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探討高流動性資產、景氣循環、市場環境與企業研發支出之關聯性

Effect of Highly Liquid Current Assets, Economic and Market Environment on Corporate R&D Expenditure

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能夠完成本篇碩士論文，學生最要感謝 劉啟群主任與 尤琳蕙老師的悉心指導。首先，謝謝 劉啟群主任在校務繁忙之中，依然抽空指導學生的碩士論文，並於每一次討論中訓練學生以宏觀的角度思考問題；同時給予足夠的空間發揮；再來要謝謝 尤琳蕙老師於學生撰寫論文的過程中，不時地針對細節給予建議，並點出學生疏於注意之盲點。學生也在此感謝口試委員 林純央教授與 張窈菱教授的肯定；並謝謝您們於口試時給予的建議，使本篇論文更趨臻美。

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於台大會計學研究所

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論文摘要

美國管理大師彼得·杜拉克曾言:「企業僅有兩種行為會賺錢—研發與行銷，其他的行為終將成為成本。」根據 Booz & Company’s Global Innovation 1000 之統計結果，全球支出最多研發支出之前 1000 大企業其研發支出總額已從 2005 年的 400 億美元成長至 2014 年的 647 億美元。9 年期之複合成長率達到 5.5%，可見企業愈趨重視研發支出。

本篇論文結合會計資訊與市場競爭之概念，探討影響企業投入研發支出的決定因子。相較於歷史文獻以單一產業為研究對象，本篇納入 1970 年至 2013 年多種產業為研究標的；以高流動性資產、景氣循環與市場環境為決定因子，探討其與企業研究與發展支出之關聯性。本篇之實證結果如下：

1. 持有愈多高流動性資產之公司，傾向投入愈多研究與發展支出。
2. 持有愈多高流動性資產之公司其於景氣蕭條時期所投入之研究與發展支出，相較於其他景氣時期所投入之研究與發展支出更多。
3. 企業間之競爭程度與企業投入之研究與發展支出呈現顯著正相關。
4. 產業需求成長率與企業投入之研究與發展支出呈現顯著負相關。

本篇論文之實證結果亦通過穩健性測試，顯示研究之可靠性。最後，希望透過本篇論文之實證研究，延伸學術上對公司研究與發展費用決定因子的認知，同時於實務上提供企業管理階層制定決策時之參考。

關鍵字: 研究與發展支出、決定因子、企業流動性、景氣循環、市場競爭

ABSTRACT

Over the past few decades, R&D related issues have been few discussed due to the uniqueness and the wide operational diversity of different industries. Different from prior literature, this article comprises a variety of industries to study the determinants of research and development expenditure by using a panel of more than 30,000 firm-years of publicly listed North America firms from 1970 to 2013. The purpose of this study is to examine how highly liquid current assets, economic and market environment affect the amount of research and development expenditure. The primary findings of this article are as follows:

(1) Firms holding more highly liquid current assets tend to invest more in research and development expenditure.

(2) The relationship between highly liquid current assets and research and development expenditure is stronger during the periods of recession.

(3) Firms tend to invest more research and development expenditure as the competition among individual firms increases.

(4) The growth of market demand by industry is negatively associated with R&D expenditure.

The results remain robust in the sensitivity test. The findings of this article advance our understanding of determinants of research and development expenditure, and provide practical implications to managers during decision-making.

Keyword: Research and Development Expenditure; Determinants; Firm's Liquidity; Economic Environment; Market Competition.

Data Availability All data used in this article are available from public sources.

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Section 1. Introduction

As Peter Drucker said in 1954: "There are two things in a business that make money—innovation and marketing; everything else is cost."

For the last decade, global research and development expenditure (R&D for abbreviation) has steadily risen from 400 billion in 2005 to 647 billion in 2014, at an accumulated growth rate of 61.75% and an annual growth rate of 5.5%; furthermore, the top 10 biggest R&D spenders worldwide—such as Volkswagen, Samsung and Intel—have invested 100.6 billion on R&D in 2013, about 8.8% of total revenue on average. Another interesting figure shown in The World Bank database is that the researchers in R&D has grown 33% from 1996 to 2012, a total number of 120 million researchers worldwide. As R&D gradually becomes the fuel of firms' growth, managers allocate a large amount of their resources to R&D in order to generate revenues, and increase firm value ultimately. One of the aim of this article is to advance the academic understanding of determinants of corporate research and development expenditure; however, the existing studies concerning of R&D are extremely few because of the tremendous challenge and difficulty involved; therefore, prior literature focuses mainly on individual and specific industry, such as industries of biopharmaceutical and telecommunications—industries investing relatively large amount on research and development expenditure. As a consequence, R&D related issues are still being hotly debated and require further analysis. For instance, the valuation of corporate R&D's effect (Theodore et al., 1994) and the relationship between R&D and financial performance (Hsu, Chen and Wang, 2013), to name a few.

Particularly, among all studies concerning of R&D, the determinants of R&D has been, and will continue to be one of widely investigated topics. Researchers put effort on studying the internal and external factors impacting the managers to cut back or spend more on R&D. For instance, whether cash holdings has a positive impact on R&D (Evgeny and Dino, 2012), which is considered as an internal factor influencing R&D; and R&D budgeting reactions to recession (Klaus and Alan, 1998) from an external aspect.

The contribution of this study differs from prior literature in several ways. First, unlike prior literature focusing on individual industry, this article provides evidence from a large sample of firms across a variety of industries to investigate the determinants of R&D expenditure. Second, this article is the first research to empirically relate research and development expenditure to accounting information and market competition. More precisely, the determinants considered here include highly liquid current assets, periods of economic recession and expansion, degree of market competition and the growth of market demand. Finally, this article investigates determinants of R&D expenditure with a holistic view, analyzing these determinants together.

This article proceeds as follows. Section 2 reviews the previous research relating to the determinants of R&D and introduces the development of hypotheses. Section 3 exhibits a frame work for the analysis. Section 4 presents the findings. Section 5 provides additional analyses. Section 6 concludes this article.

Section 2. Literature review & Hypotheses development

The importance of corporate R&D expenditure has been widely investigated by numerous academic studies, indicating that R&D expenditure plays a critical role in growth of economy and business. Hence, the analysis of the driving factors of R&D remains a main topic of empirical concern. This article attempts to extend the understanding of determinants of R&D in the following aspects.

2.1. Highly liquid current assets

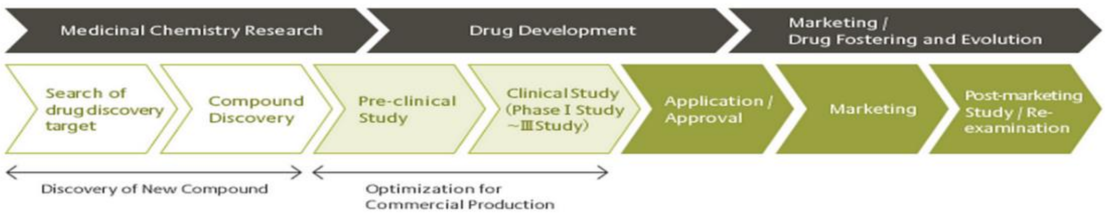
Global R&D expenditure has accounted for an estimated 647 billion in 2014. More precisely, take U.S for example, The World Bank database shows that United States remains the world's largest R&D investor with 465 billion spending in 2014, equaling to 2.8 % of U.S GDP. In turn, it consumes large amount of resources to support R&D activities. In addition, it's a common phenomenon for certain industries—such as biopharmaceutical, taking a lengthy period that spans over ten years to reap from R&D efforts due to the nature of industry (Figure 1). Thus, in order to continuously support R&D activities, firm's liquidity has been deemed as an extremely crucial index for manager during decision-making, for instance, James and Bruce (2010) implied that firms reserve cash to smooth their R&D expenditure, inferring that firms' liquidity has a significant impact on manager real investment decision. In addition, Murillo, John, Campbell (2009) pointed out that firms which are restricted by financial constrained might bypass attractive investment opportunities, and even cancel or postpone their planned investments. Hence, it could be reasonably assumed that firms' liquidity has a positive impact on firms' investment willingness.

Unlike prior research that mainly discussed the relationship between cash holdings and R&D (see, for example, Evgeny and Dino, 2012; Zhaozhao and Babajide, 2013), this study incorporates highly liquid current assets instead of cash holdings for further investigation. Following the definition of Taiwan Stock Exchange (TSE for abbreviation), highly liquid current asset includes not only cash and cash equivalent, but also short-term investments, which is considered to be highly liquid as well[1]. The evidence of firms carrying more highly liquid current assets could be easily discovered. According to the article of INVESTER'S BUSINESS DAILY released in March 2015, "Cash and short-term investments among all companies in the S&P 500 is at a record high $1.43 trillion. The previous record, set in Q4 2013, was $1.41 billion." Moreover, this phenomenon is relatively clearer among some of the largest R&D spenders shown in the figures below (Figure 2A and 2B). Hence, given the empirical results of prior research and characteristic of R&D, this article assumes that highly liquid current assets have a positive impact on R&D expenditure; thus, the first hypothesis of this article is:

H1. Firms holding more highly liquid current assets tend to invest more in research and development expenditure.

Figure 1

R&D Process in Biopharmaceutical Industry



[1] According to IAS 1 regarding the presentation of financial statements, short-term investments is classified right after cash and cash equivalent under current assets, indicating that short-term investments is considered highly liquid as well.

Figure 2A

Cash and Short-term Investments of Firms in Different Industries from 2007 to 2014

In $billions

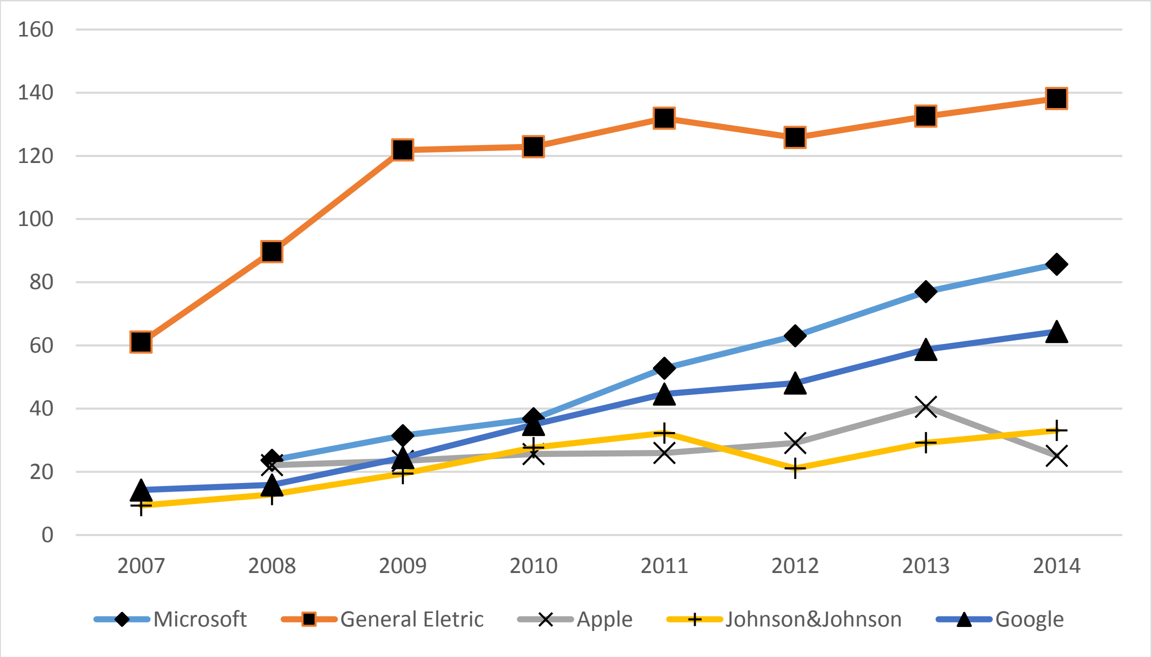
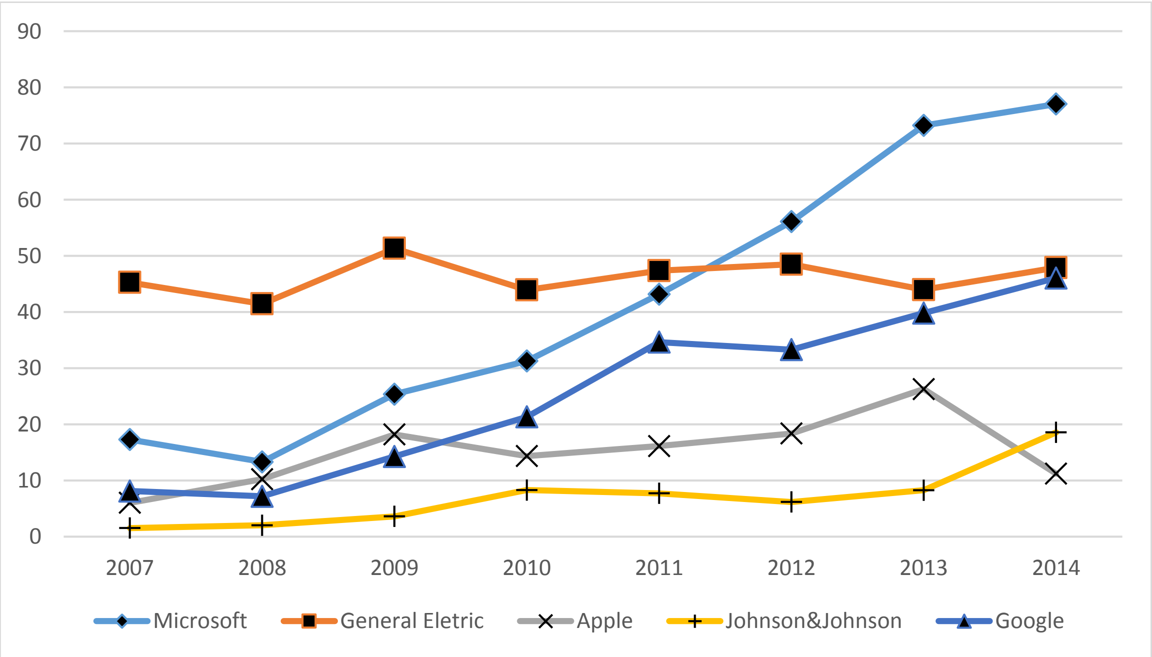


Figure 2B

Short-term Investments of Firms in Different Industries from 2007 to 2014

In $billions



2.2. Periods of recession and economic expansion

The foregoing hypothesis pertains to how the overall economic environment, on average, influences the relationship between highly liquid current assets and R&D. During the periods of recession, firms are under pressure to control costs to maintain liquidity; hence, whether to invest in R&D and advertising expenditure during recessions or not has been a popular social scientific topic for years. Businesses frequently run into such dilemmas. For instance, when Kevin Johnson, CEO of Juniper Networks Inc., was under press to slash costs to survive the 2008 recession, he had to decide what to do about the firm's $800 million research budget, which constituted only 20% of Juniper's revenue but was fuel for its sales growth. He decided against R&D cuts, noting, "We've tightened up on other areas so we can fund more R&D" (Worthen 2009, p. B1). However, not all firms make the same decision. A series of marketing journals (see, for example, Michele, Claudio, Alexander, Peter, 2011) indicated that during the periods of recession, most of the industries remain or even cut back the R&D spending significantly. Moreover, Anne-Leigh and Benton (2013) found that firms tend to reserve more cash holdings after the announcement of a recession from the National Bureau of Economic Research (NBER for abbreviation). Based on the findings of prior research, it could be assumed that the periods of recession might weaken the relationship between highly liquid current assets and R&D.

On the other hand, reflecting on several economic theory and competitive strategies, such as "Creative Destruction"— an economic theory proposed by economist Joseph Schumpeter in 1912— described as the process of industrial mutation that incessantly revolutionizes the economic structure from within, incessantly destroying the old one and incessantly creating a new one; and the concept of "Disruptive Innovation" as an extension of Joseph Schumpeter's theory, proposed by Clayton M.

Christensen, a professor at the Harvard Business School; and the "Dynamic Competition" strategy nowadays. Simply put, instead of following conventional strategies, it's clear that incessantly changing and being innovative have become a trend for firms to grow and stay competitive. Unlike the strategy that the majority of firms deployed in the past, firms with sufficient highly liquid current assets might allocate more resource on R&D and innovation to thrive through the downturn and thus seek to gather the benefits or become technology leader in the upswing to come.

This phenomenon could be discovered in the nearest economic downturn. A partner of Booz & Company, a global management consulting firm, once said, "Reducing efforts on innovation would be similar to unilateral disarmament in wartime"; "Now is an opportune time to build advantage over competitors, especially weaker ones that may have to skimp on R&D for financial reasons." During the nearest recession in 2008, Booz & Company's Global Innovation 1000 survey of the biggest R&D spenders showed an innovation investment growth rate of 5.7% in 2008 (Figures 3), even though net incomes plummeted by 34%, indicating that innovation is considered a vital element for firms with long-term perspective.

Due to the mixed empirical results of prior studies and economic theories, this article has no prediction on how the periods of recession influence the relationship between highly liquid current assets and R&D; hence the first sub-hypothesis of this article is as follows:

H1a. Recession affects the relationship between highly liquid current assets and R&D.

Furthermore, this article also takes the periods of economic expansion into account, interested in whether it influences the relationship between highly liquid current assets and R&D as well. It is intuitive that firms hold more cash due to the increase in sales during the economic expansion; hence, based on the first hypothesis, the relationship might be stronger during the periods. Yet, as firms' cash holding increases, the free cash flow increases at the same time, leading to a higher agency cost (Michael, 1986). Commonly, managers manipulate earnings by means of cutting discretionary spending such as advertising and R&D expenditure, so as to optimize individual performance.

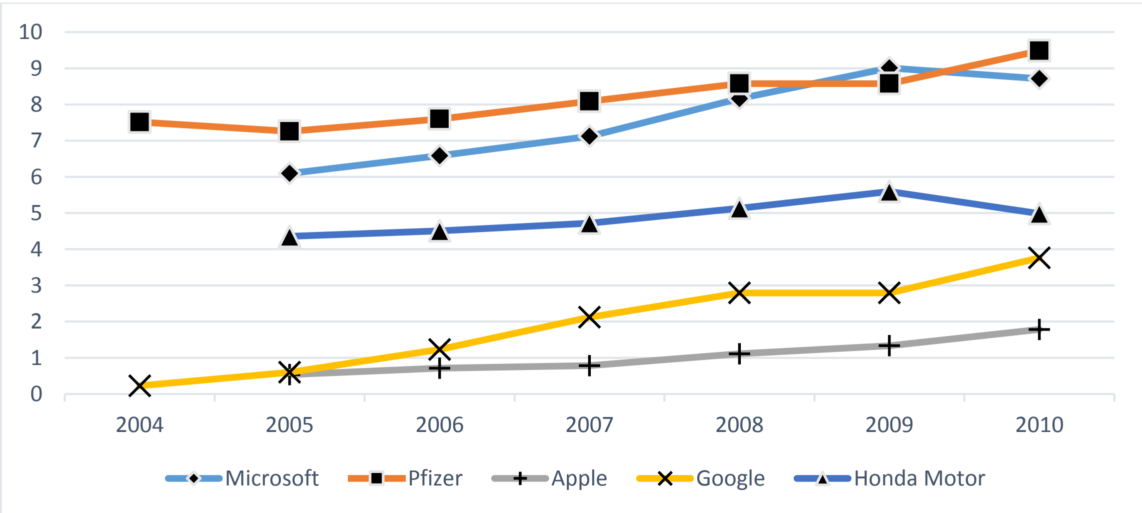
Given the mixed possibilities inferred above, the influence of economic expansion on the relationship between highly liquid current assets and R&D is also unclear and requires further testing; hence, the second sub-hypothesis of this article is as follows:

H1b. Economic expansion affects the relationship between highly liquid current assets and R&D.

Figure 3

R&D Expenditure of Firms in Different Industries after Recession of 2004

In $billions



2.3. Market competition

Peter Drucker advised that, in order to survive,

companies needed to: "innovate or die."

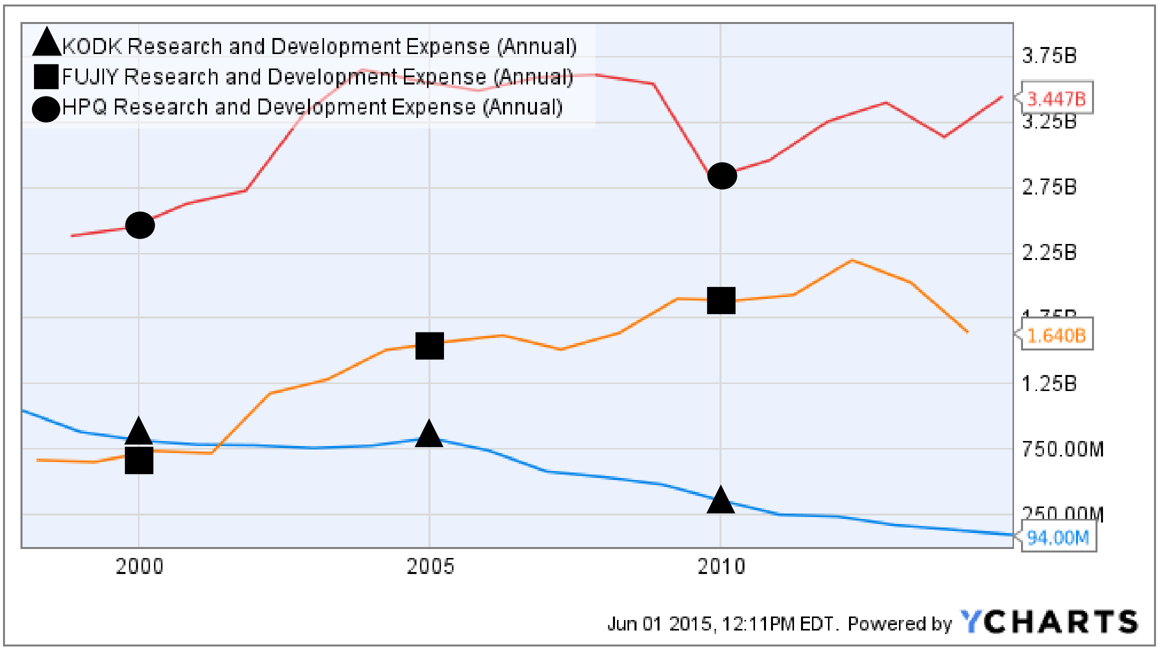
Over the past few decades, numerous historic giants have fallen or even gone extinction due to lack of innovation in competitive market. For instance, Kodak, one of the most instantly recognizable names and leading firm in the photography industry, has had its plan to exit bankruptcy approved ending a 125 year history as a camera company because of missing the chance to catch up the era of digital camera (Figure 4). After few years, the same pattern happened to another giant as well. Sony, once the iconic manufacturer of electronic products for the consumer and professional markets, now ended up selling off its VAIO laptop division last year and planned to redo for mobile division after generating billions of losses, as the result of failing to ride some of the biggest waves of technological innovation in recent decades: digitalization, a shift toward software and the importance of Internet. According to a report released from Stratgey& and PwC, of the top 20 R&D spenders of Computing & Electronics industry from 2005 to 2014, Sony was on the list for only 2005, 2006 and ranked 20th in 2013; on the other hand, one of Sony's main competitor—Samsung, has been on the list for the past 10 years, and was ranked 2th in 2013. In addition to real cases, theory of industry life cycle also highlights the importance of innovation in competitive market. Theoretically, on average, roughly 5 to 10 percent of the firms in the given market leave that market over the span of a single year. After that, the stage of growth and maturity are the most competitive periods in the industry life cycle; potential entrants will be apparent and will try to steal market share from emerging or existing market. In the growth stage, even inefficient companies made money; however, only the best companies and their products survive in the maturity stage. In turn, the majority of firms are striving to live in competitive market. In order to protect the existing market share, firms need to make changes to the product or services to better reflect customers' needs and suggestions; therefore, two competitive strategies would be commonly applied—product differentiation and cost leadership. Some authors (see, for example, Ping and Kamal, 2002) claimed that Bertrand firms (price competition) have a stronger incentive for product R&D whereas Cournot firms (quantity competition) invest more in process R&D. Preston and Donald (1992) also proposed that firms accelerate product launch to gain competitive advantage by the means of shortening product development cycle. Moreover, other authors (Richard and Andrew, 2015) focused on merely biotechnology and pharmaceutical companies, indicating that market competition has a significant positive effect on R&D. Therefore, according to real cases, theory and existing studies, it could be posited that market competition is positively associated with R&D expenditure. On the other hand, from the perspective of "The Schumpeterian Effect", competitive market might negatively affect the firms' financial performance, hence reducing managers' incentive to continuously exert effort.

The majority of prior research incorporated HHI and concentration ratio as proxy for market competition. The main consideration toward these proxies is that they capture only the aspect of industry structure, but fail to capture the aspect of competition among individual firms. Hence, following the empirical result of Anthony J. Dukes (2008) that advertising is an important competitive tool for firms, this work is the first research to employ advertising expenditure as an additional alternative proxy for market competition as it captures the competition among individual firms. Therefore, this study predicts that firms tend to invest more research and development expenditure in a more competitive market. The second hypothesis of this article is as follows:

H2. Research and development expenditure is positively related to the degree of market competition.

Figure 4

R&D Expenditure of Kodak and Its Competitors



KODK stands for Kodak; FUJIY stands for Fujifilm; HPQ stands for Hewlett-Packard Company

2.4. Growth of market demand

The last determinant of R&D investigated in this article is growth of market demand. From an economic point of view, market would still be considered profitable if demand keeps growing steadily, giving incentive for potential entrants to compete for the emerging or existing market. Considering the second hypothesis, growth of market demand has great possibility to engage firms in investing in R&D to counter with the potential entrants competing for market share. In addition, some empirical studies (see, for example, Bean, 1995; Alex and Rekha, 2007) proposed that firms' sales growth is positively associated with R&D spending. Therefore, by the perspective on academic research and the causation of second hypothesis, it could be rationally posited that growth of market demand has a positive impact on R&D. However, Lee, Li and Yue

(2005) held a different point of view, claiming that as firms growing bigger resulting from the growth of market demand, managers might conduct earnings management by the means of slashing discretionary expenditure—including R&D and advertising expenditure—to optimize earnings performance due to more careful overseeing from investors.

Different from prior research (see, for example, Bean, 1995; Alex and Rekha, 2007) investigating the effects of demand growth to R&D expenditure mainly focused on sales growth by firm, this article employs sales growth by industry as an alternative proxy for demand growth, examining the relationship between R&D expenditure and growth of market demand from a macro perspective as managers making decisions in a wide-angle view. Thus, the final hypothesis of this article is as follows:

H3. The growth of market demand by industry is associated with R&D expenditure.

Section 3. A framework for the analysis

3.1. The basic framework

The main purpose of this article is to investigate the corporate determinants of R&D. To be specific, this article focuses on the impact of highly liquid current assets, periods of recession and economic expansion, market competition and growth of market demand on R&D.

3.2. Sample

The financial data used in this article were obtained from Compustat North America Annual database, GDP growth from The World Bank and the periods of recession from National Bureau of Economic Research. Specifically, financial data were cautiously selected under six procedures. Firstly, this article comprises a variety of industries listed on Compustat database over the period from 1970 to 2013, consisting more than 400,000 firm-year observations initially. Secondly, consistent with previous practice in the literature, financial institutions[2] (SIC code 6000-6999) were excluded because of the different nature of investment for these institutions. Thirdly, regulated industries (SIC code 4800-4900) were also excluded as their characteristics differ from those of other industries. Fourthly, this article further eliminates observations with missing variables and values of interests for the regression models. Fifthly and the most crucial, the sample used in the regressions are strictly restricted with research and development expenditure available on Compustat database. Finally, in order to mitigate the influence of outliers, all continuous variables were winsorized[3]at 1% and 99% levels

[2] Financial institutions are typically examined separately as their financial ratios and valuations metrics are different to those of general industries. It should be noted that the loan ratio, adequacy ratio and liquidity ratio of financial institutions are strictly regulated.

[3] Before winsorizing, some firms have large amount of R&D expenditure but zero assets, resulting in an abnormal value of dependent variable (RDEXP). In this study, those observations are considered to be outliers.

by year at the firm-year level. After the necessary sample selection procedures, there are 38,072 firm-year observations. The descriptive statistics of the sample are shown in Table 1 (Panel A).

3.3. Measures and measurement of variables

The only dependent variable used in this article is research and development expenditure (RDEXP), which is defined as the ratio of research and development expenditure to total assets of the firm.

With respect to the main variables employed, firstly, highly liquid current assets (HCARATIO) is defined as the ratio of highly liquid current assets to total assets of the firm. Following the definitions of highly liquid current assets from Taiwan Stock Exchange (TWSE for abbreviation), it's defined as sum of cash, cash equivalent, short-term investments[4], listed and OTC stocks (including unrealized gain or loss from valuation).

Secondly, on the purpose of capturing various nature of market competition, this article incorporates four proxies of market competition. More specifically, two proxies—Herfinahl-Hirschman Index (HHI) and four-firm concentration ratio (CONC)—capture the aspect of industry structure, which are defined as the sum of squared market share of all firms in an industry (2-digit SIC) for Herfinahl-Hirschman Index and a portion of sales of four largest firms in the industry for the latter; the other two proxies—advertising expenditure (ADVEXP) and industry leading firm indicator (LEADER)—capture the aspect of individual firm competition, which are defined as the ratio of advertising expenditure to the total assets of the firm for advertising expenditure and dummy variable that takes the value 1 if the firm is one of the largest four firms in

[4] To be specific, short-term investments defined by Taiwan Stock Exchange is consisted of financial assets at fair value through income statement and financial assets in available-for-sale.

industry in terms of total sales and 0 otherwise for the latter.

Thirdly, as a proxy for the periods of recession (REC), this article follows the announcement of a recession from the National Bureau of Economic Research, defining a dummy variable taking the value 1 if the year is 1970, 1974, 1980, 1982, 1990, 2001 and 2008; 0 otherwise. As for the periods of economic expansion (EGROWTH), it's defined as a dummy variable taking the value 1 if the GDP growth of the year is top 25%[5] of GDP growth over the period from 1970 to 2013; 0 otherwise.

Finally, this article employs average industry sales growth (AISGROWTH) as a proxy for growth of market demand by industry, measuring it using five-year average sales growth of the industry.

Regarding to the control variables, this article measures lagged research and development expenditure (LRDEXP) using RDEXP lagged by one year before; firm age (AGE) is defined as the difference between the date of beginning stock data and the date of ending stock data on Compustat database; firm size (SIZE) is calculated as the natural logarithm of a firm's total assets; loss (LOSS) is an indicator variable that is equal to 1 if a firm has a loss in the current period and 0 otherwise; firm leverage (LEV) is measured as the ratio of sum of total long- and short-term debt to the total assets; at last, this article employs industry indicator (INDUS) for industry-fixed effects. Appendix summarizes variable names used and definitions.

[5] From 1970 to 2013, the mean, Q1, median and Q3 of GDP growth of North America are 2.78, 1.79, 3.23 and 4.17, respectively, which are not tabulated in this article. Economic expansion is broadly defined as a period of time in which GDP increases; but in order to highlight the significance of economic expansion, this article sets the benchmark at the third quantile of GDP growth, which is top 25% of GDP growth.

3.4. Model specification

The analyses in this study focus on the relationship between R&D expenditure (RDEXP), the dependent variable, and highly liquid current assets (HCARATIO), periods of recession (REC) and economic expansion (EGROWTH), market competition (ADVEXP, LEADER, HHI and CONC) and growth of market demand by industry (AISGROWTH), the main variables of interest. Hence, the first model specification is given by the following OLS regression to be estimated;

$$
\begin{aligned}
RDEXP_{it} = {} & \beta_0 + \beta_1 HCARATIO_{it} + \beta_2 ADVEXP_{it} + \beta_3 LEADER_{it} + \beta_4 HHI_{it} + \beta_5 CONC_{it} \\
& + \beta_6 AISGROWTH_{it} + \beta_7 LRDEXP_{it} + \beta_8 AGE_{it} + \beta_9 SIZE_{it} \\
& + \beta_{10} LOSS_{it} + \beta_{11} LEV_{it} + \beta_{12} \sum_1^j INDUS_{jt} + \varepsilon_{it} \qquad \text{Eq. (1)}
\end{aligned}
$$

where subscript *i* refers to firm, *t* refers to time and *j* refers to industry. Equation 1 investigates the coefficient of β_1 and β_6 to β_{10} to test for H1, H2 and H3, examining the relationship between highly liquid current assets, four proxies of market competition, average industry sales growth and R&D.

As for testing the influence of periods of recession and economic expansion on the relationship between highly liquid current assets and R&D, the next model specification is given by the following OLS equation to test for H1a and H1b:

$$
\begin{aligned}
RDEXP_{it} = {} & \beta_0 + \beta_1 HCARATIO_{it} + \beta_2 HCARATIO_{it} \times REC_{it} + \beta_3 HCARATIO_{it} \times EGROWTH_{it} \\
& + \beta_4 REC_{it} + \beta_5 EGROWTH_{it} + \beta_6 ADVEXP_{it} + \beta_7 LEADER_{it} + \beta_8 HHI_{it} \\
& + \beta_9 CONC_{it} + \beta_{10} AISGROWTH_{it} + \beta_{11} LRDEXP_{it} + \beta_{12} AGE_{it} + \beta_{13} SIZE_{it} \\
& + \beta_{14} LOSS_{it} + \beta_{15} LEV_{it} + \beta_{16} \sum_1^j INDUS_{jt} + \varepsilon_{it} \qquad \text{Eq. (2)}
\end{aligned}
$$

the coefficient of β_2 and β_3 are tested for H1a and H1b, which incorporates two indicators—REC and EGROWTH—as moderator variables. Equation 2 includes two interaction terms—HCARATIO×REC and HCARATIO×EGROWTH—so as to examine the influence of periods of recession and economic expansion on the effect of highly liquid current assets on R&D.

Section 4. Result

4.1. Descriptive statistics

Table 1 (Panel A) presents the descriptive statistics for the explanatory and control variables of interest. Overall, the descriptive statistics for the control variables are similar to those documented in prior research. While year indicators, LEADER, HHI and CONC are available for the full samples; RDEXP, ADVEXP and AISGROWTH are only available for approximately 38, 26 and 61 percent of the observations. The maximum and mean values for RDEXP is 142.1 percent (151175 percent before winsorising, unreported) and 1 percent, respectively, indicating that the amount of R&D spending varies dramatically across firms. Therefore, in the section of additional analysis, this article divides the dependent variable into two sub-samples—firms with RDEXP exceeds 50% quantile and top 5 R&D-intensive industries[6]—testing whether the results are robust given the huge difference of R&D spending across firms.

4.2. Linear correlations

Table 1 (Panel B) shows the correlation matrix among the independent and dependent variables. The correlation between HHI and CONC is 0.858 and statistically significant ($p<0.01$), indicating that industry with higher HHI is also with higher CONC. The correlation between HHI, CONC and other two proxies of market competition are relatively smaller than 0.858 (equal or lesser than 0.07 between ADVEXP and HHI, CONC; 0.15 between LEADER and HHI, CONC), likely because ADVEXP and

[6] Top 5 R&D-intensive industries are determined by total amount of R&D expenditure by industries in North America from 1970 to 2013. To be specific, they are chemical and allied products (2-digit SIC code 28), business services (2-digit SIC code 73), electronic and other electrical equipment and components, except computer equipment (2-digit SIC code 36), measuring, analyzing, and controlling instruments; photographic, medical and optical goods; watches and clocks (2-digit SIC code 38), industrial and commercial machinery and computer equipment (2-digit SIC code 35). The top 5 R&D-intensive industries constitute of approximately 86% of total amount of R&D expenditure from 1970 to 2013.

LEADER capture the aspect of competition among individual firms which is different from the aspect of industry structure. Overall, except for the correlation between HHI and CONC, the absolute value of any other correlations between individual variables are below 0.8, suggesting that the collinearity among individual variables are still within acceptable range.

4.3. Multivariate analyses

Table 2 presents empirical result of equation 1 concerning to H1, H2 and H3, incorporating highly liquid current assets (HCARATIO), four proxies of market competition (ADVEXP, LEADER, HHI and CONC), and average industry sales growth (AISGROWTH) as main variables of interest. This article found empirical evidence that firms holding more highly liquid current assets tend to invest more research and development expenditure. That is, the estimated coefficient β_1 on HCARATIO is positive and statistically significant at 0.01 levels. The t-statistic is 6.41. To provide some perspective on economic significance, a one standard deviation increase in HCARATIO corresponds to an approximate 0.003% increase in RDEXP. These findings are consistent with H1.

Move on to the second hypothesis, predicting that whether firms tend to invest more research and development expenditure under competitive market, the results of four proxies of market competition are inconsistent. Specifically, the estimated coefficients β_4 on HHI and β_5 on CONC—capturing the aspect of industry structure—are both negative and statistically insignificant. On the other hand, the other two proxies—ADVEXP and LEADER—which capture the aspect of competition among individual firms, the estimated coefficients β_2 and β_3 are both positive and statistically significant at 0.01 level. The t-statistics are 13.44 and 5.32, respectively.

Meanwhile, in terms of the economic significance, increasing ADVEXP and LEADER by one standard deviation increases by 0.006% and 0.19%, respectively. Overall, these findings provide an empirical support for H2's prediction that R&D expenditure is positively related to the degree of market competition.

The final test of equation 1 is to verify H3—the prediction that whether growth of market demand by industry is associated with research and development expenditure. The estimated coefficient β_6 on AISGROWTH is negative and statistically significant at 0.01 level, which is opposite to the initial intuition. The t-statistic is -3.85. Therefore, the result suggests that as firms growing bigger resulting from the growth of market demand, managers might, in a wide-angle view, conduct earnings management by the means of slashing R&D expenditure to optimize earnings performance due to more careful overseeing from investors. Thoroughly, the empirical evidence supports H3's prediction that the growth of market demand by industry is negatively associated with R&D expenditure.

Table 3 exhibits further empirical evidence of equation 2 concerning to H1a and H1b, employing two interaction terms—HCARATIO×REC and HCARATIO×EGROWTH, aiming at testing whether the periods of recession and economic expansion influence the relationship between highly liquid current assets and R&D. To be specific, the estimated coefficient β_2 on HCARATIO×REC is positive and statistically significant at 0.01 level; as for HCARATIO×EGROWTH, the estimated coefficient β_3 is negative and statistically insignificant[7]. The t-statistics are 5.48 and -1.55, respectively. Overall, equation 2 provides an empirical proof that the periods of recession not only influence the relationship between highly liquid current assets and R&D, but also reinforce the relationship to be even stronger; yet none supportive

[7] For further inspection, this article revises the definition of EGROWTH as the top 5% of GDP growth to re-run equation 2. The result remains insignificant.

evidence for the influence of economic expansion on the relationship between highly liquid current assets and R&D is found.

Section 5. Additional analyses

5.1. Sensitivity analysis

This article conducts two additional sets of tests, highlighting the impact of highly liquid current assets, the competition among individual firms and growth of market demand by industry on R&D expenditure and the influence of periods of recession on the relationship between highly liquid current assets and R&D expenditure by the means of dividing dependent variable—RDEXP—into two sub-samples. Employing equation 2, Table 4 re-runs the regression with firms above 50% quantile of RDEXP, demonstrated in column (I) and top 5 R&D-intensive industries demonstrated in column (II). As shown in Table 4, compared with main result in Table 3, the estimated coefficients on HCARATIO, HCARATIO×REC, ADVEXP and LEADER in both column maintain positive and statistically significant at 0.01 level; and the estimated coefficient on AISGROWTH in both column maintain negative and statistically significant at 0.05 and 0.10 level, respectively —highlighting that the empirical evidences from the perspective of a variety of industries are consistent with the results of relatively R&D-intensive firms and also indicating that the results aren't affected by non-R&D-intensive industries.

5.2. Concavity analysis

It has already been proven that highly liquid current assets and adverting expenditure have a positive impact on R&D expenditure; however, this article is interested in whether the increasing R&D expenditure through these two variables will saturate at some point. That is, the effect of highly liquid current assets and advertising expenditure start diminishing once firms overinvest and the market becomes over competitive. As a supplemental analysis, this article employs square value of highly liquid current assets (HCARATIO_SQ) and advertising expenditure (ADVEXP_SQ) as additional independent variables to investigate whether the relationship between these two items and R&D expenditure are linear or not. Table 5 exhibits the result of concavity analysis. The estimated coefficients on HCARATIO_SQ and ADVEXP_SQ are both negative and statistically significant at 0.01 level and 0.05 level, respectively, indicating that relationship between these two variables and R&D expenditure are concave rather than linear. Some reasonable explanations are provided for these phenomenon. Firms holding excess cash holdings might not only intend to invest in R&D expenditure, but also looking for potential mergers and acquisitions, depending on firm's growth strategy. In addition, excess cash holdings might also leads to higher agency cost that induces managers to conduct earnings management by means of cutting discretionary spending such as advertising and R&D expenditure, so as to optimize individual performance. As for the relationship between R&D expenditure and degree of market competition, a reasonable explanation is that adequate market competition drives firms to invest more in R&D to gain competitive advantage; however, over competitive market, on average, might negatively affect the firms' financial performance, hence reducing managers' incentive to continuously exert effort.

Due to the vast samples used in this article, it would be infeasible to find out the inflection point, which might be an interesting topic as well; thus, it's decided to leave for future investigation.

5.3. Change analysis

Furthermore, in order to provide some insight on the causal relation between R&D expenditure and determinants of interest, this article examines the lead-lag relation between changes in each determinants and changes in R&D expenditure by employing the following changes specification of equation 2:

$$\begin{aligned}\Delta RDEXP_{it} = \beta_0 &+ \beta_1 \Delta HCARATIO_{it} + \beta_2 \Delta HCARATIO_{it} \times \Delta REC_{it} \\ &+ \beta_3 \Delta HCARATIO_{it} \times \Delta EGROWTH_{it} + \beta_4 \Delta REC_{it} + \beta_5 \Delta EGROWTH_{it} \\ &+ \beta_6 \Delta ADVEXP_{it} + \beta_7 \Delta LEADER_{it} + \beta_8 \Delta HHI_{it} + \beta_9 \Delta CONC_{it} \\ &+ \beta_{10} \Delta AISGROWTH_{it} + \beta_{11} \Delta LRDEXP_{it} + \beta_{12} \Delta SIZE_{it} + \beta_{13} \Delta LOSS_{it} \\ &+ \beta_{14} \Delta LEV_{it} + \varepsilon_{it}\end{aligned}$$

The only two variables that are excluded in equation 3 but exist in equation 2 are INDUS and AGE, as there were no changes in the INDUS status among firms in the sample during the period of this article and the lead-lag relation for firm age is meaningless. Table 6 shows the regression result for equation 3, suggesting that increases in advertising expenditure lead to future increases in R&D expenditure as the coefficient on △ADVEXP remains positive and statistically significant at 0.01 level, whereas △LEADER is statistically insignificant. Therefore, these findings appears that changes in advertising expenditure outweigh changes in the market leadership among firms in explaining future changes in R&D expenditure.

Section 6. Conclusions

6.1. Research results' response to research hypotheses

The existing studies concerning of corporate R&D are extremely few because of the tremendous challenge and difficulty involved; therefore, the existing literature mainly focus their research on individual and specific industry. This article extends research by comprising a variety of industries with a panel of more than 30,000 firm-years of publicly listed North America firms from 1970 to 2013 to investigate the determinants of corporate R&D.

The main findings of this article are as follows. First, firms holding more highly liquid current assets tend to invest more in research and development expenditure, which are consistent with the assumption of H1. In addition, the relationship between highly liquid current assets and research and development expenditure is stronger during the periods of recession. In turn, firms with more highly liquid current assets tend to invest more in research and development expenditure during the periods of recession, which is also consistent with the assumption of H1a; whereas there's no supportive evidence for influence of economic expansion on the relationship. Furthermore, this article found empirical proof that is consistent with H2—firms tend to invest more research and development expenditure as the competition among individual firms increases, whereas found no supportive evidence for the aspect of industrial structure. Finally, the empirical result shows that the growth of market demand by industry is negatively associated with R&D expenditure, which is consistent with assumption of H3.

6.2. Practical implications

One of the aims of this article is to assist managers in establishing effective competitive strategies to counter with competitors in several aspects, such as careful inspection on assets allocation strategies of itself and competitors, particularly during the period of recession and the competition among individual firms. Finally, the result of supplemental analysis suggests that managers should be cautious about adverse effect of overinvesting in highly liquid current assets and entering into an over competitive market.

6.3. Further research and limitations

This work is not without limitations which also constitutes opportunities for future research. First, the sum of cash, cash equivalent and short-term investment from Compustat database doesn't exactly meet the definition of highly liquid current assets from TSE, the result might be more convincing with correct measurement. Second, it's unfortunate that this article isn't able to distinguish the specific stage of industry life cycle and economic condition, which might provide deeper insight into the relationship between the degree of competition and R&D expenditure. Finally, how the different determinants of research and development interact is an unexplored issue which require further research.

Table 1

Descriptive statistics and correlations.

Panel A: descriptive statistics						
Variable	N	Mean	St. Dev.	Min	Median	Max
RDEXP	38,072	0.10	0.21	0	0.03	1.42
HCARATIO	38,072	0.16	0.21	0	0.07	0.95
HCARATIO_SQ	38,072	0.07	0.17	0	0	0.90
REC	38,072	0.14	0.35	0	0	1
EGROWTH	38,072	0.25	0.43	0	0	1
ADVEXP	38,072	0.04	0.06	0	0.02	0.41
ADVEXP_SQ	38,072	0.01	0.02	0	0	0.17
LEADER	38,072	0.03	0.16	0	0	1
HHI	38,072	0.07	0.07	0.01	0.04	0.43
CONC	38,072	0.36	0.18	0.08	0.34	0.87
AISGROWTH	38,072	0.09	0.06	-0.04	0.08	0.29
LRDEXP	38,072	0.10	0.20	0	0.03	1.35
AGE	38,072	11.21	11.30	0	8.00	63.00
SIZE	38,072	4.62	2.66	-1.92	4.57	10.96
LOSS	38,072	0.29	0.45	0	0	1
LEV	38,072	0.30	0.37	0	0.22	2.65

This table (Panel A) presents the descriptive statistics for the variables used in the analyses. See the appendix for specific variable definitions.

Table 1
Descriptive statistics and correlations.

Panel B: Pearson correlation matrix														
	RDEXP	HCARATIO	REC	EGROWTH	ADVEXP	LEADER	HHI	CONC	AISGROWTH	LRDEXP	AGE	SIZE	LOSS	LEV
RDEXP	1													
HCARATIO	0.347	1												
REC	-0.017	-0.043	1											
EGROWTH	-0.055	-0.060	-0.228	1										
ADVEXP	0.076	0.042	-0.002	0.028	1									
LEADER	-0.068	-0.064	0.010	0.011	0.006	1								
HHI	-0.143	-0.049	0.037	0.054	0.044	0.155	1							
CONC	-0.195	-0.029	0.039	0.056	0.071	0.153	0.858	1						
AISGROWTH	-0.088	-0.068	0.105	0.228	0.038	0.009	0.106	0.075	1					
LRDEXP	0.744	0.416	-0.034	-0.065	0.015	-0.070	-0.145	-0.197	-0.095	1				
AGE	-0.153	-0.151	-0.009	-0.042	-0.008	0.168	-0.042	-0.058	-0.114	-0.155	1			
SIZE	-0.321	-0.252	-0.029	-0.075	-0.132	0.243	-0.173	-0.255	-0.046	-0.287	0.406	1		
LOSS	0.347	0.210	0.003	-0.040	0.066	-0.063	0.050	0.110	-0.084	0.318	-0.101	-0.365	1	
LEV	0.177	-0.198	0.016	-0.002	0.044	-0.001	0.029	0.037	0.010	0.110	-0.022	-0.130	0.184	1

Table 2

Determinants of research and development expenditure.

VARIABLES	Dependent variable = $RDEXP_t$
	Equation 1
$HCARATIO_t$	**0.0161^{***}**
	(6.41)
$ADVEXP_t$	**0.0980^{***}**
	(13.44)
$LEADER_t$	**0.0117^{***}**
	(5.32)
HHI_t	-0.0124
	(-0.74)
$CONC_t$	-0.0025
	(-0.28)
$AISGROWTH_t$	**-0.0359^{***}**
	(-3.85)
$LRDEXP_t$	0.7190^{***}
	(192.93)
AGE_t	0.0001^{*}
	(2.37)
$SIZE_t$	-0.0032^{***}
	(-15.06)
$LOSS_t$	0.0147^{***}
	(15.47)
LEV_t	0.0305^{***}
	(22.64)
No. of observations	38,072
Adjusted R^2 (%)	63.42

This table presents an analysis of the relation between research and development expenditure (RDEXP) and different determinants using highly-current assets (HCARATIO), four proxies—advertising expenditure (ADVEXP), industry leader firm (LEADER), Herfinahl-Hirschman Index (HHI) and a portion of sales of four largest firms (CONC)—as independent variables. *,**,*** Indicate significance at the 0.10, 0.05, and 0.01 levels, respectively, using two-tailed tests. All regressions include industry fixed-effects; however, for brevity, these separate intercepts are not reported. See the appendix for specific variable definitions.

Table 3

The moderating effect of periods of recession and economic expansion.

VARIABLES	Dependent variable = $RDEXP_t$
	Equation 2
$HCARATIO_t$	0.0128***
	(4.51)
$HCARATIO_t \times REC_t$	**0.0356*****
	(5.48)
$HCARATIO_t \times EGROWTH_t$	-0.0097
	(-1.55)
REC_t	-0.0012
	(-0.72)
$EGROWTH_t$	-0.0026
	(-1.90)
$ADVEXP_t$	0.0992***
	(13.60)
$LEADER_t$	0.0119***
	(5.43)
HHI_t	-0.0125
	(-0.74)
$CONC_t$	-0.0035
	(-0.38)
$AISGROWTH_t$	-0.0295**
	(-3.01)
$LRDEXP_t$	0.7190***
	(193.11)
AGE_t	0.0001*
	(2.29)
$SIZE_t$	-0.0033***
	(-15.27)
$LOSS_t$	0.0142***
	(14.92)
LEV_t	0.0304***
	(22.60)
No. of observations	38,072
Adjusted R^2 (%)	63.49

This table presents an analysis of the relation between research and development expenditure (RDEXP) and highly-current assets (HCARATIO) with moderating effect of periods of recession (HCARATIO×REC) and economic upturn (HCARATIO×EGROWTH). *, **, *** Indicate significance at the 0.10, 0.05, and 0.01 levels, respectively, using two-tailed tests. All regressions include industry fixed-effects; however, for brevity, these separate intercepts are not reported. See the appendix for specific variable definitions.

Table 4

Determinants of research and development expenditure. Sensitivity analysis.

	Dependent variable = $RDEXP_t$	
	(I)	(II)
$HCARATIO_t$	**0.0189^{***}**	**0.0166^{***}**
	(4.04)	**(4.17)**
$HCARATIO_t \times REC_t$	**0.0389^{***}**	**0.0364^{***}**
	(3.64)	**(3.96)**
$HCARATIO_t \times EGROWTH_t$	0.0006	-0.0082
	(0.06)	(-0.90)
REC_t	-0.0013	0.0006
	(-0.41)	(0.23)
$EGROWTH_t$	-0.0076^{**}	-0.0040
	(-2.67)	(-1.72)
$ADVEXP_t$	**0.1950^{***}**	**0.1530^{***}**
	(13.71)	**(12.89)**
$LEADER_t$	**0.0158^{***}**	**0.0156^{***}**
	(3.43)	**(3.51)**
HHI_t	-0.1050^{*}	-0.0771
	(-2.16)	(-1.69)
$CONC_t$	0.0163	0.0081
	(0.77)	(0.41)
$AISGROWTH_t$	**-0.0681^{**}**	**-0.0400^{*}**
	(-3.04)	**(-2.07)**
$LRDEXP_t$	0.6490^{***}	0.7110^{***}
	(117.09)	(147.78)
AGE_t	0.0003^{**}	0.0001^{*}
	(3.21)	(2.16)
$SIZE_t$	-0.0069^{***}	-0.0041^{***}
	(-17.20)	(-12.47)
$LOSS_t$	0.0233^{***}	0.0214^{***}
	(13.53)	(14.62)
LEV_t	0.0656^{***}	0.0387^{***}
	(27.46)	(19.81)
No. of observations	19,133	23,113
Adjusted R^2 (%)	58.89	60.03

This table presents an analysis of the relation between two sub-sample of research and development expenditure (RDEXP)—firms above 50% quantile of RDEXP in column (I) and top 5 R&D-intensive industries in column (II)—and all determinants. *, **, *** Indicate significance at the 0.10, 0.05, and 0.01 levels, respectively, using two-tailed tests. All regressions include industry fixed-effects; however, for brevity, these separate intercepts are not reported. See the appendix for specific variable definitions.

Table 5

Analysis of concavity of highly-current assets and advertising expenditure.

VARIABLES	Dependent variable = $RDEXP_t$
	Equation 4
$HCARATIO_t$	0.1310^{***}
	(19.36)
$HCARATIO\_SQ_t$	**-0.1700^{***}**
	(-19.15)
$HCARATIO_t \times REC_t$	0.0297^{***}
	(4.58)
$HCARATIO_t \times EGROWTH_t$	-0.0256^{***}
	(-4.09)
REC_t	0.0001
	(0.04)
$EGROWTH_t$	-0.0003
	(-0.23)
$ADVEXP_t$	0.1350^{***}
	(7.59)
$ADVEXP\_SQ_t$	**-0.1380^{**}**
	(-2.60)
$LEADER_t$	0.0127^{***}
	(5.80)
HHI_t	-0.0143
	(-0.86)
$CONC_t$	-0.0041
	(-0.44)
$AISGROWTH_t$	-0.0156
	(-1.59)
$LRDEXP_t$	0.7190^{***}
	(194.07)
AGE_t	0.0001^{**}
	(2.79)
$SIZE_t$	-0.0035^{***}
	(-16.38)
$LOSS_t$	0.0154^{***}
	(16.24)
LEV_t	0.0341^{***}
	(25.20)
No. of observations	38,072
Adjusted R^2 (%)	63.84

This table presents an analysis of concavity of highly-current assets and advertising expenditure using square of highly-current assets (HCARATIO_SQ) and square of advertising expenditure (ADVEXP_SQ) as additional independent variables. *, **, *** Indicate significance at the 0.10, 0.05, and 0.01 levels, respectively, using two-tailed tests. All regressions include industry fixed-effects; however, for brevity, these separate intercepts are not reported. See the appendix for specific variable definition.

Table 6

Changes in research and development expenditure and changes in determinants.

VARIABLES	Dependent variable = $\triangle RDEXP_t$
	Equation 3
$\triangle HCARATIO_t$	-0.0548***
	(-14.77)
$\triangle HCARATIO_t \times REC_t$	-0.0047
	(-0.65)
$\triangle HCARATIO_t \times EGROWTH_t$	0.0016
	(0.17)
$\triangle REC_t$	0.0003
	(0.44)
$\triangle EGROWTH_t$	0.0011
	(1.23)
$\triangle ADVEXP_t$	**0.2160*** **
	(14.43)
$\triangle LEADER_t$	0.0081
	(1.86)
$\triangle HHI_t$	0.0204
	(0.50)
$\triangle CONC_t$	-0.0260
	(-1.32)
$\triangle AISGROWTH_t$	0.0038
	(0.24)
$\triangle LRDEXP_t$	-0.2630***
	(-52.79)
$\triangle SIZE_t$	0.0031***
	(3.67)
$\triangle LOSS_t$	0.0593***
	(27.57)
$\triangle LEV_t$	0.0556***
	(26.50)
No. of observations	32,638
Adjusted R^2 (%)	24.17

This table presents an analysis of the relation between changes in research and development expenditure (△RDEXP) and changes in all determinants. *, **, *** Indicate significance at the 0.10, 0.05, and 0.01 levels, respectively, using two-tailed tests. This is the only regression excludes industry fixed-effects and AGE; however, for brevity, these separate intercepts are not reported. See the appendix for specific variable definitions.

Appendix. Variable definitions

Dependent variable	Variable	Definition
Research and development expenditure	RDEXP	Ratio of research and development expenditure to total assets of the firm
Main explanatory variables	**Variable**	**Definition**
Highly liquid current assets	HCARATIO	Ratio of sum of cash, cash equivalent and short-term investment to total assets of the firm
Herfinahl-Hirschman Index	HHI	Sum of squared market share of all firms in an industry (2-digit SIC)
Four-firm concentration ratio	CONC	A portion of sales of four largest firms in the industry
Advertising expenditure	ADVEXP	Ratio of advertising expenditure to total assets of the firm
Industry leading firm	LEADER	Dummy variable taking the value 1 if the firm is one of the largest four firms in industry in terms of total sales; 0 otherwise
Periods of recession	REC	Dummy variable taking the value 1 if the year is 1970, 1974, 1980, 1982, 1990, 2001 and 2008; 0 otherwise
Periods of economic upturn	EGROWTH	Dummy variable taking the value 1 if the GDP growth of the year is top 25% quantile of GDP growth over the period from 1970 to 2013; 0 otherwise
Average industry sales growth	AISGROWTH	Five-year average sales growth of the industry
Control variables	**Variable**	**Definition**
Lagged research and development expenditure	LRDEXP	Using RDEXP lagged by one year before
Firm age	AGE	Difference between the date of beginning stock data and the date of ending stock data on Compustat database
Firm size	SIZE	Natural logarithm of a firm’s total assets
Loss	LOSS	Dummy variable taking the value 1 if a firm has a loss in the current period; 0 otherwise
Firm leverage	LEV	Ratio of sum of total long- and short-term debt to the total assets
Industry indicator	INDUS	Dummy variable identifying firms which belong to a certain industry (2-digit SIC)

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