)/ sales revenue$_{i,t-2}$. From this, I subtract the median 2-year percentage change in sales revenue for the 3-digit SIC industry in which the firm competes. The measure is calculated for each firm i and year t (with the exception of 1978 and 1979) in the sample.

Leverage: Leverage is equal to the ratio of firm i's total debt (defined as Total Long-Term Debt + Debt in Current Liabilities, or Compustat Annual Data Item #A9 +

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selection. Hall (1992) tests the use of a number of different lags and selects the 2-year and 3-year lag as her preferred specification.

Compustat Annual Data Item #A34) to firm i's total asset book value for each year t in the data sample.

3.4.2 Empirical Results

As shown in Table C5, consistent results are evidenced for the coefficients of Industry-Adjusted Profitability$_{-1}$, Industry-Adjusted Profitability$_{-2}$, Ln(TABV), and $[\text{Ln(TABV)}]^2$. In particular, the coefficient estimates of Industry-Adjusted Profitability$_{-1}$ are statistically significant in 11 of the 18 tests, and are positive in all but one of these cases. For Industry-Adjusted Profitability$_{-2}$, the coefficient estimates are positive and statistically significant in 12 of the 18 tests. Together, these results are consistent with prior empirical findings of a positive relationship between internal cash flow and investment and imply that the more profitable the firm, the more likely it will commit to a relatively high level of R&D intensity.

The coefficients of Ln(TABV) are negative and statistically significant in all 18 of the tests. This suggests that the larger a firm's size the more likely it will choose a low level of R&D intensity. Recall that in Section 3.2, the data's summary statistics show that the sample firms rank among the largest in their respective industries, both at a 2-digit and 3-digit SIC level. Therefore, the negative sign of the size coefficient in my probit model is consistent with prior empirical findings of diminishing R&D activity among larger firms. Finally, the coefficient for size^2 is positive and statistically significant in every case, which indicates that as firms increase in size, the higher the probability they will choose a relatively high level of R&D intensity.

3.5 Panel Data Tests of the Effects of Firm-Specific and Industry-Specific Variables on the Choice of R&D Intensity

3.5.1 Model Specification

The model is specified as follows:

$$\begin{aligned} \text{R\&D Intensity}_{i,t} = \alpha + \beta_1 \text{ Industry-Adjusted Profitability}_{i,-1} + \beta_2 \text{ Industry-Adjusted} \\ \text{Profitability}_{i,-2} + \beta_3 \text{ Ln(TABV)}_{i,t} + \beta_4 [\text{Ln(TABV}_{i,t})]^2 \\ + \beta_5 \text{ Market Share}_{i,t} + \beta_6 \text{ Industry-Adjusted Growth}_{i,t} \\ + \beta_7 \text{ Leverage}_{i,t} + \beta_8 \text{ Herfindahl} + \text{Time Dummies} + \varepsilon \end{aligned}$$

where the explanatory variables are as defined in Section 3.4.1. One additional explanatory variable is included and is defined as follows:

Herfindahl Index: The Herfindahl index is calculated for each year t in the sample period and is defined as the sum of squared market share over every firm in an industry. Market share is the ratio of firm i sales revenue to industry sales revenue, and "industry" is defined to be the 3-digit standard industrial classification in which firm i competes. As a measure of industry concentration, the larger the Herfindahl index, the more concentrated is the industry.

For each test of the above specification, either the data sample of 324 firms that made research and development investments continuously over the sample period 1978 – 1997 is used in its entirety, or a sub-sample of the data is employed.[50] In all cases, a level fixed effects form of the model is run with allowance for unbalanced panel data. Inherent to the fixed effects model, intercept variables for each cross section are estimated in each model, but are suppressed in the reporting of results. In addition, annual dummy

variables are included in each model, but these results are also suppressed. Because the coefficient of determination is inflated by the inclusion of these explanatory variables, R^2 is not reported in the results that follow. As a measure of the model's validity, however, I test the hypothesis that my primary explanatory variables are jointly equal to zero. The p-values of this F-test are reported with the results.

3.5.2 Empirical Results for Full Sample and Across the 2-Digit SICs

As shown in Table C6, both lags of industry-adjusted profitability have a negative and significant effect on R&D intensity in the test of the full data sample. Contrary to prior empirical findings, the results imply that, on average, as the flow of internally generated funds increases the proportion of revenues committed to R&D declines. In addition, the estimated coefficient of –0.002 indicates that industry-adjusted growth has a negative and significant effect on R&D intensity.[51] Finally, the coefficient of the Herfindahl index is –0.056 and is significant at a 5% level. This suggests that the more concentrated the industry in which the firm competes, the lower the R&D intensity.

When the data is broken into sub-samples based on 2-digit SICs, the coefficients for both lags of industry-adjusted profitability are statistically significant in three of the

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[50] As previously noted, the years 1978 and 1979 are necessarily omitted because of the use of lagged variables in the model specification.

[51] There may be reason to suspect that the negative relationship between industry-adjusted growth in sales revenue and R&D intensity is "hard-wired". That is, a relatively high growth rate in sales revenue corresponds to an increasing denominator in the R&D intensity measure, and because R&D generally varies relatively little over time, the numerator will remain fairly constant. To address this issue, all of the tests were re-run using R&D expenditure/Total Asset Book Value as the measure of R&D intensity. The negative sign and significance of the industry-adjusted growth coefficients does not change. The results are not reported, but are available from the author upon request.

industries. Specifically, in the Chemicals and Allied Products industry (SIC 28) and the Industrial Machinery and Equipment industry (SIC 35), the coefficients are positive, implying that as the average firm within these industries becomes more profitable, the relative commitment to R&D intensifies. For the Instruments and Related Products industry (SIC 38), however, the opposite results hold, as is reflected in the coefficients of –0.224 and –0.072, respectively.[52]

With respect to the other independent variables, firm size has a statistically significant effect on R&D intensity in both SIC 35 and SIC 38, but is opposite in sign across the two industries. In SIC 35, size has a negative effect on R&D intensity (-0.049), while in SIC 38, the effect is positive (0.034). Industry-adjusted growth has a consistently negative effect across all 2-digit SICs, and is statistically significant in all but SIC 28.

Finally, three of the five industries show significant results for leverage, but the sign of the results again varies. Specifically, the negative effect of leverage on R&D intensity in both SIC 36 (–0.030) and SIC 37 (-0.011) is consistent with competition in "strategic complements" as put forth by Chevalier and Scharfstein (1996) and Dasgupta and Titman (1998). In contrast, for SIC 28 the positive leverage coefficient of 0.107 is consistent with competition in "strategic substitutes" as argued by Brander and Lewis (1986) and Maksimovic (1988).

The importance of the results in Table C6 is twofold. First, breaking the data into industry sub-samples, even though coarsely defined at a 2-digit SIC level, reveals

[52] Note that the Electronic and Other Electric Equipment industry (SIC 36) also has negative coefficients for both lags of industry-adjusted profitability, but only the coefficient of –0.105 associated with the 1-year lag of the variable is (highly) statistically significant.

information that is lost in the aggregation of the data in the full sample. Second, with the disaggregation of the data, we see that firm-specific characteristics do not have universal effects on the choice of R&D intensity, but instead, those effects vary with the specific environment in which the firm competes.

3.5.3 Empirical Results Across the Core 3-Digit SICs

Based on the information provided in Table C3, I identify the "core" 3-digit SICs that contribute the majority of the data sample points within each 2-digit SIC, and re-run the tests. For example, of the 9 different 3-digit SICs within SIC 35, the General Industrial Machinery industry (SIC 356) and the Computer and Office Equipment industry (SIC 357) together account for 55% of the data points in that 2-digit SIC sample. Therefore, within SIC 35, these two industries are identified as "core" 3-digit SICs. The core 3-digit classifications are shown in Table 2 as follows:

Table 2
Core 3-Digit Standard Industrial Classifications

SIC	**Classification**
283	Drugs
284	Soap, Cleaners and Toilet Goods
356	General Industrial Machinery
357	Computer and Office Equipment
366	Communication Equipment
367	Electronic Components and Accessories
371	Motor Vehicles and Equipment
382	Measuring and Controlling Devices
384	Medical Equipment and Supplies

As shown in Table C7, disaggregating the data again reveals additional information. For the Drugs industry sample (SIC 283), the coefficient for the one-year lag of industry-adjusted profitability is a positive 0.096 and is significant at a 10% level. The coefficients for the 2-year lag of industry-adjusted profitability (0.188) and for leverage (0.416) are also positive, and both are highly significant. Recall that based on the summary statistics in Table C3, the sample of firms from the Drugs industry ranked among the top of the sample SIC 28 classification in median size, profitability, and R&D intensity. These statistics, combined with the above results, suggest that my sample of firms within the Drugs industry are relatively large, profitable firms that maintain a relatively high commitment to research and development with both internally- and externally generated funds.

For the SIC 284 sample (the Soap, Cleaners, and Toilet Goods industry), the coefficients for both lags of industry-adjusted profitability are again positive and

significant. In contrast to SIC 283, however, the coefficient of leverage is a statistically significant –0.015. Moreover, the coefficients of market share (-0.063), industry-adjusted growth (-0.006), and firm size (-0.009) are negative as well.

These results suggest that as a firm within this sub-sample grows in size, market share and sales, its R&D intensity will decline. In addition, as is consistent with competition in "strategic complements", the more levered a firm becomes the less aggressive will be its commitment to investment in R&D. This is consistent with the summary statistics of Table C3, which show the sample of firms from SIC 284 to be among the least R&D intensive firms of the SIC 28 sample.

To the extent that the intangible nature of R&D investment creates information asymmetries, we should expect that firms who invest proportionately more in R&D to be relatively constrained in their access to external funding. Drawing on the existing empirical literature (e.g. Fazzari, Hubbard, and Peterson (1988); Hoshi, Kashyap, and Scharfstein (1991); Calomiris and Hubbard (1995)), we should then expect relatively higher sensitivity of R&D investment to internally generated funds for these firms.

Applying this logic at an industry level, consider the magnitudes of the profitability coefficients in SIC 283 and SIC 284. As previously noted, within the SIC 28 classification, SIC 283 ranks highest in terms of median R&D intensity while SIC 284 ranks at the bottom. The combined magnitude of the lagged profitability coefficients in SIC 283 is 0.284. For SIC 284, the combined magnitude is only 0.08. Therefore, consistent with the empirical literature to date, the sample of firms within the R&D-intensive Drugs industry appear to be significantly more financially constrained than are those within the Soap, Cleaners, and Toilet Goods industry.

For the sub-sample of firms within the General Industrial Machinery industry (SIC 356), the one-year and two-year lags of industry-adjusted profitability are both positive and significant. In addition, the coefficient for industry-adjusted growth is a statistically significant –0.005. These results suggest that the more profitable the firm or the lower its relative sales growth, the higher the level of R&D intensity. A similar interpretation holds for the Computer and Office Equipment sub-sample (SIC 357), where Industry-Adjusted Profitability$_{-1}$ and Industry-Adjusted Growth have estimated coefficients of 0.337 and –0.112, respectively. In addition, the latter sub-sample also has a statistically significant coefficient of –0.115 for the firm size variable.

In a pattern similar to that found in SIC 28, note the difference in the combined magnitudes of the profitability coefficients for SIC 356 and SIC 357. Within the SIC 35 classification, SIC 357 ranks highest in terms of median R&D intensity and it has a combined magnitude of 0.417 for its profitability coefficients. In contrast, SIC 356 ranks in the bottom third of SIC 35 in terms of median R&D intensity, and the combined magnitude of its profitability coefficients is 0.058. Once again, the results imply that the R&D-intensive industry is relatively more financially constrained.

The summary statistics in Table C3 show the sample firms from both the Communication Equipment industry (SIC 366) and the Electronic Components and Accessories industry (SIC 367) to be relatively small, but to have comparatively large median R&D intensity levels. According to the empirical results in Table C7, however, both industry-adjusted profitability and leverage have opposite signs across the two sub-samples. In SIC 366, the coefficient estimate for both the one-year lag (-0.138) and the two-year lag (-0.109) of industry-adjusted profitability depart from traditional empirical results in that they are negative in sign. In addition, the coefficient estimate for leverage is a statistically significant –0.090.

Alternatively, for SIC 367 the coefficients for both lags of industry-adjusted profitability (0.052 and 0.031) and for leverage (0.016) are all positive and significant at the 1%, 10%, and 5% level, respectively. These results suggest that as profitability and leverage increase, firms in the Communication Equipment industry sample (SIC 366) commit relatively less to R&D. In the Electronic Components and Accessories industry sample (SIC 367), however, increasing levels of profitability and leverage translate into a more aggressive commitment to R&D.

Finally, for the Measuring and Controlling Devices industry sample (SIC 382), both firm size and leverage have positive and significant effects on R&D intensity. In contrast, the coefficients of industry-adjusted growth (-0.036) and of the Herfindahl index (-7.57) are both negative and significant at the 1% and 10% level, respectively. This suggests that the greater the firm's relative growth and the more concentrated the industry in which the firm competes, the lower the commitment to R&D intensity.

Similar to the results in Section 3.5.2, the evidence in Table C6 and Table C7 suggest that certain characteristics influence the firm's commitment to research and development. Among them, industry-adjusted profitability and industry-adjusted growth play routinely significant roles, and to a lesser extent, so do leverage and firm size. Moreover, the environment in which a firm competes impacts both the direction and importance of those influences. Finally, as the definition of the competitive environment is refined, so is the nature of the relationship between firm-specific characteristics and the R&D investment decision.

3.5.4 Division of the Data Sample

In this section, I am interested in isolating how the explanatory variables affect the level of R&D intensity when the data is sorted on different firm characteristics. Specifically, I divide the sample based on median R&D expenditure and run the empirical test separately for those firms identified as "top spenders" and those firms identified as "bottom spenders". Similarly, I divide the sample based on median sales revenue in order to compare results for the largest firms to those for the smallest firms. My third division of the data compares the most profitable firms to the least profitable, while my fourth, and last, division compares highly levered firms to those with relatively little leverage.

Beginning with the full sample, I calculate the median R&D expenditure for each firm over the 1978 – 1997 sample period. To allow for outliers, I then eliminate the top 1% of the firms from the sample. The remaining firms are ranked according to these median measures, and the top third and bottom third of the firms are identified. This division of the sample is then repeated based upon median firm sales revenue, median firm profitability, and median firm leverage.

To allow for the effect of the individual industries in which the firms compete, I prefer to work with the 3-digit SIC definition of the industry, but I do not have enough data to make the above divisions.[53] Therefore, the 2-digit SIC is the most refined definition of industry with which I can work. Within each 2-digit SIC (with the exception of SIC 37, for which there is not enough data), I calculate the median R&D

[53] I attempted the divisions for the identified "core" 3-digit SICs, but the empirical results lacked statistical significance.

expenditure for each firm over the 1978 – 1997 sample period. To allow for outliers, I again eliminate the top 1% of the firms within that SIC from the sample. The firms are then ranked within each 3-digit SIC into the top third and bottom third based on median R&D expenditure and are grouped across the corresponding 2-digit SIC. This division of the sample is then repeated based upon median firm sales revenue, median firm profitability, and median firm leverage.[54]

My reason for ranking the data within each 3-digit SIC and then grouping across the corresponding 2-digit SIC is as follows. As previously noted there is a group of "core" 3-digit SICs that account for a relatively large percentage of the data sample. If I simply divide the data into the top third and bottom third within each 2-digit SIC, I risk the dominance of any one division by a single 3-digit SIC. For example, within SIC 28, the Drugs industry (SIC 283) is large in sample size and has a median level of profitability (0.299) that is large relative to the medians of the other 3-digit SICs (see Table C3). Dividing the entire SIC 28 sample into the top third and bottom third based on median profitability essentially results in a comparison between SIC 283 in the top third and the remaining 3-digit SICs in the bottom third, which is not my intent. Therefore, I equally-weight the splitting of the data within each 3-digit SIC in order to avoid this issue of dominance.[55,56]

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[54] Although there is limited evidence of outliers at the bottom of the sample, because the profitability measure may assume a negative value, both the top 1% and bottom 1% of the sample based on the median profitability measure were omitted. The empirical results are virtually identical to those associated with omitting only the top 1% of the sample, and therefore are not reported.

[55] As a robustness check, I do divide each 2-digit SIC into the top third and bottom third based on each median measure and re-run the tests. In the majority of the cases, each core 3-digit SIC is represented in both the top and bottom third. Therefore, the

Once the top third (bottom third) are identified within each 3-digit SIC, I then assume there is an element of commonality among these firms within their corresponding 2-digit SIC and group them accordingly. As a result, when the data is divided according to median firm sales revenue, for example, my empirical test shows how the same firm-specific characteristics affect the level of R&D intensity for the largest firms within each 2-digit industry as opposed to the smallest firms.

3.5.4a Summary Statistics for Full Data Sub-Samples

In Table C8 and Table C9, I provide summary statistics for the divisions of the full data sample. In each table, Panel A represents the division of the data sample into the top third and bottom third based on median firm R&D expenditure. Panel B, Panel C, and Panel D correspond to the divisions based on median firm sales revenue, median firm profitability, and median firm leverage, respectively.

For each division of the full data sample, Table C8 shows the number of data points contributed to the top third and bottom third by each 3 digit SIC and each 2-digit SIC. In general, every 2-digit SIC is represented in both the top third and bottom third of each panel. Note that in Panel A and Panel B, SIC 28 contributes proportionately more sample firm years to the top third than to the bottom third, while the opposite is generally true for SIC 35, SIC 36, and SIC 38. In Panel C, SIC 28 and SIC 38 each contributes

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empirical test results are very similar to those I report. The results are available from the author upon request.

[56] As a second robustness check, I divide the sample within each core 3-digit SIC only, and then group the data across the corresponding 2-digit SIC. For SIC 28 and SIC 35, the empirical results are similar, but are less statistically significant than those reported in the paper. For SIC 36, the results are again similar and are slightly more

proportionately more to the top third of the sample based on median profitability than to the bottom third. The opposite is again true for SIC 35.

In Table C9, each panel shows the mean, median, and standard deviation of key variables for both the top third and bottom third of the full data sample. In particular, Panel A reports the summary statistics for the top third and bottom third of the sample based on median R&D expenditure. Focusing on the medians, note that the top spenders of research and development dollars are generally larger and more profitable than are the bottom spenders. In addition, the top spenders also commit a relatively larger fraction of revenue to R&D than do the bottom spenders, as is reflected in the median intensity measures of 0.046 and 0.029, respectively. The difference between the median leverage of the two sub-samples is not statistically significant.

As shown in Panel B, when the sample is divided based on median sales revenue, the larger firms are relatively more profitable, more levered, and spend relatively more on R&D than the smaller firms. In contrast, the median R&D intensity for the larger firms (0.037) is significantly lower than that of the smaller firms (0.045). As expected, Panel C shows that the more profitable firms are generally larger, carry less leverage, and commit relatively more to research and development. In Panel D, the top third of firms based on median leverage are generally less profitable (0.143) and have a lower median R&D intensity (0.037) than the bottom third (0.171 and 0.051, respectively).

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statistically significant than the results I report. For SIC 38, the results are virtually identical to what is reported in the paper.

3.5.4b Empirical Results for Full Data Sub-Samples

Corresponding to the division of the data in Table C8 and Table C9, Panel A of Table C10 shows the empirical results of the fixed effects panel data model for both the top third and bottom third of the sample based on R&D expenditure. Specifically, the estimated coefficients for both the 1-year lag (0.056) and 2-year lag (0.099) of industry-adjusted profitability show that profitability has a positive and statistically significant impact on R&D intensity for the top R&D spenders. Moreover, the estimated coefficient for leverage is 0.010 and is statistically significant at a 5% level. This suggests that an increase in both internally- and externally generated funds leads to a higher commitment to R&D intensity for the highest spenders on R&D. In contrast, the estimated coefficients for the bottom spenders show that both the 1-year lag (-0.111) and the 2-year lag (-0.069) of profitability have a negative impact on R&D intensity.

For the top spenders, size has a positive (0.018) and statistically significant effect on R&D intensity, although the relationship is concave in nature. A similar, although less statistically significant relationship holds true for the bottom spenders as well. Finally, the estimated coefficient of –0.037 for the Herfindahl index indicates that, for the top R&D spenders, the more concentrated the industry in which the firm competes, the lower the level of R&D intensity.

In Panel B, the data sample is divided into the top third and bottom third based on median sales revenue. In general, the results are similar to those of Panel A. That is, industry-adjusted profitability has a positive and significant impact on R&D intensity for the larger firms, but has a negative and significant impact for the smaller firms. Departing slightly from the results in Panel A, size and $size^2$ are significant only for the smaller firms, but again indicate a positive and concave relationship to R&D intensity. Finally, the Herfindahl index indicates a significantly negative effect of industry concentration on R&D intensity for both large and small firms.

In Panel C, the sample division is based on median profitability. Once again, industry-adjusted profitability has a significantly positive effect on R&D intensity for the top third and a significantly negative effect for the bottom third. Specifically, the coefficients for the 1-year lag and 2-year lag are a positive 0.150 and 0.113 for the most profitable firms, but are –0.195 and –0.057, respectively for the least profitable firms. In addition, the estimated coefficient for leverage is 0.046 for the most profitable firms and is -0.031 for the least profitable.

In summary, the empirical results for the full data sample suggest that larger firms, more profitable firms, and firms that expend relatively more on research and development generally show a significantly positive relationship between lagged profitability and R&D intensity. Relatively profitable firms and firms with relatively high R&D expenditures also associate leverage with a more aggressive commitment to R&D intensity. In contrast, smaller firms, less profitable firms, and firms that expend relatively few resources on R&D show a significantly negative relationship between lagged profitability and R&D intensity. Less profitable firms also associate leverage with a less aggressive commitment to R&D intensity. Finally, where firm size is significant, it is everywhere positive and concave in its relationship to R&D intensity.

3.5.4c Summary Statistics for 2-Digit Industry Sub-Samples

Table C11 – Table C14 show the summary statistics for the data sub-samples within each 2-digit SIC. As before, Panel A within each table corresponds to the division of each industry sample into the top third and bottom third of firms based on median R&D expenditure. Focusing on median measures of sales revenue, total asset book value, and profitability, this panel shows that, within each industry, the top R&D spenders are generally larger and more profitable than are the bottom spenders. Furthermore, the top spenders in each of the industries also commit to a higher median level of R&D intensity than do the bottom spenders.

With respect to median leverage, however, the results vary across the industries. In both SIC 35 (Industrial Machinery and Equipment) and SIC 38 (Instruments and Related Products), the difference between the median leverage of the top third and bottom third is not statistically significant. In SIC 28 (Chemicals and Allied Products), the median leverage of 0.208 for the top third significantly exceeds the median leverage of 0.168 for the bottom third. In SIC 36 (Electronic and other Electric Equipment), the top third's median leverage of 0.148 is significantly lower than the bottom third's median of 0.197.

Similar results arise in Panel B, where the division of the data is based on median firm sales revenue. The top third of the sample within each industry has a significantly larger median R&D expenditure, profitability, and total asset book value. Again, the difference between the median leverage is statistically significant in only SIC 28 and SIC 36 and the results mirror those of Panel A. While median R&D intensity is higher for the largest firms within SIC 35 and SIC 36, the opposite is true for SIC 38 and there is no statistical difference within SIC 28.

In Panel C, the direction of the relationship between each median measure for the most profitable firms as compared to the least profitable firms is uniform across every 2-digit classification. Specifically, the median level of sales revenue and total asset book value for the top third within each industry is significantly higher than the corresponding median for the bottom third within each industry. The same holds true for both R&D expenditure and R&D intensity. With respect to leverage, the top third within each industry has a lower and statistically different median leverage than that of the corresponding bottom third.

In Panel D, each industry is divided into the top third and bottom third based on median firm leverage. In both SIC 28 and SIC 35, the most highly levered firms are larger in size than the firms with the lowest levels of leverage. In SIC 36 and SIC 38, however, the opposite is true. Based on median profitability, firms with higher leverage are less profitable than those with lower leverage in SIC 28, SIC 36, and SIC 38. The difference in median profitability within SIC 35 is not statistically significant. Finally, among the statistically significant results, the median level of R&D expenditure and R&D intensity is lower for the top third than for the bottom third within both SIC 36 and SIC 38.

3.5.4d Empirical Results for 2-Digit Industry Sub-Samples

Table C15 summarizes the panel data results for the Chemicals and Allied Products industry (SIC 28). As shown in Panels A through D, the effects of both profitability and leverage are uniform regardless of how the data is split within SIC 28. That is, where the results are statistically significant, the estimated coefficients for industry-adjusted profitability and leverage are positive for the largest and smallest firms (Panel B), and for the firms with the highest and lowest R&D expenditures (Panel A), profitability (Panel C), and leverage (Panel D). The size effect is also uniformly positive and statistically significant for the bottom third of each panel. For the top third of each panel, the size effect is everywhere negative, and is statistically significant in all but Panel C.

Based on these results, it appears that for firms in the Chemicals and Allied Products industry, increases in profitability and leverage are associated with a relatively stronger commitment to R&D intensity, regardless of the variable upon which the sample is divided. As the firm increases in size, however, large firms, highly levered firms, and firms with relatively high R&D expenditures decrease R&D intensity. In contrast, small firms and firms with relatively low leverage, low profitability, and low R&D expenditures increase their R&D intensity in response to an increase in size.

As shown in Table C16, the empirical evidence for the Industrial Machinery and Equipment industry (SIC 35) is relatively limited. In Panel A through Panel D, both the 1-year and 2-year lag of industry-adjusted profitability have a significantly positive effect on R&D intensity for the top third of each sample division. With the exception of significantly positive results in Panel D, however, evidence of the effect of profitability on R&D intensity for the bottom third of each sample division is tenuous.

The estimated coefficient of leverage is –0.017 for the top third of Panel A and is statistically significant at a 5% level. This suggests that while top R&D spenders commit internally generated funds to research and development, higher levels of leverage curtail that commitment. Increases in leverage have a similar effect on the bottom spenders, as is reflected in the estimated leverage coefficient of –0.024.

In Panel C, both increases in market share (-0.072) and industry-adjusted growth (-0.012) have a negative effect on R&D intensity for the most profitable firms. In Panel D, the estimated leverage coefficient is -0.022 for the firms with an already high level of debt, but is a positive 0.150 for firms with relatively little debt. This implies that an increase in debt leads to a less aggressive R&D commitment among highly levered firms and a more aggressive R&D commitment among low-levered firms.

The empirical results for the Electronic and Other Electric Equipment industry (SIC 36) are reported in Table C17. For the top third in Panel A, the respective coefficients of 0.094 and 0.162 for the 1-year and 2-year lag of industry-adjusted profitability are both positive and significant at a 1% level. In addition, the top R&D spenders show a positive effect on R&D intensity for both firms size (0.019) and leverage (0.028).

In contrast, the estimated coefficients for industry-adjusted growth (-0.024) and the Herfindahl index (-0.118) are both negative and significant among the top spenders. Therefore, access to both internal and external sources of funds fuel the top spenders' commitment to R&D intensity. However, the higher the top spenders' growth relative to the industry or the more concentrated the industry in which the top spenders' compete, the lower the commitment to R&D intensity. Similar results hold for the largest firms within the industry, and are shown in Panel B.

In Panel C, note that for the top third of the sample, both coefficients for lagged profitability are significantly positive as well. In addition, the Herfindahl index is –0.123, suggesting that the more concentrated the industry in which the most profitable firms compete, the less aggressive is the commitment to R&D intensity. For the least profitable firms within SIC 36, the most notable results are those for lagged profitability and leverage. In this case, each variable has a significantly negative effect on R&D intensity (-0.129, -0.124, and –0.056, respectively), suggesting a relatively less aggressive commitment to research and development. Similar results hold true for the most highly levered firms in Panel D, where the estimated coefficients of industry-adjusted profitability (-0.128 and –0.100) and leverage (-0.058) are again negative and statistically significant.

Finally, results for the Instruments and Related Products industry (SIC 38) are shown in Table C18. Most notable among them are the results for lagged industry-adjusted profitability. Where significant, the sign of these coefficients for the top third of the sample in Panel A through Panel D are everywhere positive while for the bottom third of each panel, the opposite is true. In addition, note that where significant results arise, firm size has a uniformly positive effect on R&D intensity and the Herfindahl index has a uniformly negative effect.

In sum, the results for the effect of firm profitability on R&D intensity are generally consistent with those of prior empirical literature (e.g. see Himmelberg and Peterson (1994), Hall (1992, 1998), and Fazzari, Hubbard, and Peterson (1988)). That is, in the majority of my tests, firm profitability has a positive and significant effect on R&D investment. Within SIC 36 and SIC 38, however, certain divisions of the industry samples depart from traditional findings and document a significantly negative relationship between firm profitability and R&D.

With respect to leverage, I find empirical evidence consistent with both competition in "strategic substitutes" (i.e. a positive effect of leverage on R&D investment) and competition in "strategic complements" (i.e. a negative effect of leverage on R&D investment).[57] In addition, the effect of size on R&D intensity is fairly consistent in its significance and affirms the general consensus that it varies across industries. Finally, there is limited evidence of a generally negative Herfindahl coefficient among the top performers within each industry. This implies that, among these sub-samples, as industry concentration increases, the intensity of the average firm's commitment to research and development diminishes.

3.6 Summary

The empirical results for both my probit and panel data models suggest that a firm's internally generated funds significantly influence the research and development investment decision. While those results are generally consistent with prior empirical work and find this profitability/investment relationship to be positive, there are pockets of evidence to the contrary. For example, within both the Electronic and Other Electric Equipment industry (SIC 36) and the Instruments and Related Products industry (SIC

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[57] Recall that in Kedia's (1996) study, 59% of her sample industries can be categorized as competing exclusively in strategic substitutes or strategic complements. Although my leverage results suggest both types of strategic interaction may occur in the same industry, this is not a dramatic departure. First, Kedia is unable to identify any significant strategic interaction in nearly 30% of her sample SICs. In addition, Sundaram, John, and John (1996) find evidence of both types of strategic interaction within the same 4-digit SIC.

38), there is a significantly negative effect of profitability on R&D intensity among particular sub-samples of the data.

In addition, significant results for firm leverage suggest that debt plays an important role in a firm's commitment to research and development investment. The direction of that commitment, however, may depend upon the nature of the firm's product market environment. In particular, I show evidence of debt's link to more aggressive investment in R&D, which is consistent with competition in "strategic substitutes". However, I also empirically document a negative relationship between debt and R&D, which is consistent with competition in "strategic complements". Finally, although more limited in scope, there is evidence of significant roles played by both firms size and industry concentration in the firm's investment in R&D.

In summary, the empirical results suggest that the influence of firm-specific characteristics on R&D activity is not universal, but varies both within and across industries. Therefore, in order to gain a better understanding of the factors that influence a firm's investment in research and development, we must consider the environment in which the firm competes as well as the firm's relative position within that environment. Moreover, as the definition of that competitive environment is refined, so is the nature of the relationship between firm-specific characteristics and the R&D investment decision.

SUMMARY

This dissertation contains three chapters that address separate issues in the area of corporate finance. The first chapter is an empirical analysis of firms' strategic choice of equity markets. It investigates whether the form of equity (public issue or private placement) matters and finds that it does. That is, attributes that correspond to a firm's tendency to issue equity publicly or privately are identified. Based upon these characteristics, the results show that the firms issuing "with type" have a more favorable stock price reaction than firms that issue "against type", regardless of which form of equity they are expected to issue. Given this outcome, the incentives that induce firms to issue "against type" are considered. Chapter 1 shows that firms deviate to public markets to take advantage of investors' optimism, and they deviate to private markets to increase ownership concentration and reduce agency problems. Finally, issuing "against type" under certain market conditions (i.e. "hot" or "cold" periods) has a more pronounced effect.

The second chapter presents a theoretical model of an innovator's choice of product quality when imitation is anticipated. Specifically, the model identifies a median range of relative imitation costs over which the innovator chooses a preemptive quality level. Anecdotal evidence from the semiconductor industry is also presented. The relatively low development costs associated with reverse engineering and the weaknesses of legislative protection suggest that relative imitation costs in the semiconductor industry are not prohibitive. As a result, it appears reasonable to view the trends of

terminating second-sourcing agreements and aggressive product development by industry leaders as preemptive moves against potential imitators.

Finally, the third chapter of the dissertation contains an empirical investigation of the differences in investment in research and development both across firms within the same industry and across different industries. The empirical results suggest that the influence of firm-specific characteristics on R&D activity is not universal, but varies both within and across industries. For example, the empirical results suggest that a firm's internally generated funds significantly influence the research and development investment decision. While those results are generally consistent with prior empirical work and find this profitability/investment relationship to be positive, there are pockets of evidence to the contrary. In addition, significant results for firm leverage suggest that debt plays an important role in a firm's commitment to research and development investment. The direction of that commitment, however, may depend upon the nature of the firm's product market environment. Finally, although more limited in scope, there is evidence of significant roles played by both firm size and industry concentration in the firm's investment in R&D.

APPENDICES

APPENDIX A

TABLES FOR CHAPTER 1: THE STRATEGIC CHOICE OF EQUITY MARKETS: PRIVATE OR PUBLIC

Table A1
Distribution of Private and Public Equity Offerings by Year and by Sequence

Our sample consists of 283 private placements and 1,016 public offerings of common stock brought to the market by industrial firms. The sample of private placements is from the period 1980-1993, as reported in the Dow Jones News Retrieval database. The sample of public offerings is from 1980-1994, as reported by Securities Data Corporation.

Year	Private Offerings		Public Offerings	
	Number	Percentage	Number	Percentage
1980	4	1.4%	58	5.7%
1981	4	1.4%	58	5.7%
1982	8	2.8%	54	5.3%
1983	13	4.6%	101	9.9%
1984	7	2.5%	37	3.6%
1985	13	4.6%	68	6.7%
1986	14	4.9%	86	8.5%
1987	16	5.7%	72	7.1%
1988	20	7.1%	6	0.6%
1989	19	6.7%	47	4.6%
1990	28	9.9%	46	4.5%
1991	32	11.3%	125	12.3%
1992	41	14.5%	108	10.6%
1993	64	22.6%	99	9.7%
1994	0	0.0%	51	5.0%
Total issues	283	100%	1016	100%

Table A2: Panel A
Summary Statistics for Firm and Offering Characteristics

Our sample consists of 283 private placements and 1,016 public offerings of common stock brought to the market by industrial firms. Proceeds is the offering dollar amount. Pretax operating cash flow is Net sales-Cost of Goods Sold-Selling/Administrative Expenses, but before deducting depreciation and amortization. Annual industry-adjusted performance subtracts the industry median from the firm value, where the industry median is calculated for all CompuStat firms with either the same 4-, 3- or 2-digit SIC code. The percentage of firms in distress is based on the number of firms with negative cash flow in the two years prior to the offering. Leverage is long-term debt/(long-term debt + equity market value). For public issuers, ANNRET is the two-day returns (-1,0) around the announcement date. For private issuers, ANNRET is the difference between the issuer's and a benchmark portfolio's monthly announcement return. D_RUNUP is the difference in buy-and-hold returns for the issuing firm and its benchmark portfolio over month (−12, −2)[1].

Panel A:

	Private Offerings		Public Offerings	
Variable	Mean	Median	Mean	Median
	n=283		n=1,016	
Book value ($MM)	1717.23	14.657[a]	2857.75	274.87
Sales ($MM)	365.65	9.024[a]	1109.34	226.89
Proceeds ($MM)	22.34	3.35[a]	59.06	32.5
Cash flow to book value (cfbv)	-0.2169	-0.0230[a]	0.0777	0.1102
Industry-adjusted (cfbv)	-0.2878	-0.0870[a]	-0.0141	0.0034
Cash flow to sales (cfsa)	-2.6917	-0.0273[a]	-0.4687	0.1237
Industry-adjusted (cfsa)	-2.7805	-0.1133[a]	-0.5839	0.0190
Percentage of firms in distress	43.46%	0[a]	10.73%	0
Leverage (%)	0.1442	0.0614[a]	0.2171	0.2055
% of Shares Issued	33.29%	10.73%	13.35%	10.56%
ANNRET	10.39%	3.26%[a]	-2.49%	-2.03%
(D_RUNUP)	27.89%	4.044%[a]	34.43%	18.56%

[1]a, b, & c indicate the medians of public offering and private placements are significantly different at the 1%, 5%, and 10% significance levels respectively.

Table A2: Panel B
Use of Capital Raised by Private and Public Equity Offerings

Our sample consists of 283 private placements and 1,016 public offerings of common stock brought to the market by industrial firms. The sample of private placements is from the period 1980-1993, as reported in the Dow Jones News Retrieval database. The sample of public offerings is from 1980-1994, as reported by Securities Data Corporation. Of this sample, information regarding the use of the capital raised was available for 192 private placements and 627 public offerings.

Panel B:

Use of Capital Raised	Private Offerings		Public Offerings	
	Number	Percentage	Number	Percentage
General Corp. Purposes	94	49.0%	357	56.9%
Refinance Debt	25	13.4%	240	38.3%
Refinance Bank Debt	-	-	150	23.9%
Refinance Fixed Income	-	-	46	7.3%
Refinance Acquisition Debt	-	-	44	7.0%
Future Acquisitions	2	1.0%	5	0.8%
Stock Repurchase	3	1.6%	6	1.0%
Recapitalization	9	4.3%	1	0.2%
Acquisition Finance	59	30.7%	17	2.7%
Secondary Stockholders	0	0.0%	1	0.2%
Total by Use of Capital Raised	192	100%	627	100%

Table A3

Probit Models of the Choice between Public and Private Equity Markets

The dependent variable is 1 if the firm issues public equity and 0 otherwise. HOT and COLD are 1 if the issuing period is hot or cold and 0 otherwise. GLEAD is the log growth rate in the index of leading economic indicators. D_RUNUP is the difference in buy-and-hold returns for the issuing firm and its reference portfolio over month (–12, –2). IDIS is 1 if a firm is in distress and 0 otherwise. D_ACQUIRE is 1 if the issuing firm is a target in a takeover contest in the year prior to the issuing year. Significance levels based on the $\chi 2$ statistic are reported in parentheses.

	(1)	(2)	(3)
Intercept	-0.4329	-0.4315	-1.0092
	(0.001)	(0.001)	(0.000)
Log (book value of assets)	0.2687	0.2691	
	(0.000)	(0.000)	
HOT	0.3018	0.3020	0.3816
	(0.002)	(0.002)	(0.002)
COLD	0.0444	0.0424	0.2691
	(0.773)	(0.780)	(0.192)
GLEAD	19.322	19.257	14.464
	(0.003)	(0.004)	(0.065)
D_RUNUP	0.1908	0.1906	0.0659
	(0.001)	(0.001)	(0.349)
Median industry change in market-to-book from Year (-1, 0)	0.0289		-0.1396
	(0.912)		(0.676)
Median change in industry P/E from year (-1,0)		0.4776	
		(0.650)	
IDIS	-0.4519	-0.4489	-0.7319
	(0.000)	(0.000)	(0.000)
D_ACQUIRE	-0.7037	-0.7045	-0.8731
	(0.000)	(0.000)	(0.000)
Log (gross proceeds)			0.7267
			(0.000)
Pseudo-R^2	0.5237	0.5238	0.6553
% of correct classifications	83.25%	83.33%	90.09%

Table A4
Comparison between Announcement Returns for Private Equity Issuers and Similar Public Equity Issuers

For public issuers, announcement returns are measured as the two day returns (-1, 0) around the announcement date. For private issuers, announcement returns are the difference between the issuer's and the benchmark's monthly announcement return. Distressed firms are defined as firms with negative cash flow in the 2 years prior to the offering. After ranking the 3-month moving average of equity issue volume into quartiles, "hot" ("cold") periods are those where the equity volume is in the upper (lower) quartile for at least three continuous months, while "normal" periods reflect all remaining levels of equity volume. The test for difference is a t-statistic for the mean and a z-statistic for the median. The test for difference for the returns categorized by issuer size compares the returns of issuers with book value <= $25m to those with book value > $100m. The test for difference for the returns categorized by equity issue volume compares the returns of both the hot and normal periods to those of the cold period[1].

	Public Equity Issues		Private Placements	
Announcement Returns	Median	Mean	Median	Mean
Full Sample (N_{public} = 1,005; $N_{private}$ = 272)	-2.03%[a]	-2.49%[a]	3.26%[b]	10.39%[a]
Distressed Issuers (N_{public} = 109; $N_{private}$ = 118)	-2.88%[a]	-2.98%[a]	3.76%	15.31%[a]
Non-distressed Issuers (N_{public} = 896; $N_{private}$ = 154)	-1.98%[a]	-2.43%[a]	2.70%[b]	6.61%[a]
Test for difference	(0.70)	(-0.79)	(-0.49)	(2.33)[b]
Issuers with book value <= $25m ($N_{public}$ = 123; $N_{private}$ = 167)	-3.41%[a]	-3.73%[a]	1.32%	12.64%[a]
Issuers with $25m < book value < = $100m ($N_{public}$ = 210; $N_{private}$ = 51)	-3.31%[a]	-3.53%[a]	7.79%	8.27%[b]
Issuers with book value > $100m ($N_{public}$ = 672; $N_{private}$ = 54)	-1.80%[a]	-1.94%[a]	3.47%[b]	5.42%[a]
Test for difference	(1.05)	(-2.01)[b]	(-0.87)	(1.77)[c]
Issues in "HOT" periods (N_{public} = 586; $N_{private}$ = 110)	-1.95%[a]	-2.12%[a]	3.52%	9.20%[a]
Issues in "NORMAL" periods (N_{public} = 353; $N_{private}$ = 132)	-2.23%[a]	-2.81%[a]	2.80%[c]	10.25%[a]
Issues in "COLD" periods (N_{public} = 66; $N_{private}$ = 30)	-2.12%[a]	-4.09%[a]	3.64%	15.37%[b]
Test for difference	(-0.01)	(-1.83)[c]	(-0.39)	(0.72)

[1] a, b, & c indicate statistical significance at the 1%, 5%, & 10% level respectively.

Table A5
Announcement Returns for Private and Public Equity Offerings

For public issuers, announcement returns are the 2-day returns (-1,0) around the announcement date. For private issuers, they are the difference between the issuer's and the benchmark's monthly announcement return. After ranking the 3-month moving average of equity issue volume into quartiles, "hot" ("cold") periods are those where the equity volume is in the upper (lower) quartile for at least three continuous months, while "normal" periods reflect all remaining levels. The test for difference reflects the p-value of the t-statistic for the mean and the z-statistic for the median[1].

	Median	Mean
Panel A: Full Sample		
Firms issuing public when expected to (N= 587)	-1.80%[a]	-1.80%[a]
Firms issuing public when NOT expected to (N= 397)	-2.80%[a]	-3.40%[a]
Test for difference (p-values)	(0.01)[a]	(0.00)[a]
Firms issuing private when NOT expected to (N= 42)	2.00%[b]	3.80%
Firms issuing private when expected to (N=230)	3.30%[c]	11.6%[a]
Test for difference (p-values)	(0.74)	(0.02)[b]
Panel B: Normal Periods		
Firms issuing public when expected to (N= 159)	-1.70%[a]	-2.00%[a]
Firms issuing public when NOT expected to (N= 174)	-3.00%	-3.60%[a]
Test for difference (p-values)	(0.03)[b]	(0.01)[a]
Firms issuing private when NOT expected to (N= 10)	2.00%	1.20%
Firms issuing private when expected to (N=122)	3.30%	11.0%[a]
Test for difference (p-values)	(0.51)	(0.01)[b]
Panel C: Hot Periods		
Firms issuing public when expected to (N= 406)	-1.90%[a]	-1.80%[a]
Firms issuing public when NOT expected to (N= 180)	-2.70%[a]	-2.80%[a]
Test for difference (p-values)	(0.21)	(0.03)[b]
Firms issuing private when NOT expected to (N= 27)	1.30%	4.30%
Firms issuing private when expected to (N=83)	4.00%	10.8%[a]
Test for difference (p-values)	(0.83)	(0.19)
Panel D: Cold Periods		
Firms issuing public when expected to (N= 22)	-0.90%	-1.20%[c]
Firms issuing public when NOT expected to (N= 43)	-2.80%[a]	-5.20%[a]
Test for difference (p-values)	(0.10)[c]	(0.01)[a]
Firms issuing private when NOT expected to (N= 5)	11.7%	6.50%
Firms issuing private when expected to (N=25)	3.50%	17.1%[c]
Test for difference (p-values)	(0.63)	(0.32)

[1] a, b, & c indicate statistical significance at the 1%, 5%, & 10% level respectively.

Table A6
Ownership Concentration of Firms Issuing Private Equity Placements

Data was gathered from the last available proxy statement prior to and the first available proxy statement following the private placement. Proxy statements report beneficial ownership of all officers and directors, and non-management beneficial ownership exceeding 5% of all outstanding shares of common stock. The mean (median) change in percent holdings is the mean (median) of [% holdings pre-issue - % holdings post-issue] for all firms with ownership data both before and after the private placement. The Wilcoxon signed-rank test is a non-parametric test of the hypothesis that the change in beneficial ownership is not different from zero.

Holdings of Largest Shareholders	Percent Holdings Prior to Issue	Percent Holdings Post-Issue	Change in Percent Holdings	P-value for Wilcoxon Signed-rank test[1]
Panel A: Total Issues				
Total	N = 213	N = 215	N = 189	
Mean	43.77	41.60	-1.99	0.287
Median	41.80	36.90	-0.84	
Management	N = 219	N = 217	N = 194	
Mean	29.53	25.43	-4.52	0.000[a]
Median	25.20	18.90	-1.85	
Non-management	N = 213	N = 216	N = 189	
Mean	13.71	16.12	2.78	0.004[a]
Median	9.90	11.95	0.00	

Table A6 (cont'd).

Panel B: With Type				
Total	N = 180	N = 180	N = 157	
Mean	47.00	44.60	-2.54	0.241
Median	44.70	42.25	-0.94	
Management	N = 184	N = 180	N = 160	
Mean	31.90	27.86	-4.75	0.000[a]
Median	29.45	23.10	-2.55	
Non-management	N = 180	N = 181	N = 157	
Mean	14.76	16.82	2.26	0.026[b]
Median	11.6	12.80	0.00	
Panel C: Against Type				
Total	N = 33	N = 35	N = 32	
Mean	26.18	26.18	0.73	0.960
Median	22.50	21.40	0.00	
Management	N = 35	N = 37	N = 34	
Mean	17.05	13.61	-3.43	0.242
Median	8.80	6.70	-0.06	
Non-management	N = 33	N = 35	N = 32	
Mean	7.99	12.48	5.32	0.018[b]
Median	5.20	5.40	0.00	

[1] a, b, and c indicate that the estimates are statistically different from zero at the 1%, 5%, and 10% significance levels, respectively.

Table A7

Regression Analysis of Announcement Returns for Public Equity Offerings

The dependent variable, ANNRET, is the two-day returns (-1, 0) around the announcement date. PROB is 0 for issues that are "with type" and 1 for issues that are "against type". IDIS is 1 if a firm is in financial distress. HOT and COLD are 1 if the issuing period is hot or cold and 0 otherwise. D_RUNUP is the difference in buy-and-hold returns for the issuing firm and its reference portfolio for month(−12, −2). PSHARES is issue proceeds/the issuing firm's market value. D_LEV is the change in the issuing firm's total debt from year (-1,0). T-statistics are in parentheses[1].

	Model 1	Model 2	Model 3	Model 4
Intercept	-0.0185	-0.0178	-0.0315	-0.0149
	(-8.84)[a]	(-5.84)[a]	(-3.27)[a]	(-3.92)[a]
PROB	-0.0154	-0.0169	-0.0106	-0.0133
	(-4.69)[a]	(-4.72)[a]	(-2.14)[b]	(-3.15)[a]
IDIS		0.0032	0.0053	-0.0001
		(0.57)	(0.89)	(-0.01)
HOT		-0.0022	-0.0010	-0.0026
		(-0.63)	(-0.28)	(-0.73)
COLD		0.0058	0.0064	0.0081
		(0.93)	(1.03)	(1.26)
D_RUNUP		0.0002	0.0017	0.0035
		(0.10)	(0.65)	(1.33)
Log(Book Value of Assets)			0.0019	
			(1.63)[c]	
Market-to-Book Value			-0.0005	-0.0006
			(-0.50)	(-0.53)
PSHARES				-0.0430
				(-2.46)[a]
D_LEV				-0.0112
				(-0.55)
N	983	983	983	836
adjusted R^2	0.021	0.019	0.021	0.029
F	21.98[a]	4.80[a]	3.98[a]	4.16[a]

[1]a, b, and c indicate that the estimates are statistically different from zero at the 1%, 5%, and 10% significance levels, respectively.

Table A8

Regression Analysis of Announcement Returns for Private Equity Offerings

The dependent variable, ANNRET, is the two-day returns (-1, 0) around the announcement date. PROB is 0 for issues that are "with type" and 1 for issues that are "against type". IDIS is 1 if a firm is in financial distress. HOT and COLD are 1 if the issuing period is hot or cold and 0 otherwise. D_RUNUP is the difference in buy-and-hold returns for the issuing firm and its reference portfolio for month(−12, −2). PSHARES is issue proceeds/the issuing firm's market value. D_LEV is the change in the issuing firm's total debt from year (-1,0). T-statistics are in parentheses[1].

	Model 1	Model 2	Model 3	Model 4
Intercept	0.0389	0.0560	0.3110	0.0545
	(0.61)	(0.78)	(1.99)[b]	(0.65)
PROB	0.1140	0.0817	-0.0771	0.0799
	(1.65)[c]	(1.09)	(-0.70)	(0.89)
IDIS		0.0605	0.0237	0.0293
		(1.14)	(0.41)	(0.45)
HOT		-0.0104	-0.0320	-0.0447
		(-0.19)	(-0.56)	(-0.69)
COLD		-0.1000	-0.0953	-0.1284
		(-1.26)	(-1.21)	(-1.32)
D_RUNUP		-0.0034	-0.0163	-0.0033
		(-0.12)	(-0.58)	(-0.11)
Log(Book Value of Assets)			-0.0324	
			(-1.87)[c]	
Market-to-Book Value			0.0022	0.0057
			(0.40)	(0.96)
PSHARES				0.0075
				(0.66)
D_LEV				-0.1007
				(-0.47)
N	275	275	275	236
adjusted R^2	0.006	0.003	0.012	-0.006
F	2.73[c]	1.15	1.46	0.82

[1] a, b, and c indicate that the estimates are statistically different from zero at the 1%, 5%, and 10% significance levels, respectively.

APPENDIX B

PROOFS AND FIGURES FOR CHAPTER 2: INNOVATION AND IMITATION: A THEORETICAL MODEL OF PREEMPTION

Proof of Proposition 1:

Proof of (3a):

Firm 2's decision:

$$\underset{q_2}{\text{Maximize}}\ z'\beta(1 - q_1 - q_2)q_2$$

FOC:

$$z'\beta - z'\beta q_1 - 2z'\beta q_2 = 0$$

$$q_2 = (1 - q_1)/2$$

$$\mathbf{q_2 = 1/4} \qquad \text{(From solution for } q_1 \text{ below)}$$

Firm 1's decision:

$$\underset{q_1}{\text{Maximize}}\ z'\beta(1 - q_1 - (1-q_1)/2)q_1$$

FOC:

$$z'\beta - 2z'\beta q_1 - (1/2)z'\beta + z'\beta q_1 = 0$$

$$\mathbf{q_1 = 1/2}$$

Equilibrium Price:

$$p = z'\beta(1 - q_1 - q_2) = \mathbf{(1/4)z'\beta}$$

Proof of (3b):

$$\pi_1 = pq_1 - K(z')$$

$$\pi_1 = (1/4)z'\beta(1/2) - K(z')$$

$$\boldsymbol{\pi_1 = (1/8)z'\beta - K(z')}$$

Proof of (3c):

$$\pi_2 = pq_2 - \lambda K(z')$$

$$\pi_2 = (1/4)z'\beta(1/4) - \lambda K(z')$$

$$\boldsymbol{\pi_2 = (1/16)z'\beta - \lambda K(z')}$$

Proof of Corollary 1:

Monopolist's decision: $\underset{Q}{\text{Maximize}}\ z'\beta(1 - Q)Q - K(z')$

FOC: $z'\beta - 2z'\beta Q = 0$

$\mathbf{Q = 1/2}$

$\Rightarrow\Rightarrow$ $\boldsymbol{\pi_m = (1/4)z'\beta - K(z')}$

Q.E.D.

Proof of Corollary 2a:

Solution of (5a): Maximize $(1/2)z\beta - \alpha z^2$ [Maximize $f(z) = \pi_m(z)$]

subject to:

$-z \leq 0$ [$g_1(z)$]

$(1/16)\, z\beta - \lambda\alpha z^2 \leq 0$ [$g_2(z)$]

Kuhn-Tucker Condition [$\nabla f(z) = \mathbf{m}'\nabla\mathbf{g}(\mathbf{z})$]:

$(1/2)\beta - 2\alpha z = -m_1 + m_2[(1/16)\beta - 2\lambda\alpha z]$

Complementary Slackness Conditions [$\mathbf{m}'\mathbf{g}(\mathbf{z}) = \mathbf{0}$]:

$-m_1 z = 0$

$m_2[(1/16)z\beta - \lambda\alpha z^2] = 0$

(a) Let $m_1 \neq 0$; $m_2 \neq 0$: $g_1(z)$ and $g_2(z)$ are both binding;

$\mathbf{z_m = 0}$; $\boldsymbol{\pi_m = 0}$; **trivial solution**

(b) Let $m_1 = 0$; $m_2 = 0$: Neither $g_1(z)$ nor $g_2(z)$ are binding;

Substituting into the K-T Condition yields: $\beta/2 - 2\alpha z = 0$

$\mathbf{z_{m1} = \beta/(4\alpha); \pi_{m1} = \beta^2/(16\alpha)}$

where π_{m1} denotes the innovator's profit function that corresponds to the quality choice, z_{m1}

Note, however, to satisfy $g_2(z)$ as an inequality, the following must be true:

$(\beta/16)[\beta/(4\alpha)] - \lambda\alpha[\beta/(4\alpha)]^2 < 0$

$(\beta^2 - 4\lambda\beta^2)/(64\alpha) < 0$

$[\beta^2/(64\alpha)]*[1-4\lambda] < 0$

$[1-4\lambda] < 0$ as $[\beta^2/(48\alpha)] > 0$

$\Rightarrow\Rightarrow$ **$\lambda > 1/4$ must hold**

(c) Let $m_1 \neq 0$; $m_2 = 0$: $g_1(z)$ is binding;

$z_m = 0$; $\pi_m = 0$; cannot hold:

By the K-T Condition: $(1/2)\beta = -m_1$, which **cannot hold** as $m_1 \geq 0$; $\beta \geq 0$

(d) Let $m_1 = 0$; $m_2 \neq 0$: $g_2(z)$ is binding: $(1/16)z\beta - \lambda\alpha z^2 = 0$;

$z_m = 0$ or $z_m = \beta/(16\lambda\alpha)$:

(d1) **If $z_m = 0$; $\pi_m = 0$; trivial solution**

(d2) **If $z_{m2} = \beta/(16\lambda\alpha)$:**

$\mathbf{m_2 = 2/\lambda - 8; \quad \pi_{m2} = \beta^2[8\lambda - 1]/[256\lambda^2\alpha]}$:

where again, π_{m2} denotes the innovator's profit value function that corresponds to the quality choice, z_{m2}.

Substituting into the K-T Condition yields:

$$\beta/2 - \beta/(8\lambda) = m_2[\beta/16 - \beta/8]$$
$$\mathbf{m_2 = 2/\lambda - 8}$$

Because $m_2 \geq 0$ and π_{m2} must necessarily be > 0, this solution holds only for $1/8 < \lambda \leq 1/4$

Therefore, solving the innovator's problem when no imitation will occur yields the following two non-trivial results, the innovator's associated value functions, and the conditions under which they hold:

$z_{m1} = \beta/4\alpha$;	$\pi_{m1} = \beta^2/(16\alpha)$;	$1 > \lambda > 1/4$
$z_{m2} = \beta/(16\lambda\alpha)$;	$\pi_{m2} = \beta^2[8\lambda - 1]/[256\lambda^2\alpha]$;	$1/4 \geq \lambda > 1/8$

Solution of (5b): Maximize $(3/8)z\beta - \alpha z^2$ [Maximize $f(z) = \pi_{im}(z)$]

subject to:

$-z \leq 0$ [$g_1(z)$]

$-(1/16)z\beta + \lambda\alpha z^2 \leq 0$ [$g_2(z)$]

Kuhn-Tucker Condition:

$$(3/8)\beta - 2\alpha z = -m_1 + m_2[-(1/16)\beta + 2\lambda\alpha z]$$

Complementary Slackness Conditions **[m'g(z) = 0]**:

$$-m_1 z = 0$$
$$m_2[-(1/16)z\beta + \lambda\alpha z^2] = 0$$

Note: $g_2(z)$ is expected to be non-binding, otherwise imitation will not occur and a different optimization problem arises. Therefore, $\mathbf{m_2 = 0}$.

(a) Let $m_1 \neq 0$: **$z_{im} = 0$; cannot hold**

By the K-T Condition: $(3/8)\beta = -m_1$, which **cannot hold** as $m_1 \geq 0$; $\beta \geq 0$

(b) Let $m_1 = 0$: Substituting into the K-T Condition then yields:

$(3/8)\beta - 2\alpha z = 0$;

$\mathbf{z_{im} = (3\beta)/(16\alpha)}$ $\qquad$ $\mathbf{\pi_{1im} = (9\beta^2)/(256\alpha)}$

where π_{1im} denotes the innovator's value function when imitation occurs.

Note that to satisfy $g_2(z)$ as an inequality, the following must be true:

$$-(\beta/16)*(3\beta/16\alpha) + \lambda\alpha[3\beta/16\alpha]^2 < 0$$
$$(3\beta^2 - 9\beta^2\lambda)/(256\alpha) > 0$$
$$[3\beta^2/(256\alpha)]*[1 - 3\lambda] > 0$$
$$[1-3\lambda] > 0 \qquad \text{as } [3\beta^2/(256\alpha)] > 0$$
$$\Rightarrow\Rightarrow \qquad \boldsymbol{\lambda < 1/3} \textbf{ must hold}$$

Therefore, solving the innovator's problem when imitation will occur yields the following non-trivial result, the associated value function for the innovator, and the condition under which it holds:

$\mathbf{z_{im} = (3\beta)/(16\alpha)}$ $\qquad$ $\mathbf{\pi_{1im} = (9\beta^2)/(256\alpha)}$ $\qquad$ $\mathbf{1/3 > \lambda > 0}$

Q.E.D.

Proof of Proposition 3:

Maximization of (10) yields:

$$\underset{z}{\text{Max}} \quad (1/4)z\beta^2\Big|_0^{\beta^*} + (3/16)z\beta^2\Big|_{\beta^*}^{1} - \alpha z^2$$

$$\underset{z}{\text{Max}} \quad (1/16)z\beta^{*2} + (3/16)z - \alpha z^2$$

$$\underset{z}{\text{Max}} \quad (1/16)z(16\lambda\alpha z)^2 + (3/16)z - \alpha z^2$$

$$\text{FOC:} \quad 48\lambda^2\alpha^2z^2 - 2\alpha z + 3/16 = 0$$

Using the quadratic equation yields:

$$\mathbf{z_{im1} = [1 + \sqrt{(1-9\lambda^2)}\,]/(48\lambda^2\alpha)} \qquad \mathbf{z_{im2} = [1 - \sqrt{(1-9\lambda^2)}\,]/(48\lambda^2\alpha)}$$

The SOC condition for maximization is then:

$$96\lambda^2\alpha^2z - 2\alpha < 0$$
$$2\alpha[48\lambda^2\alpha z - 1] < 0$$
$$[48\lambda^2\alpha z - 1] < 0 \qquad \text{because } 2\alpha > 0 \text{ by assumption.}$$

By substituting z_{im1} and z_{im2} respectively into the above inequality, it is straightforward to show that the SOC for maximization is satisfied by z_{im1} when $.333 < \lambda < 1$, and by z_{im2} when $0 < \lambda < .333$.

Although tedious, it is also straightforward to show that substitution of z_{im1} and z_{im2} respectively into the objective function yields the corresponding value functions noted in (11a) and (11b).

Q.E.D.

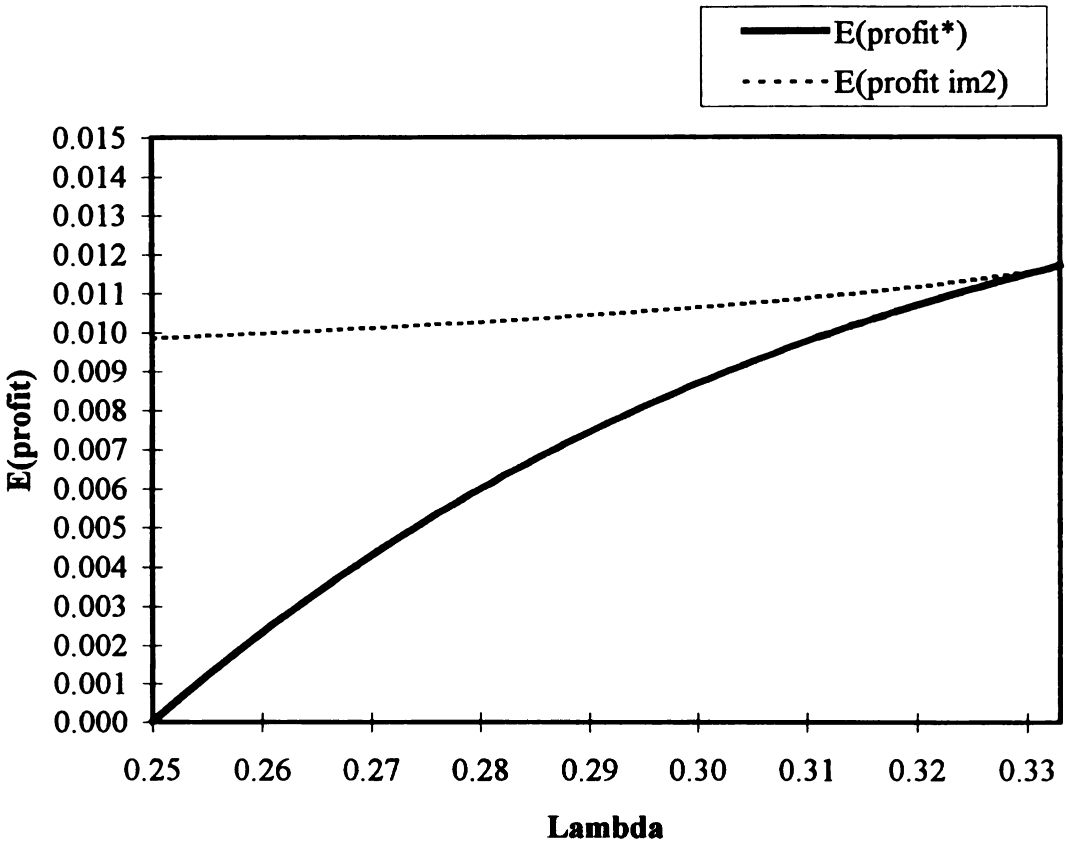

Figure BF1
Innovator's Expected Profitability with Imitation
vs. with Imitation Preemption

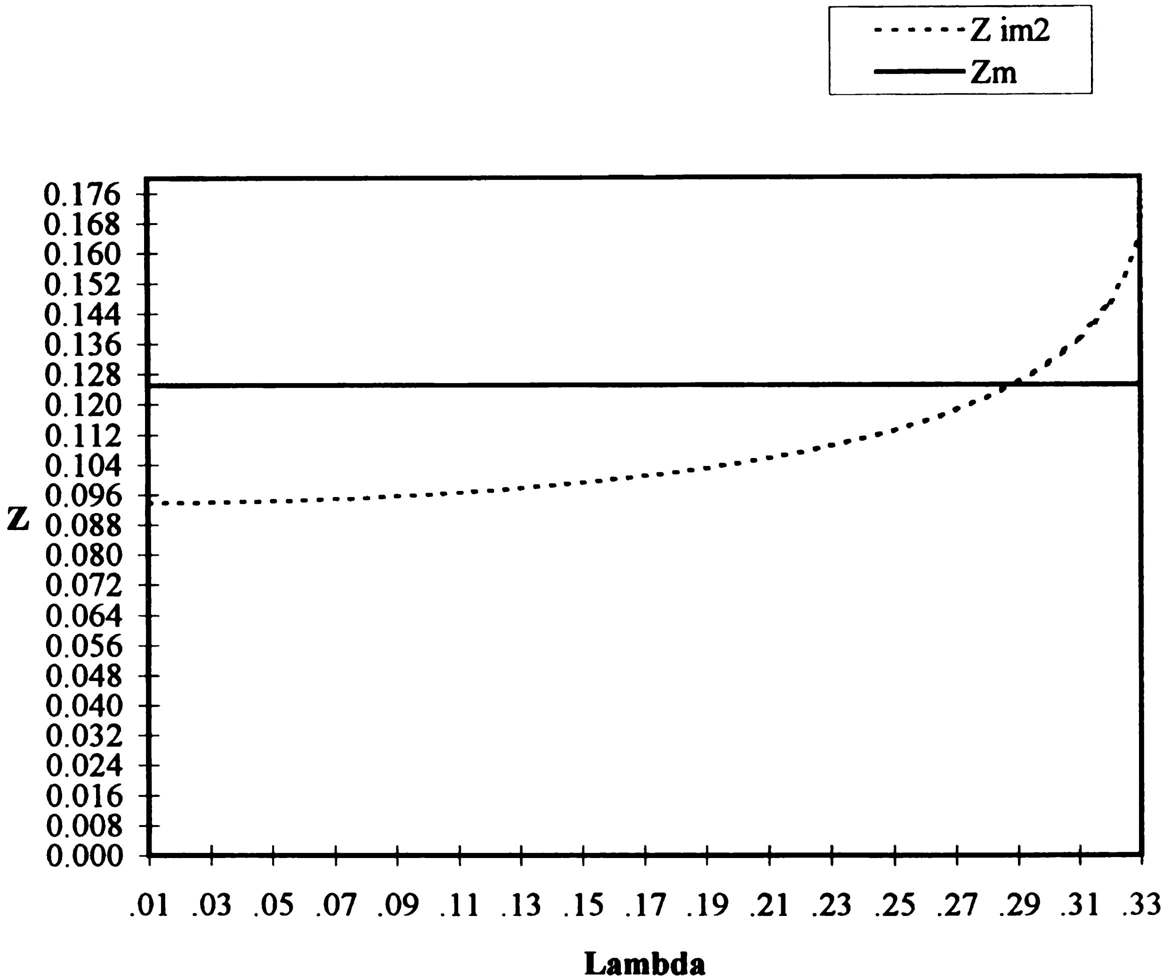

Figure BF2
Innovator's and Monopolist's Quality Choice

APPENDIX C

TABLES FOR CHAPTER 3: THE NATURE OF RESEARCH AND DEVELOPMENT INVESTMENT: AN EMPIRICAL STUDY OF DIFFERENCES WITHIN AND ACROSS INDUSTRIES

Table C1
Sample Data Summary Statistics

The full data sample is drawn from the *Active* and *Research Files* of *Compustat PC Plus*. It includes 324 firms that make research and development investments continuously over the sample period 1978-1997. Table 1 shows the portion of total R&D expenditure, sales revenue, and total asset book value for the five 2-digit Standard Industrial Classifications that is captured by the data sample.

	R&D Expenditure	Sales Revenue	Book Value of Total Assets
Full Data Sample	63.79%	60.64%	62.15%
2-Digit SICs			
SIC 28: Chemicals & Allied Products	60.47%	58.18%	55.63%
SIC 35: Industrial Machinery & Equip.	49.66%	45.36%	46.10%
SIC 36: Electronic & Other Elec. Equip.	56.92%	57.23%	64.37%
SIC 37: Transportation Equipment	81.20%	69.49%	71.40%
SIC 38: Instruments & Related Products	64.14%	70.72%	66.64%

Table C2
Sample Data and 2-Digit Industry Summary Statistics

Panels A and B contain summary information for the sample of established firms and for the corresponding 2-digit SIC industries, respectively. R&D Expenditure, Sales Revenue, and Total Asset Book Value figures are in millions of dollars. R&D Intensity is defined as R&D expenditure/sales revenue and Profitability is (firm operating cash flow + R&D expense)/sales revenue. N is the total number of firm years used for each measure.

Panel A

Sample Firms		Full Sample	SIC 28	SIC 35	SIC 36	SIC 37	SIC 38
Variable							
R&D		N=6480	N=1280	N=1680	N=1780	N=460	N=1280
Mean		163.62	160.05	99.52	126.56	867.59	49.87
Median		7.44	23.82	5.10	4.11	68.65	4.66
Std. Dev.		611.98	331.59	457.74	406.51	1721.03	144.44
Sales		N=6459	N=1260	N=1680	N=1779	N=460	N=1280
Mean		3445.78	3043.22	1785.30	2445.88	21308.55	991.69
Median		215.76	1002.86	167.82	116.58	3196.10	101.67
Std. Dev.		12659.03	5619.49	6627.19	8539.80	36837.50	2465.12
Profit.		N=6452	N=1260	N=1680	N=1773	N=460	N=1279
Mean		0.159	0.207	0.142	0.156	0.133	0.145
Median		0.158	0.186	0.143	0.160	0.134	0.172
Std. Dev.		0.177	0.134	0.107	0.171	0.091	0.282
R&D Intensity		N=6459	N=1260	N=1680	N=1779	N=460	N=1280
Mean		0.058	0.059	0.049	0.059	0.026	0.080
Median		0.037	0.032	0.029	0.046	0.025	0.057
Std. Dev.		0.135	0.108	0.114	0.083	0.016	0.229
TABV		N=6480	N=1280	N=1680	N=1780	N=460	N=1280
Mean		3627.98	2957.57	1860.23	3209.80	21045.53	940.66
Median		172.43	858.52	128.69	92.17	2628.40	86.00
Std. Dev.		16538.06	5574.20	7570.18	17391.74	45117.54	2612.41

Table C2 (cont'd).

Panel B

Industry			**SIC 28**	**SIC 35**	**SIC 36**	**SIC 37**	**SIC 38**
Variable							
R&D			N=5818	N=7499	N=7046	N=1706	N=6881
Mean			60.36	45.89	56.17	301.51	16.00
Median			4.72	2.54	1.70	7.13	1.26
Std. Dev.			213.54	295.51	293.14	1011.61	73.85
Sales			N=6594	N=8690	N=8678	N=2740	N=7504
Mean			1004.71	769.46	876.18	5496.37	268.35
Median			37.46	50.39	34.06	263.09	16.17
Std. Dev.			3159.20	4195.28	4759.71	18440.00	1191.09
Profitability			N=6565	N=8650	N=8632	N=2731	N=7481
Mean			-2.11	-0.556	-0.163	0.034	-1.34
Median			0.141	0.127	0.132	0.108	0.135
Std. Dev.			32.04	13.68	5.91	2.26	30.92
R&D Intensity			N=5495	N=7416	N=6997	N=1703	N=6760
Mean			6.54	0.471	0.268	0.035	1.39
Median			0.066	0.047	0.051	0.018	0.067
Std. Dev.			85.11	7.48	3.85	0.135	35.37
TABV			N=6988	N=8832	N=8770	N=2762	N=7652
Mean			988.30	775.67	1012.04	5258.48	265.19
Median			43.00	40.16	28.18	174.50	15.66
Std. Dev.			3208.96	4734.78	8368.98	21378.41	1341.55

Table C3

Sample Data and 3-Digit Industry Summary Statistics

Panel A contains summary information for the sample of established firms categorized by 3-digit SIC within SIC 28. Summary information for the corresponding 3-digit SIC industry is shown in Panel B. A similar pattern of tables follows for SIC 35, SIC 36, SIC 37, and SIC 38. R&D Expenditure, Sales Revenue, and Total Asset Book Value figures are in millions of dollars. R&D Intensity is defined as R&D expenditure/sales revenue and Profitability is (firm operating cash flow + R&D expense)/sales revenue. N is the total number of firm years.

Panel A

Sample Firms	SIC 280	SIC 281	SIC 282
Variable			
R&D	N=100	N=80	N=120
Mean	110.19	21.72	331.71
Median	15.39	3.89	52.99
Std. Dev.	214.47	30.82	489.09
Sales	N=100	N=60	N=120
Mean	2138.7	1316.5	8164.0
Median	940.0	1015.5	1657.9
Std. Dev.	2856.7	1154.5	12117
Profit.	N=100	N=60	N=120
Mean	0.146	0.161	0.201
Median	0.138	0.152	0.210
Std. Dev.	0.060	0.103	0.056
RD Intensity	N=100	N=60	N=120
Mean	0.028	0.015	0.038
Median	0.019	0.013	0.036
Std. Dev.	0.022	0.011	0.016
TABV	N=100	N=80	N=120
Mean	2106.3	1323.6	8227.6
Median	560.1	751.9	1216.2
Std. Dev.	3180.3	1630.1	12171

Panel B

Industry	SIC 280	SIC 281	SIC 282
Variable			
R&D	N=226	N=298	N=280
Mean	253.61	16.98	167.89
Median	37.50	4.08	9.60
Std. Dev.	431.08	29.50	353.58
Sales	N=248	N=351	N=379
Mean	4528.9	960.0	3236.1
Median	1800.6	441.3	479.1
Std. Dev.	6299.4	1244.1	7681.1
Profit.	N=248	N=349	N=376
Mean	0.139	0.075	-0.011
Median	0.151	0.188	0.158
Std. Dev.	0.126	0.877	1.48
RD Intensity	N=226	N=272	N=280
Mean	0.035	0.063	0.090
Median	0.026	0.014	0.029
Std. Dev.	0.025	0.608	0.261
TABV	N=248	N=387	N=380
Mean	4496.5	1052.3	3262.3
Median	1627.0	375.0	379.3
Std. Dev.	6732.1	1556.7	7730.7

Table C3 (cont'd).

Panel A

Sample Firms	**SIC 283**	**SIC 284**	**SIC 285**
Variable			
R&D	N=380	N=220	N=80
Mean	311.62	79.41	53.26
Median	95.30	17.31	12.46
Std. Dev.	448.69	208.88	79.78
Sales	N=380	N=220	N=80
Mean	3267.2	3060.0	1987.6
Median	1802.4	597.6	899.3
Std. Dev.	4265.1	6429.2	2134.0
Profit.	N=380	N=220	N=80
Mean	0.296	0.144	0.157
Median	0.299	0.143	0.161
Std. Dev.	0.189	0.055	0.050
RD Intensity	N=380	N=220	N=80
Mean	0.127	0.026	0.026
Median	0.081	0.023	0.024
Std. Dev.	0.178	0.015	0.015
TABV	N=380	N=220	N=80
Mean	3678.5	2284.6	1640.1
Median	1998.9	422.2	585.5
Std. Dev.	4975.4	5069.3	2051.5

Panel B

Industry	**SIC 283**	**SIC 284**	**SIC 285**
Variable			
R&D	N=3439	N=616	N=178
Mean	56.71	32.81	27.04
Median	4.07	2.29	6.52
Std. Dev.	217.11	130.22	58.69
Sales	N=3419	N=943	N=210
Mean	516.7	910.6	932.5
Median	9.1	70.6	232.1
Std. Dev.	1906.9	3359.4	1593.3
Profit.	N=3401	N=943	N=210
Mean	-3.49	-2.04	-0.052
Median	0.150	0.110	0.111
Std. Dev.	41.91	28.09	1.20
RD Intensity	N=3151	N=611	N=178
Mean	11.10	1.04	0.025
Median	0.232	0.020	0.021
Std. Dev.	112.05	12.06	0.026
TABV	N=3754	N=955	N=211
Mean	569.4	688.9	744.6
Median	22.4	45.9	124.0
Std. Dev.	2297.3	2637.2	1462.5

Table C3 (cont'd).

Panel A

Sample Firms	**SIC 286**	**SIC 287**	**SIC 289**
Variable			
R&D	N=100	N=20	N=180
Mean	37.65	136.12	31.50
Median	32.38	144.31	19.10
Std. Dev.	28.15	32.83	33.40
Sales	N=100	N=20	N=180
Mean	1815.2	3630.3	1300.3
Median	1181.4	3490.2	661.9
Std. Dev.	1989.7	517.5	1629.6
Profit.	N=100	N=20	N=180
Mean	0.179	0.162	0.190
Median	0.202	0.168	0.180
Std. Dev.	0.111	0.024	0.073
RD Intensity	N=100	N=20	N=180
Mean	0.040	0.037	0.029
Median	0.040	0.039	0.028
Std. Dev.	0.026	0.007	0.011
TABV	N=100	N=20	N=180
Mean	1627.5	2984.9	1265.3
Median	1120.9	2774.4	490.6
Std. Dev.	1816.5	693.0	1629.6

Panel B

Industry	**SIC 286**	**SIC 287**	**SIC 289**
Variable			
R&D	N=217	N=170	N=394
Mean	43.24	26.17	19.58
Median	29.72	1.55	7.32
Std. Dev.	52.11	51.35	27.67
Sales	N=311	N=280	N=453
Mean	1648.1	1033.5	696.3
Median	800.3	209.4	161.5
Std. Dev.	2218.0	2236.3	1228.4
Profit.	N=310	N=276	N=452
Mean	0.089	-0.626	0.061
Median	0.184	0.136	0.149
Std. Dev.	0.624	3.79	0.557
RD Intensity	N=216	N=169	N=392
Mean	0.087	1.12	0.231
Median	0.027	0.040	0.029
Std. Dev.	0.643	4.15	2.51
TABV	N=315	N=282	N=456
Mean	1752.5	1192.5	664.9
Median	960.2	185.0	107.7
Std. Dev.	2411.2	2504.3	1213.4

Table C3 (cont'd).

Panel C

Sample Firms	**SIC 351**	**SIC 352**	**SIC 353**
Variable			
R&D	N=60	N=80	N=160
Mean	40.50	179.36	41.31
Median	10.21	213.83	3.62
Std. Dev.	63.15	120.14	90.49
Sales	N=60	N=80	N=160
Mean	1397.6	4617.8	1600.1
Median	830.5	4491.8	151.4
Std. Dev.	1480.8	3231.7	3343.4
Profit.	N=60	N=80	N=160
Mean	0.112	0.118	0.130
Median	0.113	0.119	0.117
Std. Dev.	0.036	0.045	0.128
RD Intensity	N=60	N=80	N=160
Mean	0.018	0.038	0.026
Median	0.014	0.037	0.019
Std. Dev.	0.012	0.009	0.029
TABV	N=60	N=80	N=160
Mean	881.6	5382.0	1803.2
Median	486.0	5245.3	110.8
Std. Dev.	934.4	4172.9	3803.4

Panel D

Industry	**SIC 351**	**SIC 352**	**SIC 353**
Variable			
R&D	N=111	N=270	N=570
Mean	34.53	59.20	24.04
Median	14.84	2.62	3.21
Std. Dev.	49.70	104.55	64.17
Sales	N=113	N=367	N=750
Mean	1223.3	2157.2	725.3
Median	921.6	227.4	116.4
Std. Dev.	1218.9	3737.3	1875.2
Profit.	N=113	N=366	N=749
Mean	0.036	0.088	-0.660
Median	0.102	0.108	0.105
Std. Dev.	0.332	0.083	15.82
RD Intensity	N=110	N=270	N=558
Mean	0.105	0.023	0.268
Median	0.019	0.020	0.018
Std. Dev.	0.509	0.014	4.03
TABV	N=114	N=367	N=767
Mean	936.7	2468.7	809.0
Median	598.9	164.6	87.9
Std. Dev.	957.8	4471.8	2309.8

Table C3 (cont'd).

Panel C

Sample Firms	SIC 354	SIC 355	SIC 356
Variable			
R&D	N=140	N=140	N=500
Mean	20.94	23.78	10.54
Median	12.23	7.13	1.81
Std. Dev.	22.02	71.05	27.05
Sales	N=140	N=140	N=500
Mean	873.3	256.1	394.3
Median	564.6	104.2	73.6
Std. Dev.	1105.6	562.3	915.6
Profit.	N=140	N=140	N=500
Mean	0.138	0.177	0.138
Median	0.137	0.157	0.141
Std. Dev.	0.043	0.087	0.076
RD Intensity	N=140	N=140	N=500
Mean	0.028	0.064	0.026
Median	0.024	0.047	0.020
Std. Dev.	0.012	0.053	0.021
TABV	N=140	N=140	N=500
Mean	811.7	243.2	345.9
Median	425.7	99.5	58.3
Std. Dev.	1295.5	592.6	849.3

Panel D

Industry	SIC 354	SIC 355	SIC 356
Variable			
R&D	N=344	N=890	N=972
Mean	10.41	9.73	8.27
Median	4.73	2.34	1.04
Std. Dev.	16.98	32.53	22.40
Sales	N=467	N=994	N=1377
Mean	402.4	115.7	302.6
Median	128.5	39.9	51.9
Std. Dev.	736.2	281.3	811.8
Profit.	N=465	N=986	N=1373
Mean	0.087	-0.287	-0.824
Median	0.112	0.147	0.118
Std. Dev.	0.191	10.89	17.71
RD Intensity	N=344	N=885	N=942
Mean	0.286	0.154	0.140
Median	0.019	0.070	0.017
Std. Dev.	0.080	1.88	2.88
TABV	N=468	N=999	N=1424
Mean	387.6	105.7	264.1
Median	121.8	30.7	35.0
Std. Dev.	848.2	274.2	775.8

Table C3 (cont'd).

Panel C

Sample Firms	SIC 357	SIC 358	SIC 359
Variable			
R&D	N=420	N=100	N=80
Mean	310.12	15.36	6.07
Median	3.75	9.90	4.51
Std. Dev.	875.32	17.85	5.16
Sales	N=420	N=100	N=80
Mean	4322.5	1001.2	239.7
Median	59.0	216.0	198.2
Std. Dev.	12470	1417.4	162.8
Profit.	N=420	N=100	N=80
Mean	0.151	0.139	0.142
Median	0.176	0.138	0.148
Std. Dev.	0.165	0.043	0.038
RD Intensity	N=420	N=100	N=80
Mean	0.101	0.026	0.027
Median	0.072	0.018	0.025
Std. Dev.	0.213	0.020	0.014
TABV	N=420	N=100	N=80
Mean	4624.2	741.4	203.7
Median	40.2	170.1	165.8
Std. Dev.	14282	1064.9	138.3

Panel D

Industry	SIC 357	SIC 358	SIC 359
Variable			
R&D	N=3633	N=503	N=206
Mean	78.90	6.00	3.03
Median	3.11	1.03	0.98
Std. Dev.	419.47	17.77	4.66
Sales	N=3735	N=635	N=252
Mean	1134.5	366.1	93.0
Median	35.3	77.7	32.3
Std. Dev.	6148.3	781.1	139.6
Profit.	N=3715	N=633	N=250
Mean	-0.668	-0.776	-0.028
Median	0.158	0.103	0.107
Std. Dev.	15.09	7.80	0.682
RD Intensity	N=3602	N=499	N=206
Mean	0.770	0.518	0.084
Median	0.086	0.015	0.029
Std. Dev.	10.24	5.83	0.349
TABV	N=3797	N=645	N=251
Mean	1146.4	280.0	83.5
Median	29.7	54.8	26.2
Std. Dev.	6928.3	601.7	126.1

Table C3 (cont'd).

Panel E

Sample Firms	**SIC 360**	**SIC 361**	**SIC 362**
Variable			
R&D	N=80	N=40	N=180
Mean	1116.9	1.54	58.77
Median	1038.0	1.49	9.75
Std. Dev.	984.41	0.67	139.47
Sales	N=80	N=40	N=180
Mean	30718	64.3	1547.8
Median	27594	44.2	307.1
Std. Dev.	22132	49.8	3124.8
Profit.	N=80	N=40	N=180
Mean	0.168	0.118	0.136
Median	0.165	0.127	0.146
Std. Dev.	0.024	0.056	0.042
RD Intensity	N=80	N=40	N=180
Mean	0.036	0.037	0.040
Median	0.034	0.035	0.035
Std. Dev.	0.011	0.027	0.023
TABV	N=80	N=40	N=180
Mean	49035	45.5	1177.1
Median	24009	36.4	202.0
Std. Dev.	65350	27.3	2487.7

Panel F

Industry	**SIC 360**	**SIC 361**	**SIC 362**
Variable			
R&D	N=129	N=147	N=469
Mean	1107.2	6.69	24.32
Median	820.15	1.56	1.95
Std. Dev.	1181.5	11.67	90.57
Sales	N=132	N=158	N=606
Mean	24975	329.1	520.6
Median	22461	50.7	26.4
Std. Dev.	21809	551.0	1836.5
Profit.	N=131	N=158	N=603
Mean	0.142	-0.011	0.036
Median	0.157	0.124	0.115
Std. Dev.	0.086	1.32	0.541
RD Intensity	N=129	N=145	N=464
Mean	0.038	0.071	0.073
Median	0.034	0.020	0.032
Std. Dev.	0.021	0.491	0.228
TABV	N=132	N=160	N=611
Mean	35437	242.3	395.7
Median	18497	39.0	20.8
Std. Dev.	54464	431.5	1448.4

Table C3 (cont'd).

Panel E

Sample Firms	**SIC 364**	**SIC 365**	**SIC 366**
Variable			
R&D	N=100	N=60	N=540
Mean	26.71	439.29	104.83
Median	10.65	108.20	3.09
Std. Dev.	37.47	739.07	350.99
Sales	N=100	N=60	N=539
Mean	1084.3	7704.2	115.7
Median	378.0	2585.0	76.3
Std. Dev.	1644.4	13220	3358.7
Profit.	N=100	N=60	N=538
Mean	0.155	0.146	0.145
Median	0.146	0.156	0.172
Std. Dev.	0.055	0.063	0.250
RD Intensity	N=100	N=60	N=539
Mean	0.033	0.039	0.077
Median	0.021	0.038	0.063
Std. Dev.	0.030	0.024	0.132
TABV	N=100	N=60	N=540
Mean	1138.9	8343.8	1014.3
Median	295.1	2178.4	58.1
Std. Dev.	1959.1	14409	2975.8

Panel F

Industry	**SIC 364**	**SIC 365**	**SIC 366**
Variable			
R&D	N=344	N=320	N=2564
Mean	14.03	107.90	50.25
Median	2.14	1.07	1.84
Std. Dev.	33.54	373.23	272.86
Sales	N=623	N=469	N=2759
Mean	418.7	1450.6	593.2
Median	48.8	36.5	26.3
Std. Dev.	1019.8	6099.1	3199.0
Profit.	N=622	N=466	N=2744
Mean	-0.303	-0.278	-0.261
Median	0.118	0.079	0.150
Std. Dev.	6.14	2.59	8.58
RD Intensity	N=344	N=317	N=2543
Mean	0.360	0.164	0.273
Median	0.021	0.033	0.074
Std. Dev.	3.01	1.01	2.60
TABV	N=625	N=477	N=2796
Mean	348.8	1543.6	599.4
Median	40.4	23.4	24.8
Std. Dev.	965.1	6099.1	3598.9

Table C3 (cont'd).

Panel E

Sample Firms	**SIC 367**	**SIC 369**
Variable		
R&D	N=700	N=80
Mean	55.95	5.85
Median	3.01	1.07
Std. Dev.	183.27	10.12
Sales	N=700	N=80
Mean	618.4	96.8
Median	71.8	61.7
Std. Dev.	1957.6	96.8
Profit.	N=695	N=80
Mean	0.168	0.194
Median	0.169	0.166
Std. Dev.	0.149	0.128
RD Intensity	N=700	N=80
Mean	0.059	0.060
Median	0.049	0.022
Std. Dev.	0.050	0.074
TABV	N=700	N=80
Mean	581.6	95.2
Median	57.0	70.1
Std. Dev.	2019.2	86.8

Panel F

Industry	**SIC 367**	**SIC 369**
Variable		
R&D	N=2347	N=525
Mean	28.64	4.35
Median	1.85	0.71
Std. Dev.	127.91	9.63
Sales	N=2888	N=677
Mean	332.8	141.6
Median	35.2	13.5
Std. Dev.	1651.7	402.3
Profit.	N=2872	N=674
Mean	0.025	-0.604
Median	0.150	0.090
Std. Dev.	3.26	7.54
RD Intensity	N=2342	N=512
Mean	0.212	0.874
Median	0.052	0.051
Std. Dev.	3.61	10.12
TABV	N=2905	N=697
Mean	328.4	128.3
Median	28.2	12.0
Std. Dev.	1746.2	369.4

Table C3 (cont'd).

Panel G

Sample Firms	SIC 371	SIC 372	SIC 373
Variable			
R&D	N=180	N=120	N=60
Mean	1963.9	259.14	83.15
Median	1141.5	93.15	40.81
Std. Dev.	2339.8	391.92	101.26
Sales	N=180	N=120	N=60
Mean	46976	6685.0	3845.4
Median	36284	3210.8	3179.8
Std. Dev.	48282.	7528.1	2374.5
Profit.	N=180	N=120	N=60
Mean	0.115	0.160	0.105
Median	0.133	0.153	0.112
Std. Dev.	0.067	0.048	0.046
RD Intensity	N=180	N=120	N=60
Mean	0.028	0.033	0.019
Median	0.030	0.027	0.021
Std. Dev.	0.016	0.018	0.010
TABV	N=180	N=120	N=60
Mean	47020	6452.6	3116.6
Median	23713	2479.3	3145.1
Std. Dev.	63674	6979.6	1451.5

Panel H

Industry	SIC 371	SIC 372	SIC 373
Variable			
R&D	N=994	N=367	N=100
Mean	457.12	115.70	50.28
Median	5.43	13.45	25.26
Std. Dev.	1291.55	261.99	88.02
Sales	N=1581	N=584	N=218
Mean	8220.6	2249.0	1191.8
Median	258.7	194.1	182.2
Std. Dev.	23675	4741.7	2062.7
Profit.	N=1575	N=582	N=218
Mean	0.006	0.074	0.034
Median	0.108	0.113	0.064
Std. Dev.	2.96	0.454	0.153
RD Intensity	N=993	N=365	N=100
Mean	0.040	0.035	0.018
Median	0.016	0.024	0.014
Std. Dev.	0.173	0.057	0.015
TABV	N=1597	N=588	N=219
Mean	7944.8	2095.6	952.6
Median	163.2	134.3	127.3
Std. Dev.	27645	4377.1	1539.3

Table C3 (cont'd).

Panel G

Sample Firms	**SIC 374**	**SIC 375**	**SIC 376**
Variable			
R&D	N=20	N=20	N=60
Mean	2.60	1.95	157.04
Median	1.04	1.40	41.24
Std. Dev.	2.72	1.58	218.24
Sales	N=20	N=20	N=60
Mean	484.7	150.9	5011.5
Median	364.5	156.1	2031.6
Std. Dev.	278.5	92.1	6383.8
Profit.	N=20	N=20	N=60
Mean	0.386	-0.020	0.127
Median	0.408	-0.006	0.131
Std. Dev.	0.154	0.095	0.027
RD Intensity	N=20	N=20	N=60
Mean	0.005	0.014	0.024
Median	0.004	0.012	0.021
Std. Dev.	0.003	0.011	0.011
TABV	N=20	N=20	N=60
Mean	1632.0	192.4	3656.7
Median	1686.2	181.8	1678.9
Std. Dev.	522.3	97.8	5833.8

Panel H

Industry	**SIC 374**	**SIC 375**	**SIC 376**
Variable			
R&D	N=44	N=57	N=107
Mean	2.19	5.63	111.48
Median	1.10	1.77	35.00
Std. Dev.	2.27	9.99	178.94
Sales	N=104	N=73	N=109
Mean	601.8	402.7	3547.4
Median	436.0	226.2	1775.0
Std. Dev.	586.1	392.8	5228.6
Profit.	N=104	N=73	N=108
Mean	0.203	0.059	0.137
Median	0.126	0.079	0.134
Std. Dev.	0.188	0.086	0.083
RD Intensity	N=44	N=57	N=107
Mean	0.027	0.012	0.027
Median	0.005	0.009	0.023
Std. Dev.	0.038	0.009	0.017
TABV	N=104	N=74	N=109
Mean	904.7	267.6	2535.1
Median	734.3	177.2	1270.0
Std. Dev.	747.1	263.7	4610.2

Table C3 (cont'd).

Panel I

Sample Firms	SIC 381	SIC 382	SIC 384
Variable			
R&D	N=200	N=680	N=320
Mean	57.41	27.55	33.49
Median	8.97	3.53	4.64
Std. Dev.	93.33	69.58	75.22
Sales	N=200	N=680	N=320
Mean	1914.8	527.8	619.9
Median	341.0	64.7	107.8
Std. Dev.	2876.5	1528.6	1450.9
Profit.	N=200	N=679	N=320
Mean	0.131	0.148	0.130
Median	0.130	0.177	0.188
Std. Dev.	0.054	0.278	0.386
RD Intensity	N=200	N=680	N=320
Mean	0.033	0.087	0.099
Median	0.027	0.067	0.058
Std. Dev.	0.024	0.265	0.240
TABV	N=200	N=680	N=320
Mean	1523.9	458.3	709.4
Median	302.7	48.3	104.6
Std. Dev.	2876.0	1321.9	1764.1

Panel J

Industry	SIC 381	SIC 382	SIC 384
Variable			
R&D	N=570	N=2731	N=3027
Mean	38.12	11.45	7.26
Median	3.09	1.55	0.96
Std. Dev.	94.70	40.05	28.68
Sales	N=611	N=2964	N=3241
Mean	936.3	172.3	116.7
Median	79.5	20.2	9.2
Std. Dev.	2053.0	772.8	520.9
Profit.	N=609	N=2952	N=3233
Mean	0.100	-0.323	-2.75
Median	0.134	0.159	0.106
Std. Dev.	0.513	8.06	46.35
RD Intensity	N=570	N=2722	N=2919
Mean	0.140	0.405	2.73
Median	0.020	0.075	0.075
Std. Dev.	1.49	4.31	53.61
TABV	N=612	N=2975	N=3372
Mean	895.0	153.1	114.5
Median	70.8	19.1	9.8
Std. Dev.	2438.0	670.9	546.1

Table C3 (cont'd).

Panel I

Sample Firms	SIC 385	SIC 386
Variable		
R&D	N=20	N=60
Mean	37.71	369.05
Median	28.78	130.75
Std. Dev.	20.21	474.79
Sales	N=20	N=60
Mean	1105.1	5117.9
Median	909.3	1813.4
Std. Dev.	592.2	6480.8
Profit.	N=20	N=60
Mean	0.223	0.211
Median	0.232	0.214
Std. Dev.	0.024	0.076
RD Intensity	N=20	N=60
Mean	0.035	0.065
Median	0.034	0.072
Std. Dev.	0.005	0.026
TABV	N=20	N=60
Mean	1318.8	5570.9
Median	1095.0	1663.1
Std. Dev.	888.3	7541.9

Panel J

Industry	SIC 385	SIC 386
Variable		
R&D	N=149	N=379
Mean	8.28	89.37
Median	1.10	1.46
Std. Dev.	15.52	246.10
Sales	N=196	N=434
Mean	194.6	1176.6
Median	13.7	22.2
Std. Dev.	414.1	3278.8
Profit.	N=196	N=433
Mean	-0.489	-0.274
Median	0.119	0.147
Std. Dev.	3.10	2.79
RD Intensity	N=146	N=378
Mean	0.946	0.339
Median	0.037	0.058
Std. Dev.	7.05	2.77
TABV	N=199	N=436
Mean	234.9	1352.9
Median	15.6	20.0
Std. Dev.	531.8	3971.9

Table C4

Summary Statistics for Firm R&D Intensity: By Ranking and By Year

The full data sample is drawn from the *Active* and *Research Files* of *Compustat PC Plus*. It includes 324 firms that made research and development investments continuously over the sample period 1978-1997. Firms are ranked by R&D intensity (R&D expenditure/sales revenue) within each year of the sample period (with the exception of 1978 and 1979). A firm is defined to be a high R&D intensity firm if it falls in the top third of the rankings, and it is a low R&D intensity firm if it falls in the bottom third of the rankings. Mean, median, and standard deviation measures of R&D intensity for each group within each year are provided below.[1]

	1980	1981	1982	1983	1984	1985	1986	1987	1988
High RD Int.									
Mean	0.076	0.081	0.086	0.094	0.096	0.109	0.108	0.103	0.100
S. Dev.	0.035	0.032	0.027	0.033	0.036	0.061	0.059	0.047	0.052
Median	0.066[a]	0.074[a]	0.078[a]	0.083[a]	0.087[a]	0.092[a]	0.091[a]	0.086[a]	0.081[a]
(N=106)									
Low RD Int.									
Mean	0.011	0.013	0.015	0.016	0.015	0.015	0.016	0.015	0.014
S. Dev.	0.005	0.006	0.007	0.007	0.007	0.007	0.008	0.007	0.007
Median	0.012[a]	0.012[a]	0.014[a]	0.016[a]	0.016[a]	0.016[a]	0.016[a]	0.016[a]	0.014[a]
(N=106)									
	1989	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
High RD Int.									
Mean	0.102	0.100	0.108	0.105	0.102	0.101	0.107	0.110	0.110
S. Dev.	0.043	0.034	0.048	0.045	0.042	0.048	0.048	0.050	0.052
Median	0.088[a]	0.093[a]	0.093[a]	0.097[a]	0.088[a]	0.091[a]	0.092[a]	0.090[a]	0.094[a]
(N=106)									
Low RD Int.									
Mean	0.014	0.014	0.014	0.015	0.015	0.015	0.015	0.015	0.014
S. Dev.	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.006	0.007
Median	0.014[a]	0.015[a]	0.014[a]	0.016[a]	0.015[a]	0.017[a]	0.016[a]	0.015[a]	0.014[a]
(N=106)									

[1] a, b, and c indicate that the medians of the top third and bottom third are statistically different at the 1%, 5%, and 10% significance levels, respectively.

Table C5

Probit Models of the Choice Between High and Low R&D Intensity

Firms are ranked by R&D intensity within each year of the sample period. The dependent variable is 0 (1) if the firm falls in the top (bottom) third of the rankings. A separate probit model is run for each year 1980-1997. Industry-adjusted profitability is (firm operating cash flow + R&D expense)/sales revenue – the median ratio for the 3-digit SIC in which the firm competes. This measure is lagged 1 and 2 years, respectively. Ln(TABV) is the natural log of total asset book value and market share is (firm sales revenue/industry sales revenue). Leverage is (firm total debt/total asset book value), and industry-adjusted growth is the 2-year percentage change in firm sales - the 2-year median change in sales for each 3-digit SIC. N is the number of cross-sectional observations in each year. Significance levels based on the $\chi 2$ statistic p-values are reported in parentheses.[1]

Year	Int.	Ind.-Adj. $Profit_{-1}$	Ind.-Adj. $Profit_{-2}$	Ln TABV	$[Ln(TABV)]^2$	Market Share	Ind.-Adj. Growth	Levg.
1980	1.61	2.03	5.11	-0.96	0.09	0.77	0.25	0.54
N=212	(0.00)[a]	(0.28)	(0.01)[a]	(0.00)[a]	(0.00)[a]	(0.37)	(0.29)	(0.39)
1981	1.60	-2.48	11.76	-0.64	0.06	0.54	-0.22	0.19
N=212	(0.01)[a]	(0.01)[a]	(0.00)[a]	(0.00)[a]	(0.00)[a]	(0.48)	(0.45)	(0.74)
1982	1.32	6.05	-0.44	-0.63	0.05	0.84	0.16	-0.11
N=211	(0.00)[a]	(0.00)[a]	(0.65)	(0.00)[a]	(0.01)[a]	(0.25)	(0.00)[a]	(0.86)
1983	2.36	0.78	5.39	-0.95	0.08	0.45	0.35	-0.80
N=212	(0.00)[a]	(0.67)	(0.00)[a]	(0.00)[a]	(0.00)[a]	(0.54)	(0.19)	(0.25)
1984	2.33	2.88	3.35	-0.97	0.08	-0.06	-0.14	-0.22
N=212	(0.00)[a]	(0.01)[a]	(0.02)[b]	(0.00)[a]	(0.00)[a]	(0.94)	(0.53)	(0.71)
1985	1.12	0.42	4.99	-0.56	0.05	1.11	0.10	-0.47
N=211	(0.01)[a]	(0.39)	(0.00)[a]	(0.00)[a]	(0.00)[a]	(0.17)	(0.72)	(0.43)
1986	1.17	1.39	1.73	-0.54	0.05	0.98	0.28	-0.70
N=212	(0.01)[a]	(0.03)[b]	(0.01)[a]	(0.00)[a]	(0.00)[a]	(0.18)	(0.05)[b]	(0.21)
1987	1.42	3.17	1.19	-0.58	0.05	0.60	0.24	-1.18
N=212	(0.00)[a]	(0.01)[a]	(0.18)	(0.00)[a]	(0.00)[a]	(0.45)	(0.24)	(0.04)[b]

Table C5 (cont'd).

Year	Int.	Ind.-Adj. Profit$_{-1}$	Ind.-Adj. Profit$_{-2}$	Ln TABV	[Ln(TABV)]^2	Market Share	Ind.-Adj. Growth	Levg.
1988 N=212	0.62 (0.146)	5.72 (0.00)[a]	1.76 (0.15)	-0.31 (0.04)[b]	0.03 (0.05)[b]	1.27 (0.20)	-1.06 (0.00)[a]	-0.94 (0.13)
1989 N=212	1.20 (0.01)[a]	-0.42 (0.72)	8.38 (0.00)[a]	-0.47 (0.00)[a]	0.04 (0.02)[b]	0.32 (0.70)	-0.64 (0.02)[b]	-1.02 (0.09)[c]
1990 N=212	1.47 (0.00)[a]	2.95 (0.01)[a]	3.58 (0.00)[a]	-0.51 (0.00)[a]	0.04 (0.00)[a]	0.24 (0.76)	-0.61 (0.00)[a]	-1.60 (0.01)[a]
1991 N=212	1.39 (0.01)[a]	5.41 (0.01)[a]	3.50 (0.01)[a]	-0.48 (0.00)[a]	0.03 (0.03)[b]	0.10 (0.91)	-0.89 (0.01)[a]	-0.54 (0.29)
1992 N=210	1.82 (0.00)[a]	0.70 (0.45)	5.35 (0.00)[a]	-0.62 (0.00)[a]	0.05 (0.01)[a]	0.91 (0.25)	-0.48 (0.14)	-1.36 (0.03)[b]
1993 N=211	1.21 (0.01)[a]	2.10 (0.08)[c]	1.64 (0.21)	-0.45 (0.00)[a]	0.04 (0.01)[a]	0.24 (0.78)	-0.34 (0.02)[b]	-0.88 (0.08)[c]
1994 N=211	1.21 (0.01)[a]	8.24 (0.00)[a]	-1.02 (0.42)	-0.45 (0.00)[a]	0.03 (0.03)[b]	0.81 (0.42)	-0.75 (0.01)[a]	-0.26 (0.60)
1995 N=210	1.08 (0.01)[a]	2.00 (0.14)	3.19 (0.03)[b]	-0.34 (0.02)[b]	0.02 (0.08)[c]	0.46 (0.57)	-0.11 (0.56)	-0.66 (0.13)
1996 N=211	1.53 (0.00)[a]	0.02 (0.99)	4.83 (0.00)[a]	-0.49 (0.00)[a]	0.03 (0.01)[a]	0.39 (0.63)	0.02 (0.94)	-0.66 (0.14)
1997 N=211	1.12 (0.01)[a]	2.32 (0.08)[c]	1.96 (0.16)	-0.43 (0.00)[a]	0.03 (0.00)[a]	0.32 (0.66)	0.31 (0.06)[c]	-0.25 (0.43)
Gen. Result		(+)	(+)	(-)	(+)			

[1]a, b, and c indicate that the estimates are statistically different from zero at the 1%, 5%, and 10% significance levels, respectively.

Table C6
Results for Fixed Effects Level Tests:
Full Sample and 2-Digit Standard Industrial Classifications

The dependent variable is firm (R&D expenditure/sales revenue). Industry-adjusted profitability is (firm operating cash flow + R&D expense)/sales revenue – the median ratio for the 3-digit SIC in which the firm competes. The measure is lagged 1 year and 2 years. Market share is firm (sales revenue/industry sales revenue), leverage is firm (total debt/total asset book value), and N is the total number of sample points. Industry-adjusted growth is the 2-year percentage change in firm sales - the 2-year median change in sales for each 3-digit SIC. Intercept variables for each cross section and annual dummy variables are included in each model, but are suppressed in the reporting of results. Adjusted T-statistics are in parentheses. The F test shows the results for testing the hypothesis that the independent variables are jointly equal to zero.[1]

Regressors	Full Sample	SIC 28	SIC 35	SIC 36	SIC 37	SIC38
Intercept	0.079 (2.91)[a]	0.142 (2.34)[b]	0.278 (4.78)[a]	0.026 (1.36)	0.056 (2.97)[a]	-0.058 (-1.00)
Industry-Adj. Profitability$_{-1}$	-0.112 (-11.91)[a]	0.110 (3.94)[a]	0.184 (6.45)[a]	-0.105 (-13.80)[a]	-0.005 (-0.46)	-0.224 (-10.75)[a]
Industry-Adj. Profitability$_{-2}$	-0.026 (-2.65)[a]	0.128 (4.43)[a]	0.098 (3.34)[a]	-0.005 (-0.36)	0.008 (0.68)	-0.072 (-3.40)[a]
Ln(Total Asset Book Value)	-0.001 (-0.10)	0.001 (0.08)	-0.049 (-4.03)[a]	-0.002 (-0.46)	-0.003 (-0.83)	0.034 (2.71)[a]
[Ln(Total Asset Book Value)]^2	-0.000 (-0.06)	-0.002 (-2.33)[b]	0.002 (2.00)[b]	0.005 (1.64)[c]	0.000 (1.46)	-0.002 (-1.57)
Market Share	0.039 (1.18)	0.047 (0.87)	0.029 (0.38)	-0.025 (-0.63)	0.009 (0.50)	0.054 (0.67)
Industry-Adj. Growth	-0.002 (-5.66)[a]	-0.002 (-0.37)	-0.025 (-5.19)[a]	-0.002 (-5.15)[a]	-0.004 (-3.36)[a]	-0.035 (-4.50)[a]
Leverage	-0.007 (-0.90)	0.107 (5.43)[a]	0.009 (0.46)	-0.030 (-4.86)[a]	-0.011 (-2.20)[b]	0.015 (0.57)
Herfindahl	-0.056 (-2.20)[b]	-0.003 (-0.07)	-0.077 (-0.87)	-0.050 (-2.21)[b]	-0.005 (-0.91)	-0.134 (-1.32)
N	5796	1134	1512	1602	396	1152
F Test	0.000[a]	0.000[a]	0.000[a]	0.000[a]	0.012[a]	0.000[a]

[1] a, b, and c indicate that the estimates are statistically different from zero at the 1%, 5%, and 10% significance levels, respectively.

Table C7
Results for Fixed Effects Level Tests:
Core 3-Digit Standard Industrial Classifications

The dependent variable is firm (R&D expenditure/sales revenue). Industry-adjusted profitability is (firm operating cash flow + R&D expense)/sales revenue – the median ratio for the 3-digit SIC in which the firm competes. The measure is lagged 1 year and 2 years. Market share is firm (sales revenue/industry sales revenue), leverage is firm (total debt/total asset book value), and N is the total number of sample points. Industry-adjusted growth is the 2-year percentage change in firm sales - the 2-year median change in sales for each 3-digit SIC. Intercept variables for each cross section and annual dummy variables are included in each model, but are suppressed in the reporting of results. Adjusted T-statistics are in parentheses. The F test shows the results for testing the hypothesis that the independent variables are jointly equal to zero.[1]

Regressors	SIC 283	SIC 284	SIC 356	SIC 357
Intercept	0.174 (0.33)	-0.044 (-0.71)	0.018 (0.60)	0.576 (1.60)
Industry-Adj. Profitability$_{-1}$	0.096 (1.75)[c]	0.043 (3.25)[a]	0.028 (3.15)[a]	0.337 (4.80)[a]
Industry-Adj. Profitability$_{-2}$	0.188 (3.11)[a]	0.037 (3.01)[a]	0.030 (3.35)[a]	0.080 (1.13)
Ln(Total Asset Book Value)	0.012 (0.44)	-0.009 (-2.24)[b]	0.001 (0.58)	-0.115 (-3.20)[a]
[Ln(Total Asset Book Value)]^2	-0.008 (-3.98)[a]	0.001 (4.28)[a]	-0.000 (-0.04)	0.004 (1.45)
Market Share	0.026 (0.19)	-0.063 (-5.27)[a]	0.018 (0.81)	0.433 (0.70)
Industry-Adj. Growth	0.014 (0.75)	-0.006 (-5.38)[a]	-0.005 (-4.37)[a]	-0.112 (-4.47)[a]
Leverage	0.416 (5.83)[a]	-0.015 (-3.33)[a]	0.002 (0.37)	-0.027 (-0.48)
Herfindahl	4.79 (0.59)	0.263 (1.32)	-0.118 (-0.46)	0.711 (0.21)
N	342	198	450	378
F Test	0.000[a]	0.000[a]	0.000[a]	0.000[a]

[1]a, b, and c indicate that the estimates are statistically different from zero at the 1%, 5%, and 10% significance levels, respectively.

Table C7 (cont'd).

Regressors	SIC 366	SIC 367	SIC 371	SIC 382	SIC 384
Intercept	0.153	0.034	0.045	0.902	0.027
	(0.53)	(0.66)	(2.36)[b]	(1.91)[c]	(0.03)
Industry-Adj. Profitability$_{-1}$	-0.138	0.052	0.004	-0.015	-0.311
	(-11.56)[a]	(3.07)[a]	(0.21)	(-0.78)	(-6.80)[a]
Industry-Adj. Profitability$_{-2}$	-0.109	0.031	-0.019	-0.243	0.167
	(-4.31)[a]	(1.69)[c]	(-1.06)	(-20.28)[a]	(2.30)[b]
Ln(Total Asset Book Value)	-0.010	0.017	-0.006	0.038	0.034
	(-0.93)	(3.34)[a]	(-1.64)[c]	(5.28)[a]	(1.02)
[Ln(Total Asset Book Value)]^2	0.002	-0.002	0.000	-0.001	-0.007
	(2.27)[b]	(-3.01)[a]	(2.00)[b]	(-1.42)	(-1.85)[c]
Market Share	-0.110	0.044	-0.027	-0.017	0.375
	(-1.65)[c]	(0.56)	(-1.38)	(-0.22)	(1.10)
Industry-Adj. Growth	-0.004	-0.007	-0.006	-0.036	-0.006
	(-6.94)[a]	(-2.34)[b]	(-2.77)[a]	(-8.72)[a]	(-0.23)
Leverage	-0.090	0.016	-0.001	0.053	-0.020
	(-4.58)[a]	(2.33)[b]	(-0.23)	(4.11)[a]	(-0.20)
Herfindahl	-0.271	-0.572	-0.151	-7.57	1.66
	(-0.11)	(-1.18)	(-0.97)	(-1.83)[c]	(0.09)
N	486	630	162	612	256
F Test	0.000[a]	0.000[a]	0.006[a]	0.000[a]	0.000[a]

a, b, and c indicate that the estimates are statistically different from zero at the 1%, 5%, and 10% significance levels, respectively.

Table C8
Sample Points Contributed by Each Sample Industry
to Each Division of the Sample Firms Based on Median Measures

In Panel A, firms are ranked into the top third and bottom third based on median R&D expenditure for each firm over the sample period. This panel shows the total number of sample points contributed by each 3-digit SIC to each ranking. In Panel B, firms are ranked into the top third and bottom third according to median sales revenue, while in Panel C, the ranking is based on median profitability [(firm operating cash flow + R&D expense)/sales revenue]. Finally, in Panel D, the ranking is based on firm median leverage (Total debt/Total asset book value). To allow for outliers in each panel, the top 1% of observations based on the appropriate median measure are omitted prior to the formation of each division.

Panel A

3-Digit SIC	Top Third	Bottom Third	Total
280	36	36	72
281	18	18	36
282	54	0	54
283	198	54	252
284	90	18	108
285	18	0	18
286	72	18	90
287	18	0	18
289	72	18	90
SIC 28	**576**	**162**	**738**
351	18	18	36
352	54	0	54
353	36	54	90
354	36	0	36
355	18	54	72
356	54	270	324
357	108	180	288
358	18	18	36
359	0	18	18
SIC 35	**342**	**612**	**954**
360	72	0	72
361	0	36	36
362	36	36	72
364	36	18	54
365	36	18	54
366	126	198	324
367	126	288	414
369	18	36	54
SIC 36	**450**	**630**	**1080**

Panel B

3-Digit SIC	Top Third	Bottom Third	Total
280	54	18	72
281	36	0	36
282	54	0	54
283	198	90	288
284	90	18	108
285	36	0	36
286	72	18	90
287	18	0	18
289	54	0	54
SIC 28	**612**	**144**	**756**
351	36	0	36
352	54	0	54
353	54	36	90
354	36	0	36
355	0	36	36
356	54	252	306
357	126	198	324
358	36	18	54
359	0	18	18
SIC 35	**396**	**558**	**954**
360	72	0	72
361	0	18	18
362	54	36	90
364	36	18	54
365	36	18	54
366	90	252	342
367	90	324	414
369	0	36	36
SIC 36	**378**	**702**	**1080**

Table C8 (cont'd).

Panel A

3-Digit SIC	Top Third	Bottom Third	Total
371	72	36	108
372	72	0	72
373	54	0	54
374	0	18	18
375	0	18	18
376	36	0	36
SIC 37	**234**	**72**	**306**
381	54	36	90
382	126	252	378
384	72	126	198
385	18	0	18
386	36	18	54
SIC 38	**306**	**432**	**738**
Total	**1908**	**1908**	**3816**

Panel B

3-Digit SIC	Top Third	Bottom Third	Total
371	54	18	72
372	90	0	90
373	54	0	54
374	0	0	0
375	0	0	0
376	54	0	54
SIC 37	**252**	**18**	**270**
381	72	36	108
382	72	306	378
384	72	126	198
385	18	0	18
386	36	18	54
SIC 38	**270**	**486**	**756**
Total	**1908**	**1908**	**3816**

Panel C

3-Digit SIC	Top Third	Bottom Third	Total
280	18	36	54
281	18	18	36
282	72	18	90
283	234	36	270
284	36	54	90
285	18	18	36
286	54	36	90
287	0	0	0
289	72	54	126
SIC 28	**522**	**270**	**792**
351	0	36	36
352	0	54	54
353	0	72	72
354	18	72	90
355	54	36	90
356	72	198	270
357	162	90	252
358	18	36	54
359	0	18	18
SIC 35	**324**	**612**	**936**

Panel D

3-Digit SIC	Top Third	Bottom Third	Total
280	36	18	54
281	54	0	54
282	54	18	72
283	90	188	278
284	36	54	90
285	0	54	54
286	36	36	72
287	18	0	18
289	52	54	106
SIC 28	**376**	**422**	**798**
351	18	18	36
352	72	0	72
353	36	0	36
354	72	18	90
355	54	54	108
356	72	180	252
357	126	162	288
358	54	36	90
359	36	0	36
SIC 35	**540**	**468**	**1008**

Table C8 (cont'd).

Panel C

3-Digit SIC	Top Third	Bottom Third	Total
360	0	0	0
361	0	18	18
362	0	54	54
364	18	36	54
365	18	0	18
366	215	144	359
367	234	229	463
369	36	36	72
SIC 36	**521**	**517**	**1038**
371	0	54	54
372	18	36	54
373	0	36	36
374	18	0	18
375	0	18	18
376	0	18	18
SIC 37	**36**	**162**	**198**
381	18	108	126
382	288	143	431
384	144	90	234
385	18	0	18
386	36	0	36
SIC 38	**504**	**341**	**845**
Total	**1907**	**1902**	**3809**

Panel D

3-Digit SIC	Top Third	Bottom Third	Total
360	36	18	54
361	18	0	18
362	72	54	126
364	36	0	36
365	18	0	18
366	108	234	342
367	162	214	376
369	36	18	54
SIC 36	**486**	**538**	**1024**
371	54	54	108
372	54	18	72
373	0	18	18
374	0	0	0
375	18	0	18
376	18	0	18
SIC 37	**144**	**90**	**234**
381	54	36	90
382	198	216	414
384	108	108	216
385	0	0	0
386	0	18	18
SIC 38	**360**	**378**	**738**
Total	**1906**	**1896**	**3802**

Table C9
Summary Statistics for Division of Sample Firms
Based on Median Measures: Full Sample

Panels A through D provide summary information for the firms in each ranking. In Panel A, firms are ranked into the top third and bottom third of the sample based on median R&D expenditure for each firm over the sample period. In Panel B, the ranking is based on median sales revenue, while in Panel C, the ranking measure is median profitability In Panel D, the ranking is based on firm median leverage (Total debt/Total asset book value). To allow for outliers in each panel, the top 1% of observations based on the appropriate median measure are omitted prior to the formation of each division.[1]

Panel A

Variable	Top Third	Bottom Third
R&D	N=1908	N=1908
Mean	390.75	1.25
Median	123.30[a]	0.69[a]
Std. Dev.	697.98	1.82
Sales	N=1908	N=1908
Mean	7951.87	54.19
Median	3199.01[a]	21.30[a]
Std. Dev.	14898.39	88.59
Profitability	N=1908	N=1902
Mean	0.213	0.096
Median	0.197[a]	0.111[a]
Std. Dev.	0.096	0.207
R&D Intensity	N=1908	N=1908
Mean	0.059	0.065
Median	0.046[a]	0.029[a]
Std. Dev.	0.043	0.168
Leverage	N=1902	N=1907
Mean	0.203	0.228
Median	0.189	0.178
Std. Dev.	0.124	0.248
TABV	N=1908	N=1908
Mean	8760.01	53.80
Median	2899.63[a]	16.77[a]
Std. Dev.	23354.11	179.18

Panel B

Variable	Top Third	Bottom Third
R&D	N=1908	N=1908
Mean	389.82	1.77
Median	120.60[a]	0.74[a]
Std. Dev.	700.49	3.03
Sales	N=1908	N=1908
Mean	7745.59	32.98
Median	3200.22[a]	20.06[a]
Std. Dev.	13190.66	43.41
Profitability	N=1908	N=1902
Mean	0.200	0.108
Median	0.181[a]	0.128[a]
Std. Dev.	0.095	0.243
R&D Intensity	N=1908	N=1908
Mean	0.050	0.080
Median	0.037[a]	0.045[a]
Std. Dev.	0.038	0.182
Leverage	N=1902	N=1907
Mean	0.209	0.227
Median	0.198[a]	0.173[a]
Std. Dev.	0.124	0.250
TABV	N=1908	N=1908
Mean	8233.57	29.95
Median	2899.63[a]	15.60[a]
Std. Dev.	19164.67	70.36

[1]a, b, and c indicate that the medians of the top third and bottom third are statistically different at the 1%, 5%, and 10% significance levels, respectively.

Table C9 (cont'd).

Panel C

Variable	Top Third	Bottom Third
R&D	N=1908	N=1908
Mean	229.35	57.96
Median	32.68[a]	1.56[a]
Std. Dev.	541.26	391.69
Sales	N=1908	N=1908
Mean	3264.66	1684.88
Median	590.64[a]	78.07[a]
Std. Dev.	7846.40	8424.60
Profitability	N=1907	N=1902
Mean	0.244	0.073
Median	0.238[a]	0.102[a]
Std. Dev.	0.095	0.212
R&D Intensity	N=1908	N=1908
Mean	0.081	0.041
Median	0.071[a]	0.022[a]
Std. Dev.	0.075	0.131
Leverage	N=1898	N=1908
Mean	0.179	0.257
Median	0.160[a]	0.219[a]
Std. Dev.	0.133	0.235
TABV	N=1908	N=1908
Mean	3428.85	1304.71
Median	600.14[a]	55.50[a]
Std. Dev.	8650.35	6381.91

Panel D

Variable	Top Third	Bottom Third
R&D	N=1908	N=1908
Mean	161.95	206.84
Median	8.66	7.67
Std. Dev.	680.92	714.26
Sales	N=1908	N=1908
Mean	4189.79	3689.03
Median	202.64[c]	172.14[c]
Std. Dev.	15928.57	13959.29
Profitability	N=1902	N=1907
Mean	0.139	0.176
Median	0.143[a]	0.171[a]
Std. Dev.	0.165	0.194
R&D Intensity	N=1908	N=1908
Mean	0.050	0.079
Median	0.037[a]	0.051[a]
Std. Dev.	0.082	0.165
Leverage	N=1906	N=1896
Mean	0.335	0.097
Median	0.305[a]	0.074[a]
Std. Dev.	0.209	0.111
TABV	N=1908	N=1908
Mean	5599.55	3227.74
Median	171.85	147.94
Std. Dev.	26148.08	12005.59

[1]a, b, and c indicate that the medians of the top third and bottom third are statistically different at the 1%, 5%, and 10% significance levels, respectively

Table C10
Results for Fixed Effects Level Tests: Full Sample

The dependent variable is firm (R&D expenditure/sales revenue). Industry-adjusted profitability is (firm operating cash flow + R&D expense)/sales revenue – the median ratio for the 3-digit SIC in which the firm competes. The measure is lagged 1 year and 2 years. Market share is firm (sales revenue/industry sales revenue) and leverage is firm (total debt/total asset book value). N is the total number of sample points and industry-adjusted growth is the 2-year percentage change in firm sales - the 2-year median change in sales for each 3-digit SIC. Each panel corresponds to division of the sample as defined in Table C9. To allow for outliers in each panel, the top 1% of observations based on the appropriate median measure are omitted. Intercept variables for each cross section and annual dummy variables are included in each model, but are suppressed in the reporting of results. Adjusted T-statistics are in parentheses. The F test shows the results for testing the hypothesis that the independent variables are jointly equal to zero.[1]

	Panel A		Panel B	
Regressors	Top Third	Bottom Third	Top Third	Bottom Third
Intercept	-0.048 (-2.55)[a]	0.078 (1.86)[c]	0.018 (0.76)	0.084 (1.94)[b]
Industry-Adj. Profitability$_{-1}$	0.056 (6.41)[a]	-0.111 (-5.57)[a]	0.054 (6.97)[a]	-0.128 (-7.55)[a]
Industry-Adj. Profitability$_{-2}$	0.099 (10.34)[a]	-0.069 (-3.52)[a]	0.073 (8.64)[a]	-0.038 (-2.20)[b]
Ln(Total Asset Book Value)	0.018 (4.62)[a]	0.032 (2.23)[b]	0.001 (0.26)	0.056 (3.75)[a]
$[Ln(TABV)]^2$	-0.001 (-4.91)[a]	-0.004 (-1.73)[c]	-0.000 (-0.38)	-0.012 (-4.87)[a]
Market Share	0.013 (1.03)	0.038 (0.37)	0.014 (1.29)	0.183 (1.44)
Industry-Adj. Growth	-0.016 (-15.10)[a]	-0.029 (-4.90)[a]	-0.012 (-13.22)[a]	-0.002 (-3.53)[a]
Leverage	0.010 (2.13)[b]	0.002 (0.13)	0.001 (0.13)	0.001 (0.07)
Herfindahl	-0.037 (-4.59)[a]	-0.136 (-1.60)	-0.020 (-2.96)[a]	-0.211 (-2.18)[b]
N	1908	1908	1908	1908
F Test	0.000[a]	0.000[a]	0.000[a]	0.000[a]

Table C10 (cont'd).

	Panel C		Panel D	
Regressors	Top Third	Bottom Third	Top Third	Bottom Third
Intercept	0.111	-0.089	0.154	0.129
	(7.19)[a]	(-1.83)[c]	(7.60)[a]	(1.51)
Industry-Adj. Profitability$_{-1}$	0.150	-0.195	-0.077	-0.155
	(9.24)[a]	(-16.07)[a]	(-9.99)[a]	(-6.41)[a]
Industry-Adj. Profitability$_{-2}$	0.113	-0.057	-0.012	-0.046
	(6.87)[a]	(-4.51)[a]	(-1.07)	(-1.98)[b]
Ln(Total Asset Book Value)	0.009	0.022	-0.022	0.002
	(1.88)[c]	(2.66)[a]	(-5.18)[a]	(0.18)
[Ln(Total Asset Book Value)]^2	-0.002	-0.001	0.001	-0.001
	(-4.49)[a]	(-1.49)	(3.83)[a]	(-0.59)
Market Share	-0.000	0.036	0.069	0.028
	(-0.01)	(0.60)	(2.67)[a]	(0.30)
Industry-Adjusted Growth	-0.027	-0.003	-0.001	-0.039
	(-7.77)[a]	(-8.07)[a]	(-4.58)[a]	(-4.86)[a]
Leverage	0.046	-0.031	-0.024	0.054
	(4.29)[a]	(-2.47)[b]	(-4.13)[a]	(1.77)[c]
Herfindahl	-0.048	-0.069	-0.019	-0.193
	(-1.69)[c]	(-1.44)	(-0.87)	(-2.16)[b]
N	1908	1908	1908	1908
F Test	0.000[a]	0.000[a]	0.000[a]	0.000[a]

[1]a, b, and c indicate that the estimates are statistically different from zero at the 1%, 5%, and 10% significance levels, respectively.

Table C11
Summary Statistics for Division of Sample Firms
Based on Median Measures: SIC 28

Panels A through D provide summary information for the firms in each ranking for SIC 28. In Panel A (Panel B), firms are ranked within each 3-digit SIC into the top third and bottom third according to R&D expenditure (sales revenue) and are then grouped within the 2-digit SIC 28. In Panel C, the rankings are based on profitability ([(firm operating cash flow + R&D expense)/sales revenue] and in Panel D, firms are ranked according to firm leverage (Total debt/Total asset book value). To allow for outliers in each panel, the top 1% of observations based on the appropriate median measure are omitted from the 2-digit SIC prior to the formation of each division.[1]

Panel A

Variable	Top Third	Bottom Third
R&D	N=378	N=378
Mean	334.79	6.58
Median	147.21[a]	2.71[a]
Std. Dev.	403.42	9.75
Sales	N=378	N=378
Mean	5734.94	435.43
Median	3618.55[a]	113.60[a]
Std. Dev.	5859.15	1189.80
Profitability	N=378	N=378
Mean	0.245	0.144
Median	0.235[a]	0.131[a]
Std. Dev.	0.096	0.161
R&D Intensity	N=378	N=378
Mean	0.054	0.072
Median	0.039[a]	0.024[a]
Std. Dev.	0.040	0.165
Leverage	N=378	N=374
Mean	0.204	0.205
Median	0.208[a]	0.168[a]
Std. Dev.	0.087	0.192
TABV	N=378	N=378
Mean	5853.39	316.45
Median	3784.85[a]	92.38[a]
Std. Dev.	5912.79	808.08

Panel B

Variable	Top Third	Bottom Third
R&D	N=378	N=378
Mean	333.89	8.10
Median	137.26[a]	2.72[a]
Std. Dev.	415.25	14.23
Sales	N=378	N=378
Mean	6287.13	182.50
Median	4503.75[a]	105.03[a]
Std. Dev.	5866.22	240.53
Profitability	N=378	N=378
Mean	0.232	0.171
Median	0.231[a]	0.143[a]
Std. Dev.	0.089	0.182
R&D Intensity	N=378	N=378
Mean	0.045	0.088
Median	0.035	0.035
Std. Dev.	0.031	0.177
Leverage	N=372	N=377
Mean	0.213	0.208
Median	0.218[a]	0.162[a]
Std. Dev.	0.092	0.204
TABV	N=378	N=378
Mean	6178.47	180.79
Median	4065.45[a]	79.28[a]
Std. Dev.	6030.10	285.80

Table C11 (cont'd).

Panel C

Variable	Top Third	Bottom Third
R&D	N=378	N=378
Mean	291.99	18.50
Median	90.35[a]	4.45[a]
Std. Dev.	390.68	33.38
Sales	N=378	N=378
Mean	4365.04	1167.56
Median	1832.61[a]	197.94[a]
Std. Dev.	6052.77	1987.47
Profitability	N=378	N=378
Mean	0.274	0.121
Median	0.254[a]	0.119[a]
Std. Dev.	0.097	0.145
R&D Intensity	N=378	N=378
Mean	0.059	0.066
Median	0.045[a]	0.020[a]
Std. Dev.	0.040	0.166
Leverage	N=378	N=377
Mean	0.174	0.238
Median	0.173[a]	0.227[a]
Std. Dev.	0.105	0.181
Total Asset Book Value	N=378	N=378
Mean	4655.57	945.95
Median	2174.20[a]	129.33[a]
Std. Dev.	6152.63	1633.68

Panel D

Variable	Top Third	Bottom Third
R&D	N=378	N=378
Mean	112.35	58.81
Median	19.50	15.60
Std. Dev.	235.56	171.95
Sales	N=378	N=378
Mean	2641.60	1201.97
Median	993.48[a]	456.40[a]
Std. Dev.	3863.43	2121.97
Profitability	N=378	N=378
Mean	0.189	0.208
Median	0.156[a]	0.209[a]
Std. Dev.	0.121	0.159
R&D Intensity	N=378	N=378
Mean	0.049	0.077
Median	0.029	0.032
Std. Dev.	0.078	0.163
Leverage	N=376	N=374
Mean	0.304	0.107
Median	0.277[a]	0.082[a]
Std. Dev.	0.150	0.096
Total Asset Book Value	N=378	N=378
Mean	2621.25	1119.69
Median	1034.74[a]	412.06[a]
Std. Dev.	4359.91	2062.35

[1]a, b, and c indicate that the medians of the top third and bottom third are statistically different at the 1%, 5%, and 10% significance levels, respectively.

Table C12
Summary Statistics for Division of Sample Firms
Based on Median Measures: SIC 35

Panels A through D provide summary information for the firms in each ranking for SIC 35. In Panel A (Panel B), firms are ranked within each 3-digit SIC into the top third and bottom third according to R&D expenditure (sales revenue) and are then grouped within the 2-digit SIC 28. In Panel C, the rankings are based on profitability ([(firm operating cash flow + R&D expense)/sales revenue] and in Panel D, firms are ranked according to firm leverage (Total debt/Total asset book value). To allow for outliers in each panel, the top 1% of observations based on the appropriate median measure are omitted from the 2-digit SIC prior to the formation of each division.[1]

Panel A

Variable	Top Third	Bottom Third
R&D	N=504	N=486
Mean	170.35	2.37
Median	40.20[a]	0.57[a]
Std. Dev.	362.16	4.70
Sales	N=504	N=486
Mean	3180.82	80.95
Median	1469.06[a]	30.61[a]
Std. Dev.	4811.92	134.46
Profitability	N=504	N=486
Mean	0.178	0.092
Median	0.165[a]	0.107[a]
Std. Dev.	0.090	0.120
R&D Intensity	N=504	N=486
Mean	0.048	0.036
Median	0.038[a]	0.022[a]
Std. Dev.	0.037	0.044
Leverage	N=504	N=486
Mean	0.231	0.227
Median	0.208	0.200
Std. Dev.	0.149	0.212
TABV	N=504	N=486
Mean	3184.71	56.68
Median	1353.97[a]	22.19[a]
Std. Dev.	4586.94	85.51

Panel B

Variable	Top Third	Bottom Third
R&D	N=486	N=486
Mean	166.27	2.62
Median	37.96[a]	0.72[a]
Std. Dev.	368.46	4.80
Sales	N=486	N=486
Mean	3087.60	78.17
Median	1351.62[a]	24.03[a]
Std. Dev.	4844.42	136.13
Profitability	N=486	N=486
Mean	0.178	0.097
Median	0.161[a]	0.111[a]
Std. Dev.	0.089	0.136
R&D Intensity	N=486	N=486
Mean	0.045	0.064
Median	0.033[b]	0.028[b]
Std. Dev.	0.037	0.200
Leverage	N=486	N=486
Mean	0.214	0.220
Median	0.196	0.197
Std. Dev.	0.137	0.210
TABV	N=486	N=486
Mean	3066.17	56.24
Median	1265.75[a]	19.31[a]
Std. Dev.	4614.94	86.12

Table C12 (cont'd).

Panel C

Variable	Top Third	Bottom Third
R&D	N=486	N=486
Mean	288.88	13.31
Median	18.59[a]	0.85[a]
Std. Dev.	812.63	44.77
Sales	N=486	N=486
Mean	4583.25	511.00
Median	600.99[a]	67.53[a]
Std. Dev.	11589.1	1415.82
Profitability	N=486	N=486
Mean	0.197	0.083
Median	0.184[a]	0.098[a]
Std. Dev.	0.086	0.102
R&D Intensity	N=486	N=486
Mean	0.053	0.031
Median	0.045[a]	0.018[a]
Std. Dev.	0.036	0.039
Leverage	N=486	N=486
Mean	0.207	0.250
Median	0.188[a]	0.217[a]
Std. Dev.	0.139	0.217
Total Asset Book Value	N=486	N=486
Mean	4990.44	494.56
Median	462.02[a]	49.20[a]
Std. Dev.	13326.2	1574.49

Panel D

Variable	Top Third	Bottom Third
R&D	N=486	N=486
Mean	62.17	51.74
Median	6.77[a]	2.65[a]
Std. Dev.	154.79	216.74
Sales	N=486	N=486
Mean	1657.98	777.32
Median	171.01[a]	74.87[a]
Std. Dev.	3359.69	2310.41
Profitability	N=486	N=486
Mean	0.141	0.124
Median	0.139	0.132
Std. Dev.	0.115	0.110
R&D Intensity	N=486	N=486
Mean	0.039	0.065
Median	0.027	0.027
Std. Dev.	0.039	0.201
Leverage	N=486	N=486
Mean	0.323	0.104
Median	0.308[a]	0.070[a]
Std. Dev.	0.171	0.111
Total Asset Book Value	N=486	N=486
Mean	1885.37	687.32
Median	148.73[a]	60.37[a]
Std. Dev.	3918.57	2031.41

[1]a, b, and c indicate that the medians of the top third and bottom third are statistically different at the 1%, 5%, and 10% significance levels, respectively.

Table C13
Summary Statistics for Division of Sample Firms
Based on Median Measures: SIC 36

Panels A through D provide summary information for the firms in each ranking for SIC 36. In Panel A (Panel B), firms are ranked within each 3-digit SIC into the top third and bottom third according to R&D expenditure (sales revenue) and are then grouped within the 2-digit SIC 28. In Panel C, the rankings are based on profitability ([(firm operating cash flow + R&D expense)/sales revenue] and in Panel D, firms are ranked according to firm leverage (Total debt/Total asset book value). To allow for outliers in each panel, the top 1% of observations based on the appropriate median measure are omitted from the 2-digit SIC prior to the formation of each division.[1]

Panel A

Variable	Top Third	Bottom Third
R&D	N=522	N=540
Mean	244.15	6.36
Median	52.36[a]	0.49[a]
Std. Dev.	468.05	30.87
Sales	N=522	N=540
Mean	3213.70	180.91
Median	969.21[a]	16.96[a]
Std. Dev.	6246.48	797.34
Profitability	N=522	N=534
Mean	0.230	0.110
Median	0.211[a]	0.122[a]
Std. Dev.	0.090	0.139
R&D Intensity	N=522	N=540
Mean	0.085	0.046
Median	0.078[a]	0.034[a]
Std. Dev.	0.051	0.047
Leverage	N=522	N=540
Mean	0.174	0.264
Median	0.148[a]	0.197[a]
Std. Dev.	0.128	0.289
TABV	N=522	N=540
Mean	3097.20	138.86
Median	871.00[a]	13.47[a]
Std. Dev.	6408.72	619.95

Panel B

Variable	Top Third	Bottom Third
R&D	N=540	N=540
Mean	273.54	6.37
Median	57.60[a]	0.51[a]
Std. Dev.	492.80	30.85
Sales	N=540	N=540
Mean	4352.77	172.11
Median	1099.41[a]	16.00[a]
Std. Dev.	8689.39	797.94
Profitability	N=540	N=534
Mean	0.203	0.111
Median	0.187[a]	0.128[a]
Std. Dev.	0.094	0.144
R&D Intensity	N=540	N=540
Mean	0.068	0.051
Median	0.058[a]	0.040[a]
Std. Dev.	0.049	0.046
Leverage	N=540	N=540
Mean	0.170	0.279
Median	0.148[a]	0.201[a]
Std. Dev.	0.127	0.334
TABV	N=540	N=540
Mean	4346.63	134.03
Median	1066.39[a]	13.12[a]
Std. Dev.	9531.57	620.34

Table C13 (cont'd).

Panel C

Variable	Top Third	Bottom Third
R&D	N=522	N=522
Mean	252.39	80.61
Median	30.99[a]	0.85[a]
Std. Dev.	486.18	477.17
Sales	N=522	N=522
Mean	4082.54	1531.30
Median	574.01[a]	38.36[a]
Std. Dev.	8806.40	8418.09
Profitability	N=521	N=517
Mean	0.236	0.066
Median	0.232[a]	0.103[a]
Std. Dev.	0.088	0.247
R&D Intensity	N=522	N=522
Mean	0.086	0.041
Median	0.078[a]	0.023[a]
Std. Dev.	0.056	0.132
Leverage	N=522	N=522
Mean	0.151	0.296
Median	0.137[a]	0.211[a]
Std. Dev.	0.109	0.340
Total Asset Book Value	N=522	N=522
Mean	4057.09	1685.08
Median	532.33[a]	24.33[a]
Std. Dev.	9620.24	9857.21

Panel D

Variable	Top Third	Bottom Third
R&D	N=522	N=522
Mean	98.05	130.62
Median	3.92[a]	8.55[a]
Std. Dev.	352.65	298.57
Sales	N=522	N=522
Mean	2795.68	2553.75
Median	86.08[a]	182.69[a]
Std. Dev.	10603.8	7198.16
Profitability	N=517	N=521
Mean	0.115	0.192
Median	0.151[a]	0.177[a]
Std. Dev.	0.253	0.107
R&D Intensity	N=522	N=522
Mean	0.059	0.068
Median	0.047[a]	0.054[a]
Std. Dev.	0.132	0.054
Leverage	N=522	N=520
Mean	0.362	0.102
Median	0.309[a]	0.091[a]
Std. Dev.	0.299	0.082
Total Asset Book Value	N=522	N=522
Mean	5449.52	2514.49
Median	59.89[a]	160.17[a]
Std. Dev.	29219.4	8076.62

[1]a, b, and c indicate that the medians of the top third and bottom third are statistically different at the 1%, 5%, and 10% significance levels, respectively.

Table C14
Summary Statistics for Division of Sample Firms
Based on Median Measures: SIC 38

Panels A through D provide summary information for the firms in each ranking for SIC 38. In Panel A (Panel B), firms are ranked within each 3-digit SIC into the top third and bottom third according to R&D expenditure (sales revenue) and are then grouped within the 2-digit SIC 28. In Panel C, the rankings are based on profitability ([(firm operating cash flow + R&D expense)/sales revenue] and in Panel D, firms are ranked according to firm leverage (Total debt/Total asset book value). To allow for outliers in each panel, the top 1% of observations based on the appropriate median measure are omitted from the 2-digit SIC prior to the formation of each division.[1]

Panel A

Variable	Top Third	Bottom Third
R&D	N=360	N=360
Mean	105.16	1.11
Median	61.98[a]	0.65[a]
Std. Dev.	111.28	1.87
Sales	N=360	N=360
Mean	2313.79	22.02
Median	977.76[a]	11.49[a]
Std. Dev.	2843.45	28.72
Profitability	N=360	N=360
Mean	0.213	0.085
Median	0.209[a]	0.106[a]
Std. Dev.	0.065	0.192
R&D Intensity	N=360	N=360
Mean	0.071	0.078
Median	0.068[a]	0.054[a]
Std. Dev.	0.041	0.113
Leverage	N=360	N=360
Mean	0.183	0.205
Median	0.157	0.174
Std. Dev.	0.121	0.176
TABV	N=360	N=360
Mean	2067.54	19.88
Median	852.10[a]	11.13[a]
Std. Dev.	2855.26	28.94

Panel B

Variable	Top Third	Bottom Third
R&D	N=360	N=360
Mean	106.22	1.26
Median	62.38[a]	0.74[a]
Std. Dev.	111.22	1.91
Sales	N=360	N=360
Mean	2354.08	18.26
Median	1016.80[a]	9.96[a]
Std. Dev.	2826.52	27.11
Profitability	N=359	N=360
Mean	0.206	0.063
Median	0.203[a]	0.120[a]
Std. Dev.	0.067	0.368
R&D Intensity	N=360	N=360
Mean	0.066	0.113
Median	0.062[c]	0.070[c]
Std. Dev.	0.039	0.243
Leverage	N=360	N=360
Mean	0.194	0.192
Median	0.169	0.146
Std. Dev.	0.121	0.176
TABV	N=360	N=360
Mean	2133.56	17.16
Median	911.61[a]	8.42[a]
Std. Dev.	2853.17	28.61

Table C14 (cont'd).

Panel C

Variable	Top Third	Bottom Third
R&D	N=360	N=360
Mean	99.61	4.02
Median	20.04[a]	0.75[a]
Std. Dev.	236.84	15.33
Sales	N=360	N=360
Mean	1809.35	123.44
Median	235.33[a]	15.31[a]
Std. Dev.	3779.81	352.22
Profitability	N=360	N=359
Mean	0.227	0.037
Median	0.230[a]	0.089[a]
Std. Dev.	0.065	0.362
R&D Intensity	N=360	N=360
Mean	0.078	0.092
Median	0.071[a]	0.038[a]
Std. Dev.	0.043	0.246
Leverage	N=360	N=360
Mean	0.159	0.210
Median	0.127[a]	0.188[a]
Std. Dev.	0.136	0.174
Total Asset Book Value	N=360	N=360
Mean	1757.05	135.89
Median	250.57[a]	13.22[a]
Std. Dev.	4163.65	529.32

Panel D

Variable	Top Third	Bottom Third
R&D	N=360	N=360
Mean	25.42	80.62
Median	4.01[a]	8.10[a]
Std. Dev.	67.41	237.35
Sales	N=360	N=360
Mean	522.42	1340.37
Median	90.86	112.28
Std. Dev.	1386.33	3602.31
Profitability	N=359	N=360
Mean	0.151	0.180
Median	0.163[a]	0.189[a]
Std. Dev.	0.116	0.126
R&D Intensity	N=360	N=360
Mean	0.062	0.079
Median	0.052[a]	0.069[a]
Std. Dev.	0.048	0.093
Leverage	N=360	N=360
Mean	0.296	0.092
Median	0.303[a]	0.068[a]
Std. Dev.	0.165	0.103
Total Asset Book Value	N=360	N=360
Mean	645.78	1330.19
Median	84.72	94.85
Std. Dev.	1720.70	4049.80

[1]a, b, and c indicate that the medians of the top third and bottom third are statistically different at the 1%, 5%, and 10% significance levels, respectively.

Table C15
Results for Fixed Effects Level Tests: SIC 28

The dependent variable is firm (R&D expenditure/sales revenue). Industry-adjusted profitability is (firm operating cash flow + R&D expense)/sales revenue – the median ratio for the 3-digit SIC in which the firm competes. The measure is lagged 1 year and 2 years. Market share is firm (sales revenue/industry sales revenue) and leverage is firm (total debt/total asset book value). N is the total number of sample points and industry-adjusted growth is the 2-year percentage change in firm sales - the 2-year median change in sales for each 3-digit SIC. In each panel, firms are ranked into the top/bottom third (as defined in Table C9) within each 3-digit SIC, and are then grouped across the 2-digit SIC 28. To allow for outliers in each panel, the top 1% of observations based on the appropriate median measure are omitted. Intercept variables for each cross section and annual dummy variables are included in each model, but suppressed in the reporting of results. Adjusted T-statistics are in parentheses. The F test shows the results for testing the hypothesis that the independent variables are jointly equal to zero.[1]

	Panel A		Panel B	
Regressors	Top Third	Bottom Third	Top Third	Bottom Third
Intercept	0.125 (2.14)[b]	-0.262 (-1.84)[c]	0.232 (4.09)[a]	0.188 (2.38)[b]
Industry-Adj. Profitability$_{-1}$	0.114 (4.63)[a]	0.089 (1.90)[c]	0.106 (4.49)[a]	0.113 (2.26)[b]
Industry-Adj. Profitability$_{-2}$	0.047 (1.89)[c]	0.153 (3.09)[a]	0.034 (1.42)	0.133 (2.52)[a]
Ln(Total Asset Book Value)	-0.028 (-2.10)[b]	0.151 (4.41)[a]	-0.055 (-4.29)[a]	0.164 (4.34)[a]
$[Ln(TABV)]^2$	0.002 (2.22)[b]	-0.015 (-4.40)[a]	0.003 (4.56)[a]	-0.023 (-6.14)[a]
Market Share	0.054 (2.59)[a]	0.012 (0.07)	0.038 (2.09)[b]	-0.246 (-1.64)[c]
Industry-Adj. Growth	-0.015 (-3.32)[a]	-0.006 (-0.53)	-0.017 (-3.75)[a]	-0.008 (-0.64)
Leverage	0.009 (0.99)	0.187 (4.30)[a]	0.021 (2.61)[a]	0.206 (4.81)[a]
Herfindahl	-0.028 (-1.94)[b]	-0.034 (-0.26)	-0.013 (-0.97)	-0.206 (-1.46)
N	378	378	378	378
F Test	0.000[a]	0.000[a]	0.000[a]	0.000[a]

Table C15 (cont'd).

Regressors	Panel C Top Third	Panel C Bottom Third	Panel D Top Third	Panel D Bottom Third
Intercept	0.039 (1.34)	-0.420 (-2.70)[a]	0.905 (13.50)[a]	-0.309 (-2.47)[a]
Industry-Adj. Profitability$_{-1}$	0.115 (5.10)[a]	0.106 (2.25)[b]	0.282 (5.54)[a]	0.087 (1.86)[c]
Industry-Adj. Profitability$_{-2}$	0.085 (3.68)[a]	0.168 (3.41)[a]	0.014 (0.27)	0.186 (3.56)[a]
Ln(Total Asset Book Value)	-0.002 (-0.28)	0.161 (5.09)[a]	-0.138 (-8.93)[a]	0.127 (4.58)[a]
$[Ln(TABV)]^2$	-0.000 (-0.64)	-0.014 (-4.73)[a]	-0.004 (-2.99)[a]	-0.013 (-5.20)[a]
Market Share	0.011 (0.72)	0.040 (0.26)	0.013 (0.27)	0.007 (0.05)
Industry-Adjusted Growth	-0.009 (-2.32)[b]	-0.002 (-0.16)	-0.009 (-1.04)	0.002 (0.14)
Leverage	0.023 (2.76)[a]	0.183 (4.37)[a]	0.040 (2.06)[b]	0.450 (5.87)[a]
Herfindahl	-0.026 (-1.78)[c]	0.032 (0.25)	0.051 (0.97)	-0.014 (-0.11)
N	378	378	378	378
F Test	0.000[a]	0.000[a]	0.000[a]	0.000[a]

[1]a, b, and c indicate that the estimates are statistically different from zero at the 1%, 5%, and 10% significance levels, respectively.

Table C16
Results for Fixed Effects Level Tests: SIC 35

The dependent variable is firm (R&D expenditure/sales revenue). Industry-adjusted profitability is (firm operating cash flow + R&D expense)/sales revenue – the median ratio for the 3-digit SIC in which the firm competes. The measure is lagged 1 year and 2 years. Market share is firm (sales revenue/industry sales revenue) and leverage is firm (total debt/total asset book value). N is the total number of sample points and industry-adjusted growth is the 2-year percentage change in firm sales - the 2-year median change in sales for each 3-digit SIC. In each panel, firms are ranked into the top/bottom third (as defined in Table C9) within each 3-digit SIC, and are then grouped across the 2-digit SIC 35. To allow for outliers in each panel, the top 1% of observations based on the appropriate median measure are omitted. Intercept variables for each cross section and annual dummy variables are included in each model, but suppressed in the reporting of results. Adjusted T-statistics are in parentheses. The F test shows the results for testing the hypothesis that the independent variables are jointly equal to zero.[1]

	Panel A		Panel B	
Regressors	Top Third	Bottom Third	Top Third	Bottom Third
Intercept	0.024	0.009	0.071	0.236
	(0.81)	(0.52)	(2.24)[b]	(2.66)[a]
Industry-Adj. Profitability$_{-1}$	0.050	-0.017	0.050	0.285
	(4.58)[a]	(-1.21)	(4.48)[a]	(4.55)[a]
Industry-Adj. Profitability$_{-2}$	0.055	0.023	0.046	0.043
	(3.60)[a]	(1.67)[c]	(2.84)[a]	(0.67)
Ln(Total Asset Book Value)	-0.006	0.007	-0.011	-0.078
	(-0.78)	(0.97)	(-1.41)	(-1.93)[b]
$[Ln(TABV)]^2$	0.001	-0.001	0.001	0.005
	(1.11)	(-0.63)	(1.07)	(0.78)
Market Share	-0.001	0.008	-0.009	0.200
	(-0.03)	(0.16)	(-0.36)	(0.77)
Industry-Adj. Growth	-0.012	-0.014	-0.011	-0.075
	(-7.72)[a]	(-4.20)[a]	(-6.93)[a]	(-3.98)[a]
Leverage	-0.017	-0.024	-0.005	0.011
	(-2.20)[b]	(-2.74)[a]	(-0.53)	(0.24)
Herfindahl	0.014	-0.085	-0.024	-0.274
	(0.51)	(-1.73)[c]	(-0.86)	(-1.05)
N	504	486	486	486
F Test	0.000[a]	0.000[a]	0.000[a]	0.000[a]

Table C16 (cont'd).

Regressors	Panel C Top Third	Panel C Bottom Third	Panel D Top Third	Panel D Bottom Third
Intercept	0.018 (0.67)	-0.046 (-2.20)[b]	-0.003 (-0.09)	0.599 (4.54)[a]
Industry-Adj. Profitability$_{-1}$	0.050 (4.59)[a]	-0.040 (-2.57)[a]	0.025 (1.92)[b]	0.505 (6.51)[a]
Industry-Adj. Profitability$_{-2}$	0.057 (3.67)[a]	0.029 (1.84)[c]	0.056 (3.74)[a]	0.161 (2.02)[b]
Ln(Total Asset Book Value)	-0.001 (-0.17)	0.014 (2.35)[b]	0.003 (0.45)	-0.133 (-3.09)[a]
$[Ln(TABV)]^2$	0.000 (0.18)	-0.000 (-0.41)[a]	0.000 (0.37)	0.004 (0.83)
Market Share	-0.072 (-2.08)[b]	-0.010 (-0.24)	-0.030 (-0.89)	0.035 (0.15)
Industry-Adj. Growth	-0.012 (-7.61)[a]	-0.013 (-3.93)[a]	-0.012 (-6.33)[a]	-0.085 (-4.26)[a]
Leverage	0.002 (0.18)	-0.029 (-3.92)[a]	-0.022 (-2.61)[a]	0.150 (1.95)[b]
Herfindahl	-0.002 (-0.08)	-0.114 (-2.47)[a]	-0.073 (-1.65)[c]	-0.040 (-0.15)
N	486	486	486	486
F Test	0.000[a]	0.000[a]	0.000[a]	0.000[a]

[1]a, b, and c indicate that the estimates are statistically different from zero at the 1%, 5%, and 10% significance levels, respectively.

Table C17
Results for Fixed Effects Level Tests: SIC 36

The dependent variable is firm (R&D expenditure/sales revenue). Industry-adjusted profitability is (firm operating cash flow + R&D expense)/sales revenue – the median ratio for the 3-digit SIC in which the firm competes. The measure is lagged 1 year and 2 years. Market share is firm (sales revenue/industry sales revenue) and leverage is firm (total debt/total asset book value). N is the total number of sample points and industry-adjusted growth is the 2-year percentage change in firm sales - the 2-year median change in sales for each 3-digit SIC. In each panel, firms are ranked into the top/bottom third (as defined in Table C9) within each 3-digit SIC, and are then grouped across the 2-digit SIC 28. To allow for outliers in each panel, the top 1% of observations based on the appropriate median measure are omitted. Intercept variables for each cross section and annual dummy variables are included in each model, but suppressed in the reporting of results. Adjusted T-statistics are in parentheses. The F test shows the results for testing the hypothesis that the independent variables are jointly equal to zero.[1]

	Panel A		**Panel B**	
Regressors	Top Third	Bottom Third	Top Third	Bottom Third
Intercept	0.048 (1.54)	0.152 (11.22)[a]	-0.044 (-1.24)	0.151 (10.95)[a]
Industry-Adj. Profitability$_{-1}$	0.094 (3.57)[a]	0.031 (1.94)[b]	0.076 (2.90)[a]	0.016 (1.01)
Industry-Adj. Profitability$_{-2}$	0.162 (6.09)[a]	-0.027 (-1.59)	0.094 (3.62)[a]	-0.020 (-1.18)
Ln(Total Asset Book Value)	0.019 (2.38)[b]	0.011 (1.65)[c]	0.025 (2.74)[a]	0.008 (1.25)
$[Ln(TABV)]^2$	-0.002 (-3.21)[a]	-0.000 (-0.20)	-0.002 (-3.49)[a]	-0.000 (-0.14)
Market Share	-0.074 (-1.10)	-0.058 (-1.51)	-0.068 (-2.15)[b]	0.063 (0.84)
Industry-Adj. Growth	-0.024 (-7.55)[a]	-0.016 (-5.32)[a]	-0.020 (-5.77)[a]	-0.016 (-5.39)[a]
Leverage	0.028 (2.68)[a]	0.008 (0.97)	0.023 (2.18)[b]	-0.001 (-0.18)
Herfindahl	-0.118 (-5.04)[a]	-0.007 (-0.23)	-0.040 (-1.63)[c]	0.004 (0.13)
N	522	540	540	540
F Test	0.000[a]	0.000[a]	0.000[a]	0.000[a]

Table C17 (cont'd).

Regressors	Panel C Top Third	Panel C Bottom Third	Panel D Top Third	Panel D Bottom Third
Intercept	0.136	0.017	0.108	0.127
	(5.14)[a]	(0.50)	(2.77)[a]	(4.16)[a]
Industry-Adj. Profitability$_{-1}$	0.071	-0.129	-0.128	0.098
	(2.97)[a]	(-12.24)[a]	(-12.14)[a]	(3.74)[a]
Industry-Adj. Profitability$_{-2}$	0.098	-0.124	-0.100	0.018
	(4.03)[a]	(-5.88)[a]	(-4.47)[a]	(0.63)
Ln(Total Asset Book Value)	-0.008	-0.003	-0.015	0.002
	(-1.33)	(-0.32)	(-1.68)[c]	(0.27)
$[\text{Ln(TABV)}]^2$	0.001	0.001	0.001	-0.001
	(1.15)	(0.60)	(1.94)[b]	(-1.30)
Market Share	-0.067	-0.066	0.017	-0.065
	(-0.84)	(-1.11)	(0.15)	(-1.52)
Industry-Adj. Growth	-0.034	-0.004	-0.004	-0.024
	(-9.28)[a]	(-8.77)[a]	(-7.33)[a]	(-6.61)[a]
Leverage	-0.002	-0.056	-0.058	0.024
	(-0.11)	(-5.44)[a]	(-5.89)[a]	(1.03)
Herfindahl	-0.123	0.017	-0.015	-0.120
	(-4.39)[a]	(0.34)	(-0.31)	(-3.62)[a]
N	522	522	522	522
F Test	0.000[a]	0.000[a]	0.000[a]	0.000[a]

[1]a, b, and c indicate that the estimates are statistically different from zero at the 1%, 5%, and 10% significance levels, respectively.

Table C18
Results for Fixed Effects Level Tests: SIC 38

The dependent variable is firm (R&D expenditure/sales revenue). Industry-adjusted profitability is (firm operating cash flow + R&D expense)/sales revenue – the median ratio for the 3-digit SIC in which the firm competes. The measure is lagged 1 year and 2 years. Market share is firm (sales revenue/industry sales revenue) and leverage is firm (total debt/total asset book value). N is the total number of sample points and industry-adjusted growth is the 2-year percentage change in firm sales - the 2-year median change in sales for each 3-digit SIC. In each panel, firms are ranked into the top/bottom third (as defined in Table C9) within each 3-digit SIC, and are then grouped across the 2-digit SIC 28. To allow for outliers in each panel, the top 1% of observations based on the appropriate median measure are omitted. Intercept variables for each cross section and annual dummy variables are included in each model, but suppressed in the reporting of results. Adjusted T-statistics are in parentheses. The F test shows the results for testing the hypothesis that the independent variables are jointly equal to zero.[1]

	Panel A		Panel B	
Regressors	Top Third	Bottom Third	Top Third	Bottom Third
Intercept	-0.105 (-2.71)[a]	-0.009 (-0.26)	-0.099 (-2.62)[a]	0.088 (0.91)
Industry-Adj. Profitability$_{-1}$	0.056 (1.81)[c]	-0.031 (-1.39)	0.061 (1.91)[c]	-0.215 (-5.46)[a]
Industry-Adj. Profitability$_{-2}$	0.071 (2.16)[b]	-0.237 (-14.04)[a]	0.083 (2.46)[a]	-0.098 (-2.31)[b]
Ln(Total Asset Book Value)	0.060 (5.77)[a]	0.039 (2.67)[a]	0.057 (5.56)[a]	0.022 (0.52)
$[Ln(TABV)]^2$	-0.004 (-5.34)[a]	0.000 (0.02)	-0.004 (-5.00)[a]	0.001 (0.09)
Market Share	0.048 (0.97)	0.288 (2.34)[b]	0.047 (0.97)	0.322 (1.09)
Industry-Adj. Growth	-0.025 (-6.13)[a]	-0.055 (-8.82)[a]	-0.025 (-6.07)[a]	-0.048 (-2.81)[a]
Leverage	0.016 (1.35)	0.032 (1.23)	0.017 (1.47)	0.039 (0.53)
Herfindahl	-0.067 (-2.05)[b]	0.207 (1.62)	-0.075 (-2.32)[b]	-0.591 (-1.61)
N	360	360	360	360
F Test	0.000[a]	0.000[a]	0.000[a]	0.000[a]

Table C18 (cont'd).

Regressors	Panel C Top Third	Panel C Bottom Third	Panel D Top Third	Panel D Bottom Third
Intercept	0.125	-0.070	0.005	-0.056
	(10.76)[a]	(-0.42)	(0.13)	(-1.90)[c]
Industry-Adj. Profitability$_{-1}$	0.078	-0.217	0.048	-0.066
	(2.88)[a]	(-5.45)[a]	(2.06)[b]	(-2.64)[a]
Industry-Adj. Profitability$_{-2}$	-0.004	-0.097	-0.041	-0.219
	(-0.14)	(-2.26)[b]	(-1.47)	(-16.25)[a]
Ln(Total Asset Book Value)	0.007	0.026	0.004	0.050
	(1.37)	(0.85)	(0.42)	(6.93)[a]
$[Ln(TABV)]^2$	-0.001	-0.001	0.000	-0.003
	(-1.40)	(-0.25)	(0.31)	(-3.39)[a]
Market Share	-0.025	0.301	0.087	-0.005
	(-1.27)	(1.02)	(1.71)[c]	(-0.18)
Industry-Adj. Growth	-0.020	-0.050	-0.024	-0.013
	(-5.73)[a]	(-2.76)[a]	(-5.02)[a]	(-2.62)[a]
Leverage	0.019	0.017	0.016	0.040
	(1.96)[b]	(0.22)	(1.20)	(2.12)[b]
Herfindahl	-0.102	-0.516	-0.015	-0.007
	(-2.75)[a]	(-1.41)	(-0.20)	(-0.12)
N	360	360	360	360
F Test	0.000[a]	0.000[a]	0.000[a]	0.000[a]

[1]a, b, and c indicate that the estimates are statistically different from zero at the 1%, 5%, and 10% significance levels, respectively.

APPENDIX D

2-DIGIT AND 3-DIGIT STANDARD INDUSTRIAL CLASSIFICATIONS

2-Digit and 3-Digit Standard Industrial Classifications

SIC 28 Chemicals and Allied Products

SIC 280 Chemicals and Allied Products
SIC 281 Industrial Inorganic Chemicals
SIC 282 Plastics and Synthetics
SIC 283 Drugs
SIC 284 Soap, Cleaners and Toilet Goods
SIC 285 Paints and Allied Products
SIC 286 Industrial Inorganic Chemicals
SIC 287 Agricultural Chemicals
SIC 289 Misc. Chemical Prods.

SIC 35 Industrial Machinery and Equipment

SIC 351 Engines and Turbines
SIC 352 Farm and Garden Machinery
SIC 353 Construction and Related Machinery
SIC 354 Metalworking Machinery
SIC 355 Special Industrial Machinery
SIC 356 General Industrial Machinery
SIC 357 Computer and Office Equip.
SIC 358 Refrigeration and Service Mach.
SIC 359 Industrial Machinery, NEC[58]

SIC 36 Electronic and Other Electric Equipment

SIC 360 Electronic and Other Electric Equip.
SIC 361 Electric Distribution Equipment
SIC 362 Electrical Industrial Apparatus
SIC 364 Electric Lighting and Wiring Equip.
SIC 365 Household Audio/Video Equip.
SIC 366 Communication Equipment
SIC 367 Electronic Components & Accessories
SIC 369 Misc. Electrical Equip. & Supplies

SIC 37 Transportation Equipment

SIC 371 Motor Vehicles and Equipment
SIC 372 Aircraft and Parts
SIC 373 Ship and Boat Building and Repair
SIC 374 Railroad Equipment
SIC 375 Motorcycles/Bicycles/Parts
SIC 376 Guided Missiles, Space Vehicles and Parts

SIC 38 Instruments and Related Products

SIC 381 Search and Navigation Equipment
SIC 382 Measuring and Controlling Devices
SIC 384 Medical Instruments and Supplies
SIC 385 Ophthalmic Goods
SIC 386 Photographic Equip./Supplies

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[58] Not Elsewhere Classified

REFERENCES

REFERENCES

Acs, Zoltan J. and David Audretsch, 1988, "Innovation in Large and Small Firms: An Empirical Analysis," *American Economic Review* 78, 678-690.

Affleck-Graves, John and Katherine Spiess, 1995, "Underperformance in Long-Run Stock Returns Following Seasoned Equity Offerings," *Journal of Financial Economics* 38, 243-267.

Aggarwal, R. and A. Samwick, 1999, "Executive Compensation, Strategic Competition, and Relative Performance Evaluation: Theory and Evidence," *Journal of Finance, forthcoming*.

Arrow, K. "Economic Welfare and the Allocation of Resources for Invention," 1962, in R. Nelson, ed., *The Rate and Direction of Economic Activity* (Princeton: Princeton University Press).

Asquith, Paul and David Mullins Jr., 1986, "Equity Issues and Offering Dilution," *Journal of Financial Economics* 15, 61-89.

Bayless, Mark and Susan Chaplinsky, 1996, "Is There a 'Window Of Opportunity' for Seasoned Equity Issuance?" *Journal of Finance* 51, 253-278.

Bernanke, B., M. Gertler and S. Gilchrist, 1996, "The Financial Accelerator and the Flight to Quality," *The Review of Economics and Statistics* 78, 1-15.

Bernstein, Jeffrey I. and M. Ishaq Nadiri, 1988, "Financing and Investment in Plant and Equipment and Research and Development," in M. H. Preston and R. E. Quandt (eds.), *Prices, Competition, and Equilibrium* (New York: Phillip Allan), 233-248.

Brander, James and Tracy Lewis, 1986, "Oligopoly and Financial Structure: The Limited Liability Effect," *American Economic Review* 76, 956-970.

Bulow, J., J. Geanakoplos, and P. Klemperer, 1985, "Multimarket Oligopoly: Strategic Substitutes and Complements," *Journal of Political Economy* 93, 488-511.

Calomiris, Charles and R. Glenn Hubbard, 1995, "Internal Finance and Investment: Evidence from the Undistributed profits Tax of 1936-37," *Journal of Business* 68, 443-482.

Chauvin, Keith and Mark Hirschey, 1993, "Advertising, R&D Expenditures and the Market Value of the Firm," *Financial Management* 22, 128-140.

Chevalier, Judith and David Scharfstein, 1996, "Capital Market Imperfections and Counter-Cyclical Markups: Theory and Evidence," *American Economic Review* 86, 566-584.

Choe, H., R. Masulis, and V. Nanda, 1993, "Common Stock Offerings Across the Business Cycle: Theory And Evidence," *Journal of Empirical Finance* 1, 3-31.

Cohen, Wesley and Steven Klepper, 1992, "The Anatomy of Industry R&D Intensity Distributions," *American Economic Review* 82, 773-799.

Daniel, K., M. Grinblatt, S. Titman, and R. Wermers, 1997, "Measuring Mutual Fund Performance with Characteristic Based Benchmarks," *Journal of Finance* 52, 1035-1058.

Dasgupta, Partha, 1988, "Patents, Priority and Imitation or The Economics of Races and Waiting Games," *The Economic Journal* 98, 66-80.

Dasgupta, Partha, and Joseph Stiglitz, 1980, "Uncertainty, Industrial Structure, and the Speed of R&D," *Bell Journal of Economics* 11, 1-28.

Dasgupta, S. and Sheridan Titman, 1998, "Pricing Strategy and Financial Policy," *Review of Financial Studies* 11, 705-738.

DeAngelo, H. and L. DeAngelo, 1989, "Proxy Contests and the Governance of Publicly Held Corporations," *Journal of Financial Economics* 23, 29-59.

Denis David, 1993, "The Costs of Equity Issues Since Rule 415: A Closer Look," *Journal of Financial Research* 16, 77-88.

Eckbo, B. E., and R. Masulis, 1992, "Adverse Selection and The Rights Offer Paradox," *Journal of Financial Economics* 32, 293-332.

Fazzari, S., R.G. Hubbard and B. Peterson, 1988, "Financing Constraints and Corporate Investment," *Brookings Papers on Economic Activity*, 141-195.

Fenn, George, Nellie Liang and Stephen Prowse, 1995, "The Economics of the Private Equity Market," Board of Governors of the Federal Reserve System, Staff Study #168.

Fishman, Michael, 1988, "A Theory of Preemptive Takeover Bidding," *Rand Journal of Economics* 19, 88-101.

Gallini, Nancy, 1992, "Patent Policy and Costly Imitation," *Rand Journal of Economics* 23, 52-63

Grabowski, Henry, 1968, "The Determinants of Industrial Research and Development: A Study of the Chemical, Drug and Petroleum Industries," *Journal of Political Economy* 76, 292-306.

Grabowski, Henry and Nevins Baxter, 1973, "Rivalry in Industrial Research and Development: An Empirical Study," *Journal of Industrial Economics* 21, 209-235.

Hall, Bronwyn, 1992, "Investment and Research and Development at the Firm Level: Does the Source of Financing Matter?" National Bureau of Economic Research Working Paper #4096.

_______, 1995, "Firm Investment with Liquidity Constraints: What Can the Euler Equations Tell Us?" Working Paper.

Hall, Bronwyn, J. Mairesse, L. Branstetter, and B. Crepon, 1998, "Does Cash Flow Cause Investment and R&D: An Exploration Using Panel Data for French, Japanese, and United States Scientific Firms," in D. B. Audretsch and Thurik (eds.), *Innovation, Industry Evolution and Employment* (Cambridge: Cambridge University Press).

Heckman, James, 1979, "Sample Selection Bias as a Specification Error," *Econometrica* 47, 153-161.

Hertzel, M., M. Lemmon, J. Linck and L. Rees, 1999, "Long-Run Performance Following Private Placements of Equity," Working Paper, Arizona State University.

Hertzel, Michael and Richard Smith, 1993, "Market Discounts and Shareholder Gains for Placing Equity Privately," *Journal of Finance* 48, 459-486.

Himmelberg, Charles and Bruce Peterson, 1994, "R&D and Internal Finance: A Panel Study of Small Firms in High-Tech Industries," *Review of Economics and Statistics*, 38-51.

Hoshi, T., A. Kashyap, and D. Scharfstein, 1991, "Corporate Structure Liquidity and Investment: Evidence from Japanese Panel Data," *Quarterly Journal of Economics* 106, 33-60.

Jensen, M., and W. Meckling, 1976, "Theory of the Firm: Managerial Behavior, Agency Costs and Ownership Structure," *Journal of Financial Economics* 3, 305-360.

Jung Kooyul, Yong-Cheol Kim and Rene M. Stulz, 1996, "Timing, Investment Opportunities, Managerial Discretion and the Security Issue Decision, " *Journal of Financial Economics* 42, 159-185.

Kamien, Morton I. and Nancy L. Schwartz, 1978, "Self-Financing of an R&D Project," *American Economic Review* 68, 252-261.

Kamien, Morton I. and Nancy L. Schwartz, 1982, *Market Structure and Innovation* (Cambridge: Cambridge University Press).

Kaplan, S., 1989, "The Effects of Management Buyouts on Operating Performance and Value," *Journal of Financial Economics* 24, 217-254.

Kaplan, Steve and Luigi Zingales, 1997, "Do Investment-Cash Flow Sensitivities Provide Useful Measures of Financing Constraints?" *Quarterly Journal of Economics* 112, 169-215.

Katz, Michael, and Carl Shapiro, 1987, "R&D Rivalry with Licensing or Imitation," *Journal of Political Economy* 77, 402-420.

Kedia, Simi, 1996, "Product Market Competition and Top Management Compensation," Working Paper, New York University.

Krasker, W.S., 1986, "Stock Price Movements in Response to Stock Issue Under Asymmetric Information," *Journal of Finance* 41, 93-105.

Korajczyk, Robert, Deborah Lucas and Robert McDonald, 1991, "The Effect of Information Releases on the Pricing and Timing of Security Issues," *Review of Financial Studies* 4, 685-708.

Krishnamurthy, Srini, Paul Spindt, Venkat Subramaniam and Tracie Woidtke, 1998, "Do Shareholders Gain From a Private Placement?" Working Paper, Tulane University.

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

Leland, Hayne and David Pyle, 1977, "Information Asymmetries, Financial Structure, and Financial Intermediation," *Journal of Finance* 32, 371-387.

Levin, Richard, Alvin Klevorick, Richard Nelson, and Sidney Winter, 1987, "Appropriating the Returns from Industrial Research and Development," *Brookings Papers on Economic Activity* N3, 783-820.

Link, Albert and John Neufeld, 1986, "Innovation versus Imitation: Investigating Alternative R&D Strategies," *Applied Economics* 18, 1359-1363.

Loughran, Tim, 1997, "The Operating Performance of Firms Conducting Seasoned Equity Offerings," *Journal of Finance* 52, 1823-1850.

Loughran, Tim and Jay Ritter, 1995, "The New Issues Puzzle," *Journal of Finance* 50, 23-52.

Loury, Glenn, 1979, "Market Structure and Innovation," *Quarterly Journal of Economics* 93, 395-410.

Lucas, Deborah and Robert McDonald, 1990, "Equity Issues and Stock Price Dynamics," *Journal of Finance* 45, 1020-1043.

Mackie-Mason, Jeffrey, 1990, "Do Taxes Affect Corporate Financing Decisions?" *Journal of Finance* 45, 1471-1493.

Maksimovic, V. 1988, "Capital Structure in Repeated Oligopolies," *Rand Journal of Economics* 19, 389-407.

Mansfield, Edwin, Mark Schwartz, and Samuel Wagner, 1981, "Imitation Costs and Patents: An Empirical Study," *The Economic Journal* 91, 907-918.

Masulis, Ronald and Ashok Korwar, 1986, "Seasoned Equity Offerings," *Journal of Financial Economics* 15, 91-118.

Michaelson, Peter, 1986, "The 1984 Semiconductor Chip Protection Act: A Comprehensive View," *Communications and the Law* 8, 23-55.

Myers, Stewart and Nicholas Majluf, 1984, "Corporate Financing and Investment Decision When Firms Have Information that Investors Do Not," *Journal of Financial Economics* 13, 187-221.

Opler, Tim and Sheridan Titman, 1995, "The Debt-Equity Choice," Working Paper, Ohio State University.

Pepall, Lynne, and Daniel Richards, 1994, "Innovation, Imitation, and Social Welfare," *Southern Economic Journal* 60, 673-684.

Pozdena, Randall; Spring, 1987, "Competition in the Semiconductor Industry," *Federal Reserve Bank of San Francisco Economic Review*, 41-56.

Reinganum, Jennifer, 1981, "On the Diffusion of New Technology: A Game Theoretic Approach," *Review of Economic Studies* 48, 395-405.

Reinganum, Jennifer, 1982, "A Dynamic Game of R and D: Patent Protection and Competitive Behavior," *Econometrica* 50, 671-688.

Ritter, Jay, 1991, "The Long-Run Performance of Initial Public Offerings," *Journal of Finance* 46, 3-27.

Safieddine, A. and S. Titman, 1999, "Leverage and Corporate Performance: Evidence from Unsuccessful Takeovers," *Journal of Finance* 54, 547-580.

Scherer, F.M., 1967, "Market Structure and the Employment of Scientists and Engineers," *American Economic Review* 57, 524-531.

_______, 1984, *Innovation and Growth: Schumpeterian Perspectives* (Cambridge: MIT Press).

Segerstrom, Paul, 1991, "Innovation, Imitation, and Economic Growth," *Journal of Political Economy* 99, 807-827.

"Semicon Summit Mulls Fab Future," *Electronic-Engineering-Times.* July 25, 1994, 1.

Smith, Clifford Jr., 1986, "Investment Banking and the Capital Acquisition Process," *Journal of Financial Economics* 15, 3-29.

Standard & Poor's Industry Surveys, 1992, 1994, (New York: Standard & Poor's).

Stiglitz, Joseph and Andrew Weiss, 1981, "Credit Rationing in Markets with Imperfect Information," *American Economic Review* 71, 393-410.

Sundaram, A., Teresa and Kose John, 1996, "An Empirical Analysis of Strategic Competition and Firm Values: The Case of R&D Competition," *Journal of Financial Economics* 40, 459-486.

Tirole, Jean, 1994, *The Theory of Industrial Organization,* (Cambridge: MIT Press).

Valueline Investment Survey, 1995, (New York: Valueline Publishing Inc.).

Williams, Jan, *Miller GAAP Guide—1994*, 1994, (San Diego: Harcourt Brace & Co.).

Wruck, Karen, 1989, "Equity Ownership Concentration And Firm Value: Evidence From Private Equity Financing," *Journal of Financial Economics* 23, 3-27.