R&D and Cash Holdings in Taiwan and China

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Abstract

We study the link between R&D investment and cash holdings for Taiwan and China. The degree of industry competition is included to explore the variation of cash holdings between R&D and non-R&D firms. Besides, we highlight the effect of financing constraints and life cycles to further investigate such link. The empirical results suggest that Taiwanese firms invest more in R&D than do Chinese firms, and R&D firms hold more cash than do non-R&D firms. Moreover, we find that the degree of industrial competition has a positive effect on cash holdings for only Taiwanese R&D firms, suggesting that cash holdings can be used as a support for industrial competition. Finally, we observe that financing constraints and life cycles do not affect the significance of the degree of industrial competition for R&D investment and cash holdings in these two markets.

Keywords: R&D investment, cash holdings, financing constraints, life cycles

JEL Classifications: G30

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1. Introduction

Given the rapid development of science and technology, research and development (R&D hereafter) and innovation have become one of the indispensable assets for enterprises. According to “2017 Survey of Global Top One Thousand Innovative Enterprises” published by PricewaterhouseCoopers (also known as PwC) Taiwan on October 24, 2017, the R&D expenses of the top one thousand innovative companies in the world have reached a record high of $701.6 billion US dollars. Moreover, 31 Taiwanese companies enter the list, with a total R&D expenditure of $398.7 billion New Taiwan Dollars, and their R&D expenditure accounts for 3.1% of the total revenues. Likewise, the Ministry of Science and Technology of Taiwan reports that R&D and innovation investment in Taiwan has been growing fast over time. The overall R&D expenditure as a percentage of gross domestic product (GDP hereafter) has reached 3.16% in 2016, far higher than the 1.72% in 1995.

Not only have Taiwanese companies increased their R&D investment in recent years, but Chinese companies have also realized the importance of R&D investment. A total of 125 Chinese companies are included "2017 Survey of Global Top One Thousand Innovative Enterprises". Among them, Alibaba is on the list for the first time, showing that the R&D capability of China is growing and improving fast. According to the National Bureau of Statistics of China, China’s total R&D expenditure in 2016 has reached 1,567.67 billion RMBs, an increase of 10.6% over 2015 setting a new record high. In addition, the ratio of R&D expenditure to GDP in China is 2.11% in 2016, exceeding 2% for three consecutive years. It is close to the average level of 2.40% in Organization for Economic Co-operation and Development countries and has surpassed the average level of 2.08% in the 15 European Union countries. The intensity of R&D investment of China has reached the level of medium-developed countries and is ranked in the forefront of the emerging countries. China's R&D investment shows a steady upward trend, and its gap with developed countries is narrowing over time.

Amid greater than ever the environmental changes, R&D investment plays a very significant role for enterprise survival. It affects the enterprise competitiveness based on efficient operations and business performance. Green *et al.* (1996) and Sougiannis (1996) point out that R&D investment has a notable impact on corporate development. The higher the R&D investment, the stronger the company’s productivity. Likewise, the better the earnings performance, the higher the corporate value. Lin *et al*. (2012) also state that R&D expenditure is positively associated with operating performance. The empirical result of Chen (2005) also suggests that R&D expenditure can increase corporate value and profitability.

The attention to cash holdings is increasing in recent years. According to Bank of America Merrill Lynch (2017), the top 25 non-financial industries in the United States hold a total of US$1.07 trillion overseas cash, cash equivalents, short-term securities, and investments, of

which Apple, Microsoft, and Google are the top three cash holders with a total of US$533.7 billion. He and Wintoki (2016) point out that the cash holdings of American companies recently have also increased sharply, rising from US$265 billion in 1980 to US$1.5 trillion in 2012. This phenomenon has attracted the attention of business circles and scholars. The same situation also occurs in Taiwan. Due to the rapid changes in economic development in recent years, the industrial competition is more intense and cash holdings is higher, showing the corporate adjustments in capital rationing as well as risk management.

Cash holding is one of the key indicators to measure a company's liquidity. Cash flows can define the survival and development capability of a firm to a large extent. Even if a company is profitable, a state of poor cash flows and scheduling may also affect adversely the company. Likewise, a falling debt solvency can directly affect the credibility that ultimately concludes the survival of a firm. Therefore, the choice of an optimal cash position for a firm has become one of the key issues. If a company holds much cash, it is often regarded as an inefficient manner since the company may overlook the chances of profitable investment and hence likely does not advance its profits. On contrary, holding too little cash may lead to a tight operation status causing more internal cash shortage and inappropriate investment decisions driving up the risk of bankruptcy. Kim *et al.* (1998), Opler *et al.* (1999), and Hoberg *et al.* (2013) all suggest that holding a higher cash position can increase firm value. Mulligan (1997) states that transaction costs are regarded as the most important determinant of the cash position. When a company lacks cash that causes higher marginal costs, it is expected to increase its cash holding. Wang (2004) adopts the research method of Pinkowitz and Williamson (2004) to explore the factors of the value from cash holdings for the samples of Taiwan controlled by industry. He finds that the value of cash holdings in the information and electronics industry is significantly higher than that in the non-information and electronics industry.

For the correlation between R&D investment and cash holdings, Arrow (1962) introduces that due to the uncertainty of the R&D progression and the nature of innovation in R&D that typically requires blocking the key knowledge from the competitors, information asymmetry rises and makes it difficult to finance R&D by external funds. As a result, R&D will mainly use internal funds (Brown *et al.*, 2009). Although the literature provides justifications to the long-term growth of cash holdings, the correlation between R&D investment and cash holdings over time is not comprehensively studied. Bates *et al.* (2009) present evidence that companies increase R&D investment, while Falato *et al.* (2013) show that the intangible capital of R&D limits a firm's debt capacity, thereby reducing financial flexibility. The adjustment cost of R&D investment is more financially binding on high R&D companies, causing the companies hold more preventive cash to smooth R&D investment (Brown and Petersen, 2011). In addition, the domestic and international competition among US firms in the past few decades have intensified, which may incentivize the firms to use cash for business purposes (Frésard, 2010; Lyandres and Palazzo, 2012) or as preventive cash position to ensure their survival. He and

Wintoki (2016) study the long-term growth of cash in total assets for the US companies from 1980 to 2012. They observe that R&D companies are more significant than are non-R&D companies in such growth pattern. R&D investment not only explains the disparity of corporate cash holding policies, but also seems to be a major factor driving the increase in corporate cash holdings for the past three decades. Doukas and Switzer (1992), and Chauvin and Hirschey (1993) find that when a company announces an increase in R&D investment, investors expect that the company will increase future cash flows, which can foster buying sentiment and hence push up stock prices. For this part, we establish hypothesis 1: Cash holdings is positively associated with R&D investment.

Typically, managers should determine their cash holdings based on their operating conditions and industrial competition. In other words, corporate characteristics can shape cash holdings (Opler *et al.*, 1999). Bates *et al.* (2009) provides that corporate characteristics may vary over time and introduce significant consequence in cash holdings. He and Wintoki (2016) show that industrial competition is a key factor in explaining the long-term growth of cash holdings. The intensity of domestic and international competition has increased in the past few decades, and corporate cash holdings has been also steadily rising in the early 1980s in the US. The cash holdings are especially higher in R&D-intensive industries, indicating the use of cash can facilitate the composition of a corporate strategy (Frésard, 2010; Lyandres and Palazzo, 2012). Hoberg *et al.* (2013) find that the increase in cash holdings may help improve corporate competitiveness. From this perspective, we construct hypothesis 2: Given higher industrial competition, cash holdings increase with R&D investment.

Further evaluating the link of R&D investment and cash holdings, we include financing constraints in our analysis. Shen and Wang (2000) present that given information asymmetry, firms must retain more internal funds to cope with future investment because financing units may not be able to comprehend the returns of investment plan and all possible risks. Analyzing the external financing behavior of high-tech companies, Himmelberg and Petersen (1994) demonstrate that information asymmetry develops the market for lemons, which makes it difficult for fund providers to recognize good companies and therefore creating adverse selection problem. Moreover, due to the greater uncertainty and higher risk of R&D investment, the adverse selection problem is more severe for R&D investment than for other types of investment. When a company faces financing constraints, its R&D investment will depend more on internal funds. He and Wintoki (2016) find that generally industrial competition has a positive and significant impact on the R&D companies in the US, regardless of the degree of their financing constraints. However, for the non-R&D companies, they do not increase cash holdings to respond to increasing industrial competition, even if they are subject to financing constraints.

We explore the correlation of R&D investment and cash holding decisions for Taiwan and

Chinese firms. Cash holdings include cash, cash equivalents, and short-term investments. We first investigate the difference in cash holdings between R&D companies and non-R&D companies, and then we study whether R&D investment affects cash holding decisions. The degree of industry competition is further included to explore the variation in cash holdings between R&D companies and non-R&D companies. Finally, financing restriction is added to measure the role of industrial competition for the association of R&D investment and cash holdings.

Since mainland China is Taiwan's largest foreign investment country and largest trade rival, the cross-strait economic relationship has formed a complementary and competitive pattern in the global industrial structure. Based on the frequent economic communications and the R&D competition between Taiwan and mainland China, we collect Taiwanese and Chinese companies to study the hypotheses. The figures show that the R&D investment of Taiwanese companies is much higher than that of Chinese firms, suggesting that Taiwan's R&D investment is more active than China. Moreover, the overall cash holdings have increased over time. Such increase for R&D companies is higher than that for non-R&D firms. R&D companies in the two markets also hold more cash than do non-R&D companies, confirming the work of He and Wintoki (2016). Likewise, the electronic industry has higher cash holdings than the non-electronic industry, which is consistent with Huang (2013) and indicating that companies have begun to focus on R&D activities with the advent of the knowledge age, especially those in the high-tech industries.

To verify whether R&D investment affects cash holdings of a firm, we signify the work of He and Wintoki (2016) using R&D investment as the independent variable and cash holdings as the dependent variable in the regression analysis. The result shows that R&D investment and cash holdings in both markets are significantly positively correlated and that R&D investment is the determinant of cash holdings, which accepts hypothesis 1. It suggests that innovation-oriented companies have more incentives to hold more cash, which is presumably caused by the higher marginal market value of cash for the firms with high R&D focus (Pinkowitz and Williamson, 2007). In addition, we further explore cash changes for the attribution of R&D investment. We employ two facets of corporate characteristics to explain cash changes. The first is the enterprise characteristic variables that significantly change over time, which is called the changing factor of enterprise characteristics. The second is the sensitivity of enterprise characteristic variables to cash holdings that may also change over time, which is called the changing factor of sensitivity. We observe that R&D investment to the increase of cash holdings is 0.27% and 0.77% for Taiwan and China respectively.

To verify the second hypothesis, we include the degree of industrial competition to study the variation of cash holdings between R&D companies and non-R&D companies. The degree of industrial competition is gauged by the Herfindahl-Hirschman Index. It is expected that cash

holdings increase with the degree of industrial competition, as stated in hypothesis 2. We finally add financing constraints and life-cycle factors to explore the effect of industrial competition on the cash holdings of R&D investment. We consider the work of Fazzari *et al*. (1988), Almeida *et al.* (2004), and He and Wintoki (2016) who classify financing constraint by dividend payout rate, firm size, and firm age. Furthermore, we adopt the method of DeAngelo *et al.* (2006) using retained earnings as a percentage of total assets (RE/TA) and retained earnings as a percentage of shareholders' equity (RE/E) to proxy for life cycle. It is projected that cash holdings are correlated to industrial competition to a certain degree, regardless of the variation in financing constraints and life cycles. The results show that, for Taiwanese R&D companies, the role of life cycles is not significant for the association of industrial competition and cash holdings, given diverse financing constraints. For Chinese samples, both financing constraints and life cycles are not significant for the effect of industrial competition on the link between R&D investment and cash holdings, which is consistent with the literature (He and Wintoki, 2016).

The rest of the paper is organized as follows. Section 2 presents research methodology. Section 3 shows the empirical results and section 4 concludes.

2. Research methodology

2.1. Sample selection

The samples are compiled from the database of Taiwan Economic Journal (TEJ) which is one of the most reputable and reliable data providers in Taiwan. We employ the sample firms of Taiwan and China covering the study period of 2006-2016[1]. The Taiwan samples include the firms listed in Taiwan Stock Exchange eliminating TDRs and financial institutions. The China samples are A Shares[2] companies excluding financial, postal, and utility firms. The sample size is 23,107 for Taiwan and 21,748 for China. We winsorize the 1% outliers.

2.2. Variable definition

This article refers to the literature using cash in total assets to measure cash holdings. Cash is defined as the sum of cash, cash equivalents, and short-term investments. We also use the ratio of cash to net operating income as a measure of cash holdings. To measure the degree of R&D investment, we employ the following three variables. The first is R&D-to-assets that is defined as R&D expenditure divided by total assets. The second is R&D-to-sales that divides R&D expenditure by net operating income (net sales income) for Taiwanese (Chinese) samples. The last one is R&D dummy variable. If a company's R&D expenditure in the current year is greater than (equal to) 0, R&D dummy is set to 1 (0).

[1] We also extend the study period to 1991-2016 for Taiwan samples.
[2] Also known as domestic shares denominated in Renminbi (Chinese yuan) and traded in the Shanghai and Shenzhen Stock Exchanges.

To further explore the association between R&D investment and cash holdings, we separate the samples into R&D companies and non-R&D companies. If a company's R&D expenditure in the current year is greater than (equal to) 0, it is grouped as a R&D company (non-R&D company). The definitions and explanations for all the variables are organized and presented in Table 1.

2.2.1. Industrial competition

We employ Herfindahl-Hirschman Index (HHI hereafter) to gauge the degree of industrial competition. Giroud and Mueller (2010) pointed out that HHI is a widely used and reasonable index to measure industrial competition. A higher HHI value indicates a higher degree of the market concentration suggesting that the industry is less competitive, and vice versa. The equation of HHI is illustrated as follows:

$$HHI_{j,t} = \sum_{t=1}^{n} \left(\frac{X_{ijt}}{X_{jt}}\right)^2. \quad (1)$$

$$X_{j,t} = \sum_{i=1}^{n} X_{ijt}. \quad (2)$$

Where $HHI_{j,t}$ is the degree of industrial concentration for industry j at time t, $X_{j,t}$ is the sales for industry j at time t, X_{ijt} indicates firm i in industry j at time t. The classification on industries is based on the method of Taiwan Stock Exchange (for Taiwanese samples) and China Securities Regulatory Commission (for Chinese samples). We set that HHI_adj = 1-HHI by which HHI_adj increases with the degree of industrial competition. We also create the dummy for HHI as HHI_Dummy that is 1 (0) for high (low) competition industry if HHI_adj is higher than the median.

2.2.2. Financing constraints

The well-knows indicators for measuring the degree of financing constraints include dividend payout ratio introduced by Fazzari *et al*. (1988), KZ-Index of Kaplan and Zingales (1997), WW-Index of Whited and Wu (2006), asset size, firm age, ownership concentration, ranking of corporate debt or commercial papers, and so forth. We apply the methods of He and Wintoki (2016), Fazzari *et al*. (1988), and Almeida *et al.* (2004) using dividend payout ratio, firm size, and firm age to gauge the degree of financing constraints. If such employed variable is higher (lower) than its median, it is classified as no (with) financing constraint.

2.2.3. Life cycle

We use retained earnings as a percentage of total assets (RE/TA) and retained earnings as a percentage of shareholders' equity (RE/E) to proxy for life cycle, according to the classification method of DeAngelo *et al.* (2006). If such a variable is higher (lower) than its median, the firm is defined as a mature (young) company, otherwise it is a young company. DeAngelo *et al.* (2006) pointed out that when a firm's RE/TA or RE/E is lower (higher), it may reflect that the firm is in the initial stage with larger (smaller) capital investment. At this time, the company's overall resources may be relatively tight (relaxed), so its dividend distribution is typically lower (higher).

Table 1. Variable definitions

Symbol	Variable title	Variable definition (and/or computation)
Cash holdings		
Cash-to-assets	Ratio of cash to total assets	(cash + cash equivalents + short-term investment)/total assets
Cash-to-sales	Ratio of cash to sales	(cash + cash equivalents + short-term investment)/sales
R&D investment		
R&D-to-assets	Ratio of R&D to total assets	R&D expenses/total assets
R&D-to-sales	Ratio of R&D to sales	R&D expenses/sales
R&D dummy	The dummy for R&D investment	1 if R&D expenses is larger than 0 and 0 otherwise.
Industrial competition		
HHI_adj	The magnitude of industrial competition	HHI_adj = 1-HHI. HHI is Herfindahl-Hirschman Index.
HHI_Dummy	The dummy for industrial competition	1 if HHI_adj is larger than median and 0 otherwise.
Financing constraints		
Payout ratio	Dividend payout ratio	Dividend/total assets. No (with) financing constraints if it is larger (smaller) than median.
Size	Firm size	LN(total assets). No (with) financing constraints if it is larger (smaller) than median.
Age	Firm age	Years from IPO. No (with) financing constraints if it is larger (smaller) than median.
Life cycles		
RE/TA	Ratio of retained earnings to total assets	Retained earnings/total assets. Mature (young) company if it is larger than median.
RE/E	Ratio of retained earnings to equity	Retained earnings/total equity. Mature (young) company if it is larger than median.
Firm characteristics		
Industry CF volatility	The volatility of industry cash flows	The standard deviation of cash flows over 5-years period by industry
CF	Common size cash flows	(operating income+depreciation-interest-taxes)/total assets
NWC	Common size net working capital	(current assets-current liability)-(cash and cash equivalents+short term investment)/total assets
Leverage	Common size debt ratio	(long term debt+short term debt)/total assets
MB	Market-to-book ratio	(debt+market value of equity)/total assets
Dividend payment dummy	The dummy for dividend payment	1 if paying dividend and 0 otherwise
CAPEX	Capital expenditure	Real assets purchase/total assets

2.3. The research model

2.3.1. R&D investment vs. cash holdings

We study whether R&D investment affects corporate cash holdings. We divide the samples into R&D companies and non-R&D companies, compares their mean and median numbers, and explores their firm characteristics. To measure the association between R&D investment and cash holdings, we refer to the research of He and Wintoki (2016) and establish equation (3) as follows.

$$Cash_{i,t} = \alpha_t + \beta_0 * R\&D\_to\_assets_{i,t} + \beta_1 * X_{i,t-1} + \epsilon_{i,t} + \gamma_j + d_t. \quad (3)$$

Where $Cash_{i,t}$ is the cash holding of firm i at time t. $R\&D\_to\_assets_{i,t-1}$ denotes R&D investment relative to assets of firm i at time t-1. $X_{i,t-1}$ indicates the explanatory variables used in the work of Bates *et al.* (2009) including industrial cash flow volatility, cash flows, net operating capital, firm size, debt ratio, book-to-market ratio, the dummy for dividend payout, and capital expenditures. $\epsilon_{i,t}$ is the error term, γ_j represents the fixed effect of industry, and d_t is the fixed effect of time. To further investigate corporate characteristics for the cash holdings of R&D companies and non-R&D companies, we later replace R&D_to_assets by R&D_Dummy that highlight the separation of R&D and non-R&D firms.

2.3.2 The R&D investment attribution

We employ the work of He and Wintoki (2016) using the following two aspects of firm characteristics to explain the changes in cash holdings. The first is the changing factor of firm characteristics in which firm characteristics significantly change over time. The second is that the sensitivity of firm characteristics to cash holdings may change over time, which is called the changing sensitivity. Equation (4) and (5) illustrate the relationship.

$$\Delta Cash_{changingfactor} = \beta_{2006-2010} * [X_{2011-2016} - X_{2006-2010}]. \quad (4)$$

$$\Delta Cash_{changing\ sensitivity} = [\beta_{2011-2016} - \beta_{2006-2010}] * X_{2006-2010}. \quad (5)$$

Where $\Delta Cash_{changingfactor}$ ($\Delta Cash_{changing\ sensitivity}$) is the changing factor (changing sensitivity) for firm characteristics and X denotes firm characteristics. The subscripts "2006-2010" denotes the time period from 2006 to 2010.

2.3.3. The role of industrial competition

If a firm stores cash as a preparation for industry competition, or as a way to ensure its survival in an economic downturn, then competition can directly affect cash holdings (Telser, 1966; Frésard, 2010). We use Herfindahl-Hirschman Index to proxy for the degree of industrial competition in this research. It is conjectured that cash holdings increases with the degree of industry competition. Equation (6) is built to test such association.

$$Cash_{i,t} = \alpha + \beta_0 HHI\_dummy_{i,t-1} + \beta_1 * X_{i,t-1} + \epsilon_{i,t} + \gamma_j + d_t. \quad (6)$$

Where $HHI\_dummy_{i,t-1}$ is the dummy to indicate industrial competition for firm i at

time t. It is 1 (0) for firms of high (low) competition if their HHI are higher (lower) than the median. A firm with higher competition may thus hold more cash for the changing future so β_0 is expected to be positive.

2.3.4. The role of financing constraints and life cycles

We include factors that proxy for financing constrains and life cycles in equation (6). It is conjectured that the association between industrial competition and cash holdings holds regardless of the variation of financing constraints and life cycles.

3. The empirical results

3.1. Descriptive statistics Table 1 explains the variable definitions and Table 2 shows the descriptive statistics. The mean ratio of cash to assets is 0.1811 for Taiwanese firms and 0.1838 for Chinese firms. The mean R&D-to-assets is 0.0213 for Taiwanese firms which is about 10% higher than that of Chinese firms at 0.0118. Moreover, the mean value of R&D-to-sales for Taiwanese firms is also higher than that of Chinese firms. The median of R&D-to-assets is much smaller than its mean value for both markets, proposing the large variation of R&D investment. There is no significant difference in firm size and firm age between both markets.

Table 3 presents the descriptive statistics separated by R&D and non-R&D firms. The number of Taiwanese R&D firms (non-R&D firms) is 16176 (6931), while it is 13200 (8548) for Chinese R&D firms (non-R&D firms). The difference between mean and median is significant for R&D and non-R&D firms in these two markets. The mean assets value of Taiwan R&D firms (non-R&D firms) is 14.6 billions (14.8 billions) New Taiwan Dollars (NTD hereafter). The mean assets value of Chinese R&D firms (non-R&D firms) is 8.8 billions (8.7 billions) Renminbi (RMB hereafter), which is opposite to the figures of Taiwanese firms. Moreover, the mean cash holdings of Taiwanese R&D firms (non-R&D firms) is 2.46 billions (1.6 billions) NTD and it is 0.56 billions (0.39 billions) NTD for the median. For the Chinese R&D firms (non-R&D firms), the mean is 1.33 billions (1.14 billions) RMB and its median is 0.47 billions (0.36 billions) RMB. It shows that R&D firms tend to hold more cash than do non-R&D firms.

For the ratio of cash to total assets, the mean of Taiwanese R&D firms (non-R&D firms) is 0.203 (0.13) and the median is 0.164 (0.089). The mean of Chinese R&D firms (non-R&D firms) is 0.20 (0.16) and the median is 0.16 (0.12). The numbers reveal that R&D firms in the two markets have a higher ratio of cash to total assets than that of non-R&D firms. As for the ratio of R&D to total assets, the average number of R&D firms in Taiwan (China) is 0.030 (0.019) and the median is 0.017 (0.016), indicating that Taiwanese R&D firms have higher R&D investment than do Chinese R&D firms. Finally, R&D firms in Taiwan and China appear to have higher cash volatility, higher net liquidity, higher market-to-net value ratio, and lower debt ratio than do non-R&D companies.

Table 2. Descriptive statistics for Taiwan and China

	Taiwan					China				
Variable	Mean	Median	25%	75%	S.D.	Mean	Median	25%	75%	S.D.
Assets (mil)	14720.59	3827.32	1732.43	9671.77	39247.97	8795.99	2770.08	1298.32	6672.26	20530.48
Cash(mil)	2206.65	511.93	196.35	1422.01	6242.72	1260.29	437.29	191.25	1028.52	2805.65
Cash-to-assets	0.181	0.139	0.067	0.254	0.150	0.184	0.146	0.088	0.241	0.136
Cash-to-sales	0.313	0.176	0.084	0.356	0.443	0.455	0.267	0.143	0.529	0.563
R&D-to-assets	0.021	0.008	0.000	0.027	0.034	0.012	0.003	0.000	0.019	0.017
R&D-to-sales	0.030	0.010	0.000	0.033	0.057	0.023	0.005	0.000	0.036	0.037
R&D dummy	0.700	1.000	0.000	1.000	0.458	0.607	1.000	0.000	1.000	0.488
HHI_adj	0.846	0.887	0.822	0.926	0.153	0.885	0.923	0.867	0.953	0.126
Payout ratio	0.378	0.291	0.000	0.682	0.424	0.243	0.174	0.000	0.357	0.297
Size (ln assets)	8.417	8.250	7.457	9.177	1.353	8.073	7.927	7.169	8.806	1.275
Age	11.353	10.000	5.000	15.000	8.690	10.514	10.000	5.000	15.000	6.078
RE/TA	0.070	0.093	0.019	0.175	0.210	0.098	0.138	0.066	0.218	0.297
RE/E	0.073	0.171	0.040	0.297	0.536	0.171	0.275	0.157	0.398	0.696
Industry CF volatility	0.041	0.040	0.030	0.050	0.014	0.040	0.036	0.029	0.044	0.019
CF	0.054	0.053	0.014	0.098	0.079	0.038	0.037	0.008	0.070	0.059
NWC	0.062	0.060	-0.031	0.160	0.158	-0.010	0.001	-0.143	0.141	0.224
Leverage	0.200	0.183	0.056	0.313	0.161	0.201	0.178	0.046	0.318	0.171
MB	1.406	1.158	0.925	1.612	0.765	2.671	2.003	1.372	3.169	2.061
Dividend pay dummy	0.586	1.000	0.000	1.000	0.493	0.648	1.000	0.000	1.000	0.478
CAPEX	0.047	0.028	0.009	0.065	0.054	0.054	0.039	0.015	0.076	0.052

Table 3. Descriptive statistics for R&D and non-R&D samples

Panel A. Taiwan

	R&D firms			Non-R&D firms			R&D minus non-R&D	
Variable	Mean	Median	S.D.	Mean	Median	S.D.	Mean	Median
Assets (mil)	14681.85	3475.84	40675.46	14811.02	4822.05	35697.64	-129.17	-1346.22***
Cash(mil)	2465.45	563.63	6833.96	1602.64	395.06	4517.76	862.81***	168.57***
Cash-to-assets	0.203	0.164	0.153	0.130	0.089	0.127	0.073***	0.075***
Cash-to-sales	0.318	0.194	0.413	0.301	0.135	0.506	0.016**	0.059***
R&D-to-assets	0.030	0.017	0.038	0.000	0.000	0.000	0.030***	0.017***
R&D-to-sales	0.043	0.022	0.064	0.000	0.000	0.000	0.043***	0.022***
HHI_adj	0.848	0.891	0.155	0.840	0.867	0.149	0.008***	0.028***
Payout ratio	0.402	0.359	0.423	0.320	0.000	0.421	0.082***	0.359***
Size (ln assets)	8.351	8.154	1.365	8.571	8.481	1.313	-0.220***	-0.327***
Age	10.437	9.000	7.826	13.490	11.000	10.114	-3.054***	-2.000***
RE/TA	0.081	0.105	0.214	0.044	0.070	0.199	0.037***	0.035***
RE/E	0.091	0.184	0.523	0.031	0.143	0.563	0.060***	0.042***
Industry CF volatility	0.043	0.041	0.013	0.037	0.034	0.013	0.005***	0.007***
CF	0.060	0.062	0.084	0.039	0.037	0.065	0.021***	0.025***
NWC	0.070	0.070	0.144	0.042	0.028	0.186	0.028***	0.042***
Leverage	0.182	0.163	0.151	0.244	0.239	0.175	-0.062***	-0.076***
MB	1.447	1.188	0.801	1.310	1.098	0.663	0.137***	0.090***
Dividend pay dummy	0.623	1.000	0.485	0.500	0.000	0.500	0.123***	1.000***
CAPEX	0.050	0.032	0.054	0.039	0.019	0.053	0.011***	0.013***

Note: ***, **, and * denote 1%, 5%, and 10% significance respectively.

Table 3 continued

Panel B. China

	R&D firms			Non-R&D firms			R&D minus non-R&D	
Variable	Mean	Median	S.D.	Mean	Median	S.D.	Mean	Median
Assets (mil)	8821.17	2777.63	20491.13	8757.12	2748.40	20592.23	64.05	29.24***
Cash(mil)	1332.66	476.16	2921.43	1148.55	366.88	2613.07	184.11***	109.28***
Cash-to-assets	0.202	0.161	0.142	0.156	0.124	0.122	0.046***	0.037***
Cash-to-sales	0.466	0.285	0.539	0.439	0.243	0.597	0.027***	0.042***
R&D-to-assets	0.019	0.016	0.018	0.000	0.000	0.000	0.019***	0.016***
R&D-to-sales	0.039	0.031	0.040	0.000	0.000	0.000	0.039***	0.031***
HHI_adj	0.898	0.929	0.106	0.866	0.914	0.149	0.031***	0.015***
Payout ratio	0.273	0.213	0.304	0.198	0.077	0.281	0.074***	0.136***
Size (ln assets)	8.109	7.929	1.226	8.016	7.919	1.345	0.093***	0.011***
Age	9.389	7.000	6.291	12.250	12.000	5.283	-2.861***	-5***
RE/TA	0.149	0.158	0.204	0.019	0.103	0.388	0.13***	0.055***
RE/E	0.225	0.284	0.523	0.088	0.257	0.894	0.136***	0.028***
Industry CF volatility	0.038	0.036	0.014	0.042	0.037	0.024	-0.004***	-0.001***
CF	0.045	0.043	0.054	0.027	0.027	0.064	0.018***	0.016***
NWC	0.032	0.045	0.197	-0.074	-0.074	0.247	0.105***	0.119***
Leverage	0.173	0.142	0.158	0.245	0.236	0.180	-0.072***	-0.095***
MB	2.871	2.228	2.022	2.361	1.663	2.081	0.51***	0.564***
Dividend pay dummy	0.726	1.000	0.446	0.528	1.000	0.499	0.197***	0***
CAPEX	0.057	0.043	0.050	0.050	0.031	0.056	0.007***	0.012***

Note: ***, **, and * denote 1%, 5%, and 10% significance respectively.

Table 4 presents the mean cash holdings of the sample firms of the two markets by year. The mean (median) ratio of cash to total assets of Taiwanese companies in 2006 is 0.1712 (0.1312). In 2016, the mean (median) rises to 0.2356 (0.2029). The mean (median) ratio cash to total assets of Taiwanese electronics firms is 0.2335 (0.1957), which is about 10% higher than of the non-electronics firms. The result shows that the cash holdings of Taiwanese companies have steadily increased overtime, and the cash holdings of the electronics industry is higher than that of the non-electronics industry. Moreover, the mean (median) of cash to total assets of Chinese companies in 2006 is 0.1385 (0.1145). In 2016, the mean (median) is 0.1830 (0.1506). In 2011, it reaches its peak at mean (median) of 0.2218 (0.1674). Although the Chinese firm size has increased over time after 2011, which causes a downward trend to the ratio of cash to total assets. However, it is still higher than that in 2006. The mean (median) cash holdings of Chinese electronics industry is 0.2499 (0.2099), which is about 8% higher than that of the non-electronics industry. With the advent of the knowledge era, companies have begun to pay more attention to R&D activities, especially in high-tech industries. Huang (2013) studies Taiwanese electronics industry for the impact of innovation efficiency on company value. He suggests that high-tech industries in the process of engaging in innovation activities should devote to the accumulation of R&D capital and pay more attention to the improvement of innovation efficiency, so that innovation can enhance the firm value.

Table 4. The cash holdings for Taiwan and China

Year	Taiwan					China				
		cash/assets		cash/sales			cash/assets		cash/sales	
	N	mean	median	mean	median	N	mean	median	mean	median
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
2006	1139	0.1712	0.1312	0.2622	0.1452	1259	0.1385	0.1145	0.3065	0.1846
2007	1171	0.1806	0.1357	0.2779	0.1537	1350	0.1497	0.1207	0.3283	0.1930
2008	1185	0.1847	0.1428	0.2697	0.1546	1443	0.1558	0.1274	0.3365	0.2030
2009	1230	0.2126	0.1712	0.3508	0.2216	1500	0.1786	0.1512	0.4116	0.2536
2010	1251	0.2143	0.1772	0.3280	0.1980	1653	0.2047	0.1615	0.4801	0.2649
2011	1302	0.2128	0.1727	0.3491	0.2078	2011	0.2218	0.1674	0.5417	0.2807
2012	1343	0.2215	0.1812	0.3831	0.2201	2246	0.2140	0.1686	0.5237	0.3033
2013	1387	0.2232	0.1862	0.4054	0.2425	2387	0.1964	0.1566	0.4885	0.2894
2014	1414	0.2229	0.1884	0.4337	0.2479	2439	0.1728	0.1373	0.4322	0.2654
2015	1449	0.2319	0.1988	0.4507	0.2700	2531	0.1724	0.1407	0.4798	0.2990
2016	1478	0.2356	0.2029	0.4673	0.2845	2929	0.1830	0.1506	0.5046	0.3295
Total	23107	0.1811	0.1393	0.3127	0.1764	21748	0.1838	0.1462	0.4554	0.2673
2006-2010 (1)	5976	0.1933	0.1509	0.2988	0.1742	7205	0.1676	0.1351	0.3783	0.2215
2011-2016 (2)	8373	0.2250	0.1884	0.4166	0.2473	14543	0.1918	0.1521	0.4936	0.2959
Diff (2)-(1)		0.0317***	0.0376***	0.1179***	0.0731***		0.0242***	0.0170***	0.1153***	0.0743***
Non-electronics (3)	12133	0.1338	0.0960	0.2910	0.1394	18694	0.1730	0.1387	0.4256	0.2531
Electronics (4)	10974	0.2335	0.1957	0.3367	0.2220	3054	0.2499	0.2099	0.6380	0.3966
Diff (4)-(3)		0.0997***	0.0997***	0.0457***	0.0826***		0.0769***	0.0712***	0.2124***	0.1435***

Note: ***, **, and * denote 1%, 5%, and 10% significance respectively.

3.2. The variation of cash holdings by firm type

Table 5 presents the association of R&D investment and cash holdings. The variation of cash to total assets between R&D firms and non-R&D firms is highlighted. For Taiwanese R&D firms, the mean (median) in 2006 is 0.19 (0.14), which is 0.13 (0.10) for non-R&D firms. In 2016, it is 0.25 (0.22) for R&D firms and 0.18 (0.15) for non-R&D firms, showing the increasing pattern. For Chinese R&D firms, the mean (median) is 0.21 (0.20) in 2006. Non-R&D firms' mean (median) is 0.14 (0.11). In 2016, the mean (median) of R&D firms is 0.19 (0.15). For non-R&D firms, the mean (median) becomes 0.17 (0.14). The ratio decreases (increases) for R&D firms (non-R&D firms), which may be due to the smaller sample size of the R&D firms at the earlier stage when R&D is not very focused in China.

The cash-to-total asset ratio of Taiwanese R&D firms increases by 3% in 2009, and its deviation from that non-R&D firms is the largest this year. It is conjectured that during the 2008 financial crisis causing economic losses worldwide, firms realize the importance of preventive motivation that can maintain normal operations and sufficient resources. As a result, their cash holdings tend to increase around the financial crisis. However, the cash-to-total asset ratio of Chinese R&D firms fall by 2% in 2009 and declines in the subsequent years. It is considered that the Chinese firm size has gradually increased in recent years, and the growth rate of cash holdings is not as fast as the firm size. As a result, the ratio of cash to total assets decreases over time. Overall, Taiwanese R&D firms have significantly higher cash holdings than Chinese R&D firms, but there is no significant difference between non-R&D firms in the two markets.

Table 5. R&D investment and cash holdings by years

Panel A. Taiwan

Year	R&D firms			Non-R&D firms			Diff-in-means	Diff-in-medians	R&D-to-assets		R&D_dummy	
		cash/assets			cash/assets							
	N	mean	median	N	mean	median			β	t-stat.	β	t-stat.
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(11)	(12)	(9)	(10)
2006	836	0.1861	0.1472	303	0.1301	0.0985	0.0560***	0.0487***	0.2604	2.27	0.0129	1.56
2007	874	0.1976	0.1536	297	0.1306	0.0940	0.0670***	0.0596***	0.2527	2.09	0.0204	2.28
2008	889	0.2023	0.1611	296	0.1318	0.0924	0.0706***	0.0687***	0.5525	5.05	0.0209	2.24
2009	931	0.2307	0.1931	299	0.1564	0.1192	0.0742***	0.0739***	0.4884	4.03	0.0185	1.92
2010	952	0.2300	0.1915	299	0.1643	0.1228	0.0657***	0.0687***	0.3734	3.25	0.0185	2.01
2011	991	0.2275	0.1887	311	0.1660	0.1248	0.0615***	0.0638***	0.4716	4.29	0.0219	2.31
2012	1023	0.2351	0.1936	320	0.1782	0.1328	0.0569***	0.0608***	0.3858	3.62	0.0200	2.06
2013	1067	0.2369	0.1965	320	0.1777	0.1396	0.0592***	0.0570***	0.4118	3.93	0.0073	0.72
2014	1094	0.2355	0.2042	320	0.1798	0.1404	0.0557***	0.0637***	0.4607	4.41	0.0027	0.27
2015	1127	0.2470	0.2165	322	0.1789	0.1403	0.0682***	0.0763***	0.4381	4.24	0.0100	1.01
2016	1147	0.2521	0.2234	331	0.1781	0.1476	0.0740***	0.0758***	0.6890	7.01	0.0247	2.54
2006-2010	4482	0.2101	0.1692	1494	0.1426	0.1049	0.0675***	0.0642***	0.4021	7.84	0.0184	4.55
2011-2016	6449	0.2394	0.2037	1924	0.1765	0.1369	0.0629***	0.0668***	0.4812	11.4	0.0142	3.58
Total	16176	0.2031	0.1635	6931	0.1300	0.0887	0.0731***	0.0749***	0.5207	19.41	0.0102	5.24

Note: ***, **, and * denote 1%, 5%, and 10% significance respectively.

Table 5 continued

Panel B. China

Year	R&D firms			Non-R&D firms			Diff-in-means	Diff-in-medians	R&D-to-assets		R&D_dummy	
		cash/assets			cash/assets							
	N	mean	median	N	mean	median			β	t-stat.	β	t-stat.
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(11)	(12)	(9)	(10)
2006	16	0.2100	0.2008	1243	0.1376	0.1128	0.0724***	0.0880***	0.3671	0.49	0.0347	1.38
2007	76	0.2352	0.2093	1274	0.1446	0.1169	0.0906***	0.0923***	1.8901	4.67	0.0670	5.33
2008	188	0.2180	0.1701	1255	0.1464	0.1214	0.0716***	0.0487***	1.6172	5.56	0.0460	5.27
2009	754	0.1943	0.1683	746	0.1627	0.1300	0.0316***	0.0383***	1.0232	3.63	0.0177	2.59
2010	950	0.2256	0.1791	703	0.1764	0.1366	0.0492***	0.0425***	0.7084	2.37	0.0171	2.18
2011	1291	0.2517	0.1964	720	0.1681	0.1306	0.0835***	0.0658***	0.6022	2.47	0.0391	5.13
2012	1695	0.2296	0.1823	551	0.1659	0.1315	0.0637***	0.0508***	0.1472	0.72	0.0287	3.54
2013	1858	0.2057	0.1673	529	0.1636	0.1257	0.0421***	0.0416***	0.3764	2.56	0.0324	4.29
2014	1905	0.1790	0.1442	534	0.1508	0.1148	0.0282***	0.0295***	0.6432	3.84	0.0115	1.62
2015	2037	0.1749	0.1445	494	0.1622	0.1228	0.0126**	0.0217***	0.3480	2.1	0.0026	0.35
2016	2430	0.1850	0.1538	499	0.1737	0.1390	0.0112*	0.0148***	0.5007	3.04	0.0049	0.67
2006-2010	1984	0.2132	0.1738	5221	0.1502	0.1212	0.0630***	0.0526***	1.2194	8.69	0.0266	7.18
2011-2016	11216	0.2000	0.1589	3327	0.1642	0.1275	0.0357***	0.0314***	0.4437	6.11	0.0238	7.76
Total	13200	0.2020	0.1612	8548	0.1557	0.1238	0.0463***	0.0374***	0.5181	8.34	0.0224	9.68

Note: ***, **, and * denote 1%, 5%, and 10% significance respectively.

To study the effect of R&D investment on cash holdings over time, we employ regression analysis for each year. R&D-to-assets is employed as explanatory variable. We observe that Taiwanese R&D firms hold 0.26 more NTDs for every one NTD R&D investment in 2006. It increases to 0.68 NTDs in 2016. For Chinese firms, it is 0.36 RMBs in 2006 and 0.5 in 2016. It declines after 2007, possibly due to the bias of smaller sample size in 2006. In addition, the firm size of Chinese firms increases faster than do their cash holdings. The overall result shows an increasing effect of R&D investment on cash holdings in both markets, but the effect is stronger over time for Taiwanese firms. Moreover, controlling for firm characteristics, we find that the sensitivity of R&D investment to cash holdings increases from 1.29% in 2006 to 2.47% in 2016. The Chinese firms show a decreasing pattern from 3.47% in 2006 to 0.49% in 2016 (ps. column 11 and 12).

3.3. R&D investment and cash holdings

Table 6 displays the regression result of cash holdings on R&D investment. The dependent variable is cash-to-assets. Three independent variables are given as follows: column 1 shows R&D-to-assets, column 2 is R&D-to-sales, and column 3 denotes the dummy for R&D firms (R&D dummy). R&D investment and cash holdings in the two markets are significantly positively correlated, indicating that R&D investment is the determinant of increasing cash holdings, supporting Hypothesis 1. Cash flows and cash holdings are also significantly positively correlated while net working capital is significantly negatively correlated with cash holdings. Firm size is significantly negatively correlated with cash holdings, proposing that when a company gets bigger, it tends not to hold much cash. The debt ratio is significantly negatively correlated with cash holdings, indicating that as a company has less debt, it can hold more cash. There is a significant positive correlation between dividend payment and cash holdings, introducing that the more cash a company holds, the more capable it can distribute dividends to shareholders. Furthermore, capital expenditure is significantly negatively associated with cash holdings. The results support that companies with high R&D investment have stronger incentives to hold more cash. In general, the empirical results are consistent with the literature. Companies with high R&D investment will have a stronger incentive to hold more cash in order to maintain the level of R&D investment. It is also presumably introduced by the higher marginal market value of cash in R&D-intensive industries (Pinkowitz and Williamson, 2007).

Table 6. Regression results

Dependent variable: Cash-to-assets$_t$	Taiwan			China		
	(1)	(2)	(3)	(4)	(5)	(6)
R&D-to-assets$_{t-1}$	0.525***			0.431***		
	(18.18)			(6.68)		
R&D-to-sales$_{t-1}$		0.393***			0.506***	
		(22.83)			(16.95)	
R&D dummy$_{t-1}$			0.009***			0.014***
			(4.26)			(5.95)
Industry CF volatility$_{t-1}$	0.116	0.065	0.023	0.000	0.000	0.000
	(1.15)	(0.65)	(0.22)	(-0.05)	(-0.18)	(-0.05)
CF$_{t-1}$	0.172***	0.217***	0.128***	0.297***	0.321***	0.304***
	(12.59)	(15.56)	(9.5)	(16.18)	(17.63)	(16.59)
NWC$_{t-1}$	-0.188***	-0.182***	-0.186***	-0.107***	-0.113***	-0.107***
	(-32.77)	(-31.93)	(-32.18)	(-22.37)	(-23.76)	(-22.3)
Size$_{t-1}$	-0.009***	-0.009***	-0.011***	-0.004***	-0.004***	-0.005***
	(-14.7)	(-14.92)	(-16.57)	(-4.64)	(-4.09)	(-5.05)
Leverage$_{t-1}$	-0.311***	-0.305***	-0.324***	-0.203***	-0.197***	-0.205***
	(-51.95)	(-51.26)	(-54.3)	(-31.01)	(-30.13)	(-31.32)
MB$_{t-1}$	0.026***	0.025***	0.031***	0.004	0.004***	0.005***
	(20.86)	(19.72)	(25.05)	(7.48)	(6.29)	(8.18)
Dividend pay dummy$_{t-1}$	0.017***	0.018***	0.018***	0.023	0.021***	0.023***
	(8.58)	(9.16)	(9.11)	(11.53)	(10.66)	(11.7)
CAPEX$_{t-1}$	-0.382***	-0.397***	-0.400***	-0.273***	-0.299***	-0.273***
	(-24.52)	(-25.61)	(-25.45)	(-16.36)	(-17.9)	(-16.3)
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
N	21,285	21,285	21,285	18,671	18,671	18,671
Adjusted R^2	0.4543	0.4591	0.4463	0.2535	0.2631	0.2532

Note: ***, **, and * denote 1%, 5%, and 10% significance respectively.

3.4. The attribute of R&D investment

Although the effect of R&D on cash holdings has increased since the past, it is still unclear how much of the increase in the overall cash holdings of Taiwanese and Chinese firms during the study period is introduced by R&D investment. We adopt the method of He and Wintoki (2016) to disassemble cash changes in two dimensions and explore the effect of R&D investment. The average R&D-to-assets of Taiwanese companies in column (5) of Table 7 is 2.4% from 2006 to 2010. From 2011 to 2016, the ratio increases by 0.3% to 2.7%. If $\beta_{2006\text{-}2010}$ is 0.426 and remains unchanged until 2016, then the calculated change factor of firm characteristics is 0.426*0.3% = 0.12%. In other words, if a company's sensitivity to cash holdings remains unchanged during 2006, the company's cash holdings as a percentage of total assets will increase by 0.12% based on the increase in the company's R&D intensity. Chinese companies, calculated based on the same method, the change factor of firm characteristics is 0.92%, indicating a higher degree of change than do Taiwanese companies.

Column (6) of Table 7 shows the regression results of changing sensitivity. The estimated value between R&D and cash holdings is 0.426 ($\beta_{2006\text{-}2010}$=0.426) from 2006 to 2010, and rises to 0.487 from 2011 to 2016. ($\beta_{2011\text{-}2016}$=0.487). In 2006, the mean value of R&D investment in total assets is 2.4%, and it remains unchanged until 2016. The increase in cash holdings in total assets is due to the sensitivity of firm characteristics to cash holdings, which is from (0.426-0.487)*2.4 %= 0.15%. The change sensitivity of Chinese companies is -0.15%. Combining the change factor of firm characteristics and the change factor of sensitivity reveals the change in cash holdings in total assets. It illustrates that the R&D investment of Taiwanese firms and Chinese firms are 0.27% and 0.77% of the overall growth in cash holdings, respectively. R&D investment is one of the important factors leading to the growth of overall cash holdings.

He and Wintoki (2016) investigate the R&D investment relative to the growth of cash holdings for the US firms from 1980 to 2012, stating that the R&D investment of the US companies accounts for 1.76% of the overall growth in cash holdings. It can be inferred that the US companies invest much more in R&D than other countries, and their overall R&D investment is still ranked the first in the world. In particular, Amazon has become the one with the highest R&D investment in the world.

Table 7. The decomposition of the change of cash holdings

Panel A: Taiwan							
	$X_{2006\text{-}2010}$	$X_{2011\text{-}2016}$	$\beta_{2006\text{-}2010}$	$\beta_{2011\text{-}2016}$	Changing factor	Changing sensitivity	Total
Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
R&D-to-assets	0.024	0.027	0.426	0.487	0.12%	0.15%	0.27%
Industry CF volatility	0.044	0.043	-0.322	0.043	0.03%	1.62%	1.65%
CF	0.060	0.047	0.151	0.144	-0.19%	-0.04%	-0.24%
NWC	0.070	0.069	-0.188	-0.239	0.03%	-0.36%	-0.33%
Size	8.373	8.430	-0.009	-0.014	-0.05%	-3.82%	-3.87%
Leverage	0.191	0.185	-0.345	-0.356	0.21%	-0.20%	0.01%
MB	1.403	1.358	0.031	0.024	-0.14%	-0.97%	-1.11%
Dividend pay dummy	0.659	0.673	0.014	0.020	0.02%	0.37%	0.39%
CAPEX	0.045	0.038	-0.437	-0.511	0.31%	-0.34%	-0.03%
Total							-3.26%
Panel B: China							
	$X_{2006\text{-}2010}$	$X_{2011\text{-}2016}$	$\beta_{2006\text{-}2010}$	$\beta_{2011\text{-}2016}$	Changing factor	Changing sensitivity	Total
Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
R&D-to-assets	0.004	0.016	0.788	0.424	0.92%	-0.15%	0.77%
Industry CF volatility	0.794	0.402	0.000	0.000	0.00%	0.00%	0.00%
CF	0.036	0.038	0.231	0.323	0.06%	0.33%	0.39%
NWC	-0.075	0.022	-0.068	-0.126	-0.66%	0.43%	-0.22%
Size	7.766	8.225	0.002	-0.007	0.10%	-6.86%	-6.77%
Leverage	0.239	0.183	-0.184	-0.209	1.02%	-0.59%	0.43%
MB	2.493	2.759	0.007	0.003	0.20%	-1.15%	-0.96%
Dividend pay dummy	0.526	0.709	0.022	0.022	0.40%	0.00%	0.40%
CAPEX	0.058	0.052	-0.228	-0.313	0.13%	-0.50%	-0.37%
Total							-6.32%

3.5. The role of industrial competition

Table 8 depicts the relationship between the degree of industrial competition and cash holdings. For Taiwan, the degree of industrial competition of R&D companies has a significant positive effect on cash holdings. Non-R&D companies show no such effect, suggesting that the degree of industrial competition does not affect the cash holdings of non-R&D companies. The result supports Hypothesis 2 and the literature. He and Wintoki (2016) point out that the degree of competition among high-R&D companies is significantly higher than that of non-R&D companies. Increasing industrial competition is likely to cause more cash holdings as well. Hence, competition will be a very important determinant of the cash holdings policy of R&D companies because companies can use cash holdings to prepare for industrial competition or to ensure their survival during economic recessions (Telser, 1966; Frésard, 2010). For China, the degree of industrial competition for the full sample companies and R&D companies is not significant for cash holdings, which is inconsistent with Hypothesis 2. Under the global competition, it will be tough for companies to improve or strengthen their ability to respond to the external competitive environment if they do not invest continuously and profoundly in R&D activities.

Table 8. Regression results including industrial competition

Cash-to-assets$_t$	Taiwan			China		
	All firms	R&D firms	Non-R&D firms	All firms	R&D Firms	Non-R&D firms
HHI dummy$_{t-1}$	0.004**	0.007***	0.004	0.001	0.005	-0.008*
	(1.99)	(2.67)	(0.86)	(0.33)	(1.05)	(-1.72)
Industry CF volatility$_{t-1}$	0.007	-0.082	0.232	0.000	0.000	0.000
	(0.07)	(-0.61)	(1.46)	(0.08)	(-0.31)	(0.87)
CF$_{t-1}$	0.127***	0.094***	0.206***	0.307***	0.300***	0.278***
	(9.4)	(5.87)	(8.01)	(16.75)	(11.39)	(10.84)
NWC$_{t-1}$	-0.185***	-0.230***	-0.129***	-0.105***	-0.156***	-0.079***
	(-31.95)	(-30.25)	(-14.85)	(-21.93)	(-21.41)	(-11.99)
Size$_{t-1}$	-0.011***	-0.011***	-0.014***	-0.005***	-0.008***	-0.001
	(-16.61)	(-13.67)	(-11.93)	(-5.05)	(-6.63)	(-0.43)
Leverage$_{t-1}$	-0.326***	-0.391***	-0.217***	-0.205***	-0.260***	-0.165***
	(-54.54)	(-50.94)	(-23.5)	(-31.23)	(-26.58)	(-18.55)
MB$_{t-1}$	0.031***	0.035***	0.018***	0.004***	0.005***	0.005***
	(25.14)	(23.9)	(6.91)	(8)	(6.11)	(5.62)
Dividend pay dummy$_{t-1}$	0.019***	0.020***	0.016***	0.024***	0.021***	0.022***
	(9.23)	(7.93)	(4.79)	(12.16)	(7.87)	(7.73)
CAPEX$_{t-1}$	-0.395***	-0.491***	-0.127***	-0.265***	-0.363***	-0.208***
	(-25.17)	(-25.76)	(-4.72)	(-15.87)	(-16.04)	(-8.29)
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
N	21,285	14,814	6471	18,671	10,724	7947
Adjusted R^2	0.4459	0.4594	0.3443	0.2518	0.2887	0.2115

Note: ***, **, and * denote 1%, 5%, and 10% significance respectively.

3.6. The role of financing constraints and life cycles

Table 9 controls for financing constraints and life cycles for the study of the effect of industrial competition on cash holdings. The samples for regression analyses are grouped into four combinations: R&D/financing constraints, R&D/no financing constraints, non-R&D/financing constraints, non-R&D/no financing constraints. For Taiwanese non-R&D firms, we find that the results using the three financing constraints and the two life cycle variables are almost insignificant, suggesting that the financing constraints and life cycles do not affect the degree of industrial competition on cash holdings for the non-R&D companies. For Taiwanese R&D companies, the results using the three financing constraints are inconsistent since the results using dividend payout and firm age for the firms with financing constraints are significant while it is insignificant for the firms without financing constraints using firm size. Controlling for life cycles, whether there are financing constraints or not, the coefficients are all significantly positive to support that life cycles does not affect the relationship between the degree of competition and cash holdings. For Chinese R&D companies, we observe that regardless of the financing constraints and life cycles, the link between industrial competition and cash holdings is not significant. The result is consistent with the prior outcome in which financing constraints and life cycles do not affect the impact of industry competition on R&D investment and cash holdings (He and Wintoki, 2016).

Table 9. Regression results including financing constraints and life cycles

Panel A: Taiwan					
		Non-R&D firms		R&D firms	
Financing constraints		No	Yes	No	Yes
Payout ratio	HHI dummy	0.010	0.000	0.006	0.006*
		(1.4)	(0.08)	(1.58)	(1.82)
	N	2,797	3,674	7,095	7,719
Size	HHI dummy	-0.011*	0.006	0.006*	0.005
		(-1.94)	(1.05)	(1.79)	(1.3)
	N	3,244	3,227	7,403	7,411
Age	HHI dummy	-0.009*	-0.005	0.004	0.009***
		(-1.7)	(-0.93)	(0.93)	(2.56)
	N	3,063	3,408	6,592	8,222
Life cycles		Mature	Young	Mature	Young
RE/TA	HHI dummy	0.004	0.009*	0.007*	0.010***
		(0.67)	(1.8)	(1.89)	(2.83)
	N	3,277	3,194	7,464	7,350
RE/E	HHI dummy	-0.001	0.008	0.007*	0.008**
		(-0.11)	(1.54)	(1.88)	(2.35)
	N	3,266	3,205	7,440	7,374
Panel B: China					
		Non-R&D firms		R&D firms	
Financing constraints		No	Yes	No	Yes
Payout ratio	HHI dummy	-0.012**	-0.007	-0.001	0.005
		(-2.06)	(-1.1)	(-0.19)	(0.7)
	N	3,904	4,043	5,356	5,368
Size	HHI dummy	-0.012**	-0.007	0.001	0.009
		(-2.44)	(-0.93)	(0.16)	(0.8)
	N	4,004	3,943	5,356	5,368
Age	HHI dummy	-0.004	-0.013**	0.008	0.001
		(-0.62)	(-2.27)	(1.24)	(0.14)
	N	3,324	4,623	5,059	5,665
Life cycles		Mature	Young	Mature	Young
RE/TA	HHI dummy	-0.010	-0.004	0.005	0.007
		(-1.56)	(-0.68)	(0.48)	(1.14)
	N	4,012	3,935	5,374	5,350
RE/E	HHI dummy	-0.010*	-0.007	0.001	0.011
		(-1.66)	(-1.06)	(0.19)	(1.43)
	N	3,983	3,964	5,367	5,357

Note: ***, **, and * denote 1%, 5%, and 10% significance respectively.

4. Concluding remarks

This article investigates how R&D investment affects the company's cash holding decisions. We first identify the variation of cash holdings between R&D companies and non-R&D companies. Then we study whether R&D investment has an effect on cash holdings. Furthermore, we include the degree of industry competition to explain the divergence of cash holdings between R&D firms and non-R&D firms. Finally, financing restrictions and life cycles are added to measure the relevance of industry competition to R&D investment and cash holdings.

We observe that R&D-to-assets of Taiwanese firms are generally much higher than that of Chinese firms, showing that Taiwan's investment in R&D is more proactive than do China. Cash holdings of all sample firms have increased compared to the past. However, the increase in R&D firms is even greater than that in non-R&D firms. R&D companies in the two markets also hold more cash than do non-R&D companies, consistent with the conclusion of He and Wintoki (2016). Moreover, the electronics industry appears to hold more cash than does non-electronics industry, supporting the work of Huang (2013). This indicates that with the arrival of the knowledge age, companies have increasingly focused on R&D activities, especially the high-tech industries. The cash-to-assets of Taiwan R&D companies increases by 3% in 2009, reaching the largest difference with non-R&D companies. It is conjectured that the financial crisis in 2008 has caused economic losses worldwide so that firms recognizing the importance of preventive motives hold more cash in order to maintain normal operations and sufficient resources. Nonetheless, the cash holdings of Chinese R&D companies (i.e., cash-to-assets) falls by 2% in 2009 and declines in subsequent years. It is possibly due to that the Chinese firm size has gradually grew in recent years which results in relatively smaller cash holdings.

For hypothesis 1, we find that R&D investment and cash holdings in the two markets are both significantly positively correlated. This signifies that R&D and innovation-based companies have more incentives to hold more cash, which is presumably caused by the higher marginal market value of cash in high R&D companies (Pinkowitz and Williamson, 2007). Moreover, the net working capital, firm size, and debt ratio are negatively correlated to cash holdings in the two markets. To explore the cash changes for R&D investment attribution, we find that the change factor of sensitivity for Taiwanese R&D investment to the overall increase in cash holdings is slightly higher than that of corporate characteristics. However, it is mainly dominated by the change factor of firm characteristics for China. The Chinese R&D investment has increased substantially in recent years. The R&D investment of Taiwanese companies and Chinese companies account for 0.27% and 0.77% of the overall increase in cash holdings, respectively. After the degree of industrial competition is added, the difference in cash holdings between R&D companies and non-R&D companies is insignificant for Chinese companies. Taiwanese R&D companies show a positive effect of industrial competition on their cash

holdings. This supports hypothesis 2 and the literature, stating that when companies intend to use cash holdings to prepare for industrial competition, cash holdings can be hence shaped (Telser, 1966; Frésard, 2010). To further illustrate the effect of industrial competition on cash holdings, we include financing constraints and life cycles for analysis. We observe that the cash holdings of Taiwanese R&D and non-R&D companies are hardly affected by financing constraints or life cycles. For Chinese R&D companies financing constraints and life cycles are insignificant to affect the association of industrial competition and cash holdings.

The results show that the R&D investment is one of the important factors leading to the growth of overall cash holdings, but the increase is still not as high as that of the US, indicating that US companies' overall R&D investment is still ranked the first in the world. Although the US continues to lead in scientific and engineering R&D, the global R&D investment is developing toward "multi-polarization", and Asian countries including China, India, and South Korea are trying to catch up. Not only Taiwan is committed to R&D investment, China is also playing an increasingly important role in knowledge- and technology-intensive industries, such as high-tech manufacturing and knowledge-intensive service industries. Jingqing Liu, vice chairperson of Zicheng Enterprise Management Office, presents in the 1000 Companies Survey of 2017 Global Innovation that Taiwan's accumulated R&D advantages over the years will remain as an important capital to compete with others in the next wave of global innovation. In addition to strengthening the leadership in technological development and aiming at an innovative value network, firms should also establish their advantages through strategic alliances, gain a dominant position in the supply chains, and further deepen the customer relationship that is built for years. He also suggests that Taiwan, when thinking about the development strategies for the future, it must know how to use its own advantages to move towards a more competitive direction. Our results show that R&D investment is an important factor in the increase of cash holdings. Companies holding more cash can provide the basis for corporate growth. They can use funds to seize investment opportunities and to manage R&D activities. Moreover, cash holding decisions can help to determine operating turnover and ability to face risks. With the emphasis on R&D investment and the increase in cash holdings in recent years, understanding the company's cash holding decisions is much highlighted. Therefore, the R&D investment becomes an indispensable condition to enhance the competitive advantage.

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