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Research Article

The Influence Mechanism of Different Cash Flow Availability on R&D Investment: Evidence from China

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It has been widely assumed and proven that a firm's research and development (R&D) investment is limited if the availability of cash flow is constrained. The purpose of this study is to verify the opposite proposition: whether firms invest heavily in R&D when more cash flow is available. This paper discusses the heterogeneous relationship between cash flow from different sources and the R&D investment of firms. The study divides the firm's cash flow into three categories according to the business activities that generate firm finance: cash flow from operating activities (CFO), cash flow from investing activities (CFI), and cash flow from financing activities (CFF). On this basis, a dynamic R&D investment model is constructed, and the relevant data for Chinese listed firms are used for the empirical research. The study finds that Chinese listed firms do not necessarily spend more cash on R&D investment, even if the availability of cash flow is not constrained. For young firms, CFO and CFI do not significantly correlate with R&D investment, and CFF significantly negatively correlates with R&D investment. For mature firms, the correlations between cash flow generated from different activities and R&D investment are nonsignificant.

1. Introduction

R&D is a vital input for innovation and thus can increase the competitiveness of firms and promote the economic development of countries and regions [1]. Studies have shown that R&D investment can be constrained by the availability of cash flow [2]. If such financing constraints are sufficiently severe and broad, a country's economic growth will suffer [3]. Based on these studies, an immediate question regarding the promotion of innovation is the following: do firms with sufficient cash flow necessarily have a high level of R&D investment? Little empirical research exists to indicate whether this proposition is valid. Therefore, concerning cash flow from different business activities, it is necessary to study whether firms spend more on R&D investment and what the relationship might be between different sources of cash flow and innovative inputs when adequate capital is available (i.e., the availability of cash flow is less constrained).

This study focuses on cash flow from firms' operating, investing, and financing activities and how changes in cash flow cause changes in firm R&D investment. The previous literature on cash flow and R&D investment has examined various factors affecting firm investments, such as corporate governance level, firm political background, industry, firm nature, financial leverage, financing ability, and investment opportunities [2]. As the development of capital markets steadily improves, sources of cash flow become increasingly abundant, and it is vital to explore the heterogeneous influences of different cash flow sources on firm R&D investment. However, this has rarely been addressed in the previous literature. To address this deficiency, the study explores the sources of cash flow. According to the Chinese Generally Accepted Accounting Principles (GAAP), firm cash flow can be categorised as cash flow from operating activities (CFO), cash flow from investing activities (CFI), and cash flow from financing activities (CFF) [4], which links business activities with R&D investment. This article

explores cash flow sources that help potential investors and shareholders of firms improve their understanding of the composition of R&D investment and provides recommendations for choosing a firm's innovation projects and cash flow sources.

According to industrial organisation theory, in the developed market environment of Europe and the U.S., an implicit assumption often underpins the study of firm R&D investment behaviour, namely, the market size remains unchanging [5]. This is markedly different from the situation in emerging economies, as represented by China, where the market has continued to expand significantly over the long term. In emerging economies, where market demand is expanding, R&D and investment behaviour are taking on new characteristics [6]. In the past, industrial organisation approaches that studied the mature oligopolistic markets of Europe and U.S. found that mature firms had advantages in R&D investment competition and usually carried out R&D investment. This can be explained bearing in mind that compared with young firms, mature firms have more money for investments and enjoy cost advantages in R&D [7]. In emerging economies, however, the monopolistic advantage of mature firms has failed, giving young firms room for development and resulting in changes in their R&D and investment strategies. Due to the impact of market demand expansion on firm R&D investment, young firms can largely focus on R&D behaviour and innovation investment to improve their competitive advantage because they do not have economies of scale. In contrast, mature firms use the advantages of scale for short-term profit-making investment [8]. Therefore, it is improper to use existing industrial organisation theory to analyse firm R&D behaviour for the economic development of emerging economies, such as China. The decision-making mechanisms and competition behaviours of firms with different levels of maturity, from the perspective of market demand expansion, are new problems for industrial organisation theory. Hence, this study has great significance for the R&D investment and cash flow decision making of firms with different maturity levels in emerging economies, such as China.

This study is based on the data for Chinese listed firms over the period 2010–2017, covering 18 industries, including manufacturing, construction, mining, and education. CFO, CFI, and CFF are used to measure the financial position of firms, and firms' innovation investment is measured by their R&D investment [3]. We adopt a variant of the dynamic investment model developed by Brown et al. [9] to analyse the impact of the cash flows from the three types of business activities on R&D investment.

This study makes several contributions to the literature on cash flow sources and R&D investment. First, it puts forward a new perspective on financing availability for innovative investment. Previous literature on innovation financing has argued that firms do not invest in innovation if they are underfunded [10]. By analysing the relationship between different cash flow sources and R&D investment, this study finds that even if the availability of cash flow is less constrained, Chinese listed firms do not necessarily spend more money on R&D. The analysis of the financing activities

shows that Chinese listed firms rarely support their innovative investment with financing activities.

Second, this paper clarifies the influencing mechanism between different cash flow sources and innovative inputs, which is the first attempt by related research. Since innovation can enhance firm competitiveness, firms are urged to raise funds from multiple channels for R&D investment. It is of great significance to analyse how the cash flow from different financing channels affects R&D investment differently.

Finally, this paper explains the heterogeneous influence of firm cash flow sources with different maturities on R&D investment. Since firms with different maturities differ greatly in their ability to withstand financial risks and bankruptcy, there are obviously significant differences in the composition of cash flow sources and in decision-making attitudes towards R&D investment. The previous research seldom considers this. The conclusion of the study may guide the strategic decision making of firms with different levels of maturity in their cash flow sourcing and R&D investment.

1.1. Literature Review and Hypotheses. Many previous studies have shown that R&D investments can be constrained by the availability of cash flow. For example, Brown et al. [9] documented that R&D investments are constrained by the internal and external financing availability of young high-tech firms that are publicly traded in U.S. Sasidharan et al. [11] reported a positive impact of internal cash flow on R&D and a nonsignificant relationship between external funds and R&D for Indian manufacturing firms. Brown [3] argued that firms with financing constraints tend to have lower levels of R&D investment than firms without financing constraints. Guariglia and Liu [10] illustrated that the difference between the cost of obtaining funding within a firm and the cost of obtaining external funding constrained the innovation activities of the firm. Based on the findings, these studies have identified a necessity to establish policies to reduce financing constraints to improve innovation [3, 10].

The existing studies on financing constraints for innovation have often made the assumption that firms underinvest in innovation because they lack the necessary money and that when firms obtain more money, they will use it for innovation purposes. Some studies have used dynamic investment models based on the Euler equation to analyse the impact of financing availability on innovation [12]. Ahiadorme et al. [13] identified three possible scenarios for such a model: the firm has sufficient funds for investment; the firm does not have sufficient funds for investment and cannot obtain funds for investment through equity issuance; and the firm does not have sufficient funds but can obtain funds for investment through equity issuance. However, will firms with sufficient (funds from different sources of) cash flow really invest more in R&D? This possibility has rarely been considered in the previous literature.

This paper discusses the impact of financing availability on R&D investment from the perspective of CFO, CFI, and CFF. The status and proportion of these three cash flows for

a firm is an important reflection of whether the firm can make continuous R&D investment. In China and other emerging economics whose capital markets are imperfect, a large number of firms experience a lack of CFO and CFF and cannot meet the requirement for investing activities (e.g., continuous R&D investment) [14]. However, even if these funds are abundant, corporate managers and investors may still prefer to use cash for projects that are more profitable in the short term rather than to support R&D investment. This is mainly due to the characteristics of R&D investment: high adjustment costs and high uncertainty.

First, the adjustment costs of R&D investment are very high. Bernstein and Mohnen [15] argued that a great amount of adjustment costs exists in the innovation-intensive sectors of developed countries (i.e., U.S. and Japan). Similarly, Guariglia and Liu [10] stated that the adjustment costs of innovation activities in emerging economies, such as China, are also considerable. Unlike ordinary investments, R&D is designed to acquire technological innovation and intellectual property rights, which are intangible assets. In cases where the product has not yet been developed or has not been patented, the "value" of R&D is actually rooted in the human capital of the developers [16]. A significant portion of R&D investment is spent on the hiring, firing, and training costs of R&D personnel (Hall & Lerner, 2010). Once the original R&D employees leave a firm, the training costs spent on these employees by the firm become sunk costs. Moreover, if the employees are rehired by the firm's competitors, the firm faces the risk of its R&D secrets being acquired by competitors [17].

Second, R&D has high uncertainty. Patel and Chrisman [18] showed that no more than 25% of R&D projects in the development phase are successful [18]. According to Guariglia and Liu [10], uncertainty can be driven by irreversibility, long-term returns of R&D activities, and market factors. According to Lee et al. [19], the funds spent on R&D activities are irreversible, and the abrupt halt of R&D activities may lead to technological backwardness and value conversion. In addition, R&D activities are by no means short-term. Not only does the R&D phase take a long time but also the subsequent transformation and product development phases also involve long cycles. In addition, the feasibility of R&D content and the estimation of R&D investment are subject to factors such as market demand and competition [20].

Based on the above inferences, firms have difficulty investing their funds in R&D activities even if their funds are sufficient. The following hypothesis is developed.

H1: when CFO, CFI, and CFF are readily available, it remains difficult for firms to invest in R&D.

Due to the immature capital markets in emerging economies (e.g., China) as well as the existence of information asymmetry, agency problems, and transaction costs, there is a significant cost difference between internal finance and external finance that cannot be completely compensated [21]. According to pecking order theory, because firms are free to control internal funds for R&D investment, internal financing is preferred to external financing [9]. Under actual market conditions, because information asymmetry exists between the firm seeking financing and the external investor, the information-deficit party assumes the valuation risk. External creditors' rights financing and equity financing require the firm seeking funding to bear the high underwriting, audit, legal, regulatory, and other direct or indirect costs, resulting in high external financing costs, which are not conducive to sustainable R&D investment. Firms, on the other hand, can use their own internal reserves of cash for R&D without incurring additional costs, which is a relatively low-cost option. According to financing constraint theory, firms with low availability of cash flow can use internal finance as a buffer for R&D investment to reduce external financing difficulties [22]. Hence, internal cash flow can be more available than external cash flow to finance R&D investment [9].

What is the link between internal and external finance and cash flow from the three different sources? According to the GAAP, CFO mainly includes cash and cash-equivalent inflows and outflows from firm operating activities, such as manufacturing and selling goods or offering services. CFO belongs to internal finance and is the normal source of cash for firms. According to Xu et al. [23], CFO represents capital turnover and improves the ability of the firm to handle risks, which can ensure the smoothing of R&D investment. CFI mainly includes cash inflows and outflows from buying machinery and equipment, plants, advanced technology, intangible assets, etc. The portion of CFI derived from financial instruments constitutes external finance, while the capital investment of CFI can be regarded as internal finance. In addition, CFF mainly includes cash and cash-equivalent inflows and outflows from financing activities, such as issuing or taking debt (e.g., bond or loan) or equity (e.g., stock or dividend). CFF comprises external funds. External creditors and investors are only willing to invest in investments that are considered to be financially sound and, hence, are reluctant to invest in R&D activities, which have the characteristics of high uncertainty [23]. Based on the statements, CFO can be the most accessible source of finance for firm R&D investment, and CFF can be the least accessible source of finance for firm R&D investment. That is, R&D investment can be least constrained by CFO and most constrained by CFF. Therefore, hypothesis 2 is presented as follows.

H2: among the three types of firm financing sources, R&D investment is influenced most by CFF availability and then by CFI availability, and it is least influenced by CFO availability.

According to previous studies, there are significant differences in the sensitivity of cash flow sources for R&D investment for firms with different levels of maturity [9, 24]. Compared with young firms, mature firms with scale advantages have stronger R&D financing capacity based on industrial organisation theory [3, 10]. However, firms with a higher level of maturity are less likely to invest in R&D [25]. In contrast, young firms can be more willing to engage in R&D activities, especially young firms with high technical requirements [9].

Following industrial organisation theory, an implicit assumption often underpins the study of firm R&D investment in developed markets, such as Europe and the U.S.: the market size is unchanging [16]. However, the market size

in emerging economies, such as China, has continued to expand significantly over the long term. In the case of the dynamic expansion of market demand, the cash flow characteristics of R&D investment will be different from those of unchanging markets. Therefore, we cannot simply use existing industrial organisation theory to analyse the R&D cash flow strategies of Chinese firms with different levels of maturity.

In the previous literature on industrial organisation theory, the mature firms in European and U.S. mature oligopolistic markets are found to have advantages in R&D investment competition (e.g., sufficient funds and cost advantages) [26]. As the market in emerging economies continues to expand, the monopolistic power of mature firms fails, giving young firms room for development and resulting in changes to their R&D investment strategies [27]. In view of the impact of market expansion on firm R&D investment, young firms have no advantage of scale or brand and need to invest in R&D to develop a unique competitive advantage, while mature firms use the advantages of scale to focus on short-term profit-making investment strategies [28]. This is because when the market expands and the demand for products is strong, mature firms can promote efficiency by making simple investments to expand production. In the context of market expansion, although mature firms also invest in R&D, the intensity of their investment is reduced. The expansion of market size contributes most significantly to the R&D investment of young firms [29]. On the whole, in emerging economies, where markets are expanding, mature firms invest mainly to increase their scale and gain market pricing power. Simple investment to expand production can promote efficiency gains without the need for high-risk R&D investment activities. However, young firms mainly invest in R&D to produce innovative products and develop a unique competitive advantage [30]. Therefore, in emerging economies where market size is expanding, the impact of cash flow sources on R&D investment can vary greatly for firms with different levels of maturity. Hypothesis 3 is presented as follows.

H3: in emerging economies, the R&D investment of young firms is more influenced by CFO, CFI, and CFF than that of mature firms.

1.2. Data Collection

1.2.1. Sample Selection. The sample includes all Chinese firms from the Main Board, Small and Medium Enterprise (SME) Board, and ChiNext Board listed on the Shanghai Stock Exchange and the Shenzhen Stock Exchange. These listed firms cover 18 industries, and the details are presented in Table 1. Since the ChiNext Board was officially launched in the Shenzhen Stock Exchange on 23 October 2009, our data range starts in 2010. Due to the reform of the Chinese accounting system in 2018, the data range ends in 2017 to ensure the consistency of the accounting-related measures (e.g., cash flow and R&D). For the source of the dataset, we obtain the majority of statistics from Wind and acquire the disclosed information on financing activities from China Stock Market & Accounting Research Database (CSMAR).

Following the previous literature [31, 32], we require a firm to have positive assets and sales to be included in the sample. Firms with no R&D observations are excluded. In addition, to reduce potential bias from the outliers, we trim all the variables at the first and ninety-ninth percentiles; thus, the final sample is an unbalanced panel of 2,401 firms and 12,245 observations. In addition, we differentiate between young and mature firms in the analysis. Following Brown et al. [9] and Gkypali et al. [33], firms with less than 15 years of listed experience are categorised as young firms, and the remaining firms are counted as mature firms [9]. All the variable definitions are described in Table 2.

1.2.2. Descriptive Statistics. The descriptive statistics for the variables are shown in Table 3. The first column reports the information for the full sample. The mean rd_t is 0.024, which is smaller than the mean value of the R&D-to-assets ratio for U.S. industrial firms (0.043) reported by He and Wintoki [31]. The mean cfo_t is 0.047, which is equal to the mean cff_t (0.047). This suggests that CFO and CFF can both be important finance sources for firms. The mean cfi_t is −0.081, showing that investing cash outflows are always greater than the inflows. In addition, the standard deviation of rd_t (0.023) is much smaller than the standard deviations for cfo_t (0.079), cfi_t (0.109), and cff_t (0.144), indicating that R&D spending is relatively stable when cash flow from operating, investing, and financing activities fluctuates.

Columns 2 and 3 present the information for the young firm and mature firm subsamples, respectively. In the last column, we show the standard *t*-test results, comparing the mean difference between the two subsamples. Since the test results are all significant, it is evident that young firms are significantly different from mature firms in all of the dimensions [31].

1.3. Model.
Based on the previously stated hypotheses, the study modifies a dynamic investment model taken from Tori and Onaran [34] to examine the impacts of different types of cash flow on R&D spending:

$$
\begin{aligned}
\mathrm{rd}_{i,t} = {} & \beta_1 \mathrm{rd}_{i,t-1} + \beta_2 \mathrm{rd}_{i,t-1}^2 + \beta_3 \mathrm{sales}_{i,t-1} + \beta_4 \mathrm{cfo}_{i,t-1} \\
& + \beta_5 \mathrm{cfi}_{i,t-1} + \beta_6 \mathrm{cff}_{i,t-1} + \beta_7 Z_{i,t} + u_t + v_i + \varepsilon_{i,t},
\end{aligned}
\tag{1}
$$

where $rd_{i,t}$ is the dependent variable, denoting the R&D spending for firm i in period t; $cfo_{i,t-1}$, $cfi_{i,t-1}$, and $cff_{i,t-1}$ denote firm i's net CFO in period $t-1$, net CFI in period t-1, and net CFF in period t-1, respectively; and $sales_{t-1}$ represents the firms' net sales, denoting the firm's output. All these variables are scaled by total assets. Following the previous studies [3], we include prior R&D expenditure and its quadratic terms in the model because these might influence the relationship between cash flow and R&D. Z is a vector of the control variables, which includes growth opportunities ($tobinq_t$), the use of cash for R&D smoothing ($\Delta\,cashholdings_t$), and firm size ($size_t$). In addition, we establish the firm's fixed effects (v_i) to control for unobserved (time-invariant) firm characteristics and time fixed

TABLE 1: Industry types.

1	Agriculture, hunting, and forestry
2	Mining
3	Manufacturing
4	Electricity, gas, and water supply
5	Construction
6	Wholesale and retail trades
7	Transportation, warehousing, and postal service
8	Accommodation and catering
9	Information transmission, software, and information technology services
10	Financial
11	Real estate
12	Renting and business services
13	Scientific research and technical services
14	Water conservancy, environment, and public facilities management
15	Education
16	Health and social work
17	Culture, sports, and entertainment
18	Comprehensive

Note. The firms listed on the Shanghai Stock Exchange and the Shenzhen Stock Exchange are from 18 industries in all. The classification of industries follows *Industrial Classification for National Economic Activities* listed on National Bureau of Statistics website (http://www.stats.gov.cn/tjsj/tjbz/).

TABLE 2: Variable definitions.

Variable	Definition
rd_t	R&D expenses in period t divided by the book value of total assets at the beginning of period t.
ocf_t	Net operating cash flow in period t divided by the book value of total assets at the beginning of period t.
icf_t	Net investing cash flow in period t divided by the book value of total assets at the beginning of period t.
fcf_t	Net financing cash flow in period t divided by the book value of total assets at the beginning of period t.
$sale_t$	Net sales in period t divided by the book value of total assets at the beginning of period t.
$tobinq_t$	Natural logarithm of Tobin's Q in period t. Tobin's Q is equal to market value over total assets.
$\Delta\,cashholdings_t$	Difference between cash and cash equivalents in periods t and t-1 divided by the book value of total assets at the beginning of period t.
$size_t$	Natural logarithm of the total number of a firm's employees in period t. The alternative measure is equal to natural logarithm of total assets.
Alternative $size_t$	Natural logarithm of the total assets in period t.
Alternative $tobinq_t$	Natural logarithm of alternative Tobin's Q in period t. Alternative Tobin's Q is equal to market value over (total assets-net intangible assets-good will).
roa_t	Return-on-assets ratio in period t.
tax_t	Total tax divided by the book value of total assets in period t.
Age_a_t	A variable that takes the value of one when a firm is listed less than 15 years and zero otherwise.
Age_b_t	A variable that takes the value of one when a firm is listed less than 10 years and zero otherwise.
Age_c_t	The number of years that a firm is listed.

effects (u_t) to control for the impact of unobserved time events. $\varepsilon_{i,t}$ is the firm-specific idiosyncratic shock [35].

In this study, the dynamic investment model is used to determine whether the costs of cash flow obtained by firms from different business activities differ. Then, by analysing the sensitivity of R&D investment to different cash flows, the study provides the new support for R&D investment by listed firms in emerging economies, such as China.

We estimate the model using the one-step GMM method instead of two-step estimates because the standard errors from two-step GMM are downward-biased for small samples (e.g., [9]). Since equation (1) is a dynamic model with firm fixed effects, we apply the first-difference GMM [36]. Similar approaches have also been employed in many recent studies, such as Brown and Petersen [9]; Sasaki [37]; and Weng and Soderbom [2]. The results are shown in the next section.

2. Results

2.1. Cash Flow Sources and R&D Investment.
Table 4 presents the first-difference GMM coefficient estimates of equation (1) for the full sample of Chinese listed firms. The study begins with a modified dynamic investment model containing the three types of cash flow, and then we add more control variables. All explanatory variables in these regression specifications are treated as potentially endogenous. Referring to Brown and Peterson [9]; Sasaki [37]; and Tori and Onaran [34], we choose lagged values dated $t-3$ to $t-5$ as instruments. The p values of the AR(1) and AR(2) statistics are reported. The p values for the AR(1) statistics show first-order autocorrelation in the errors, and the p values for the AR(2) statistics do not reject the null hypothesis of no second-order autocorrelation. In addition, we conduct Hansen tests for the overidentification of the

TABLE 3: Sample descriptive statistics.

Variables		Full (1)	Young (2)	Mature (3)	Difference (4)
rd_t	Mean	0.024	0.027	0.018	
	Median	0.019	0.022	0.011	-0.009^{***}
	SD	0.023	0.023	0.021	
	N	12245	8702	3543	
cfo_t	Mean	0.047	0.049	0.040	
	Median	0.044	0.048	0.037	-0.009^{***}
	SD	0.079	0.079	0.080	
	N	12117	8628	3489	
cfi_t	Mean	−0.081	−0.093	−0.052	
	Median	−0.056	−0.067	−0.034	0.041^{***}
	SD	0.109	0.112	0.093	
	N	12068	8605	3463	
cff_t	Mean	0.047	0.054	0.028	
	Median	0.004	0.008	−0.002	-0.026^{***}
	SD	0.144	0.149	0.129	
	N	12015	8598	3417	
$sales_t$	Mean	0.708	0.691	0.750	
	Median	0.579	0.575	0.588	0.059^{***}
	SD	0.518	0.483	0.595	
	N	12091	8628	3463	
$tobinq_t$	Mean	0.666	0.690	0.605	
	Median	0.579	0.610	0.501	-0.085^{***}
	SD	0.476	0.467	0.494	
	N	11587	8288	3299	
$\Delta\,cashholdings_t$	Mean	0.012	0.010	0.019	
	Median	0.002	0.001	0.005	0.009^{***}
	SD	0.101	0.103	0.094	
	N	12067	8577	3490	
$size_t$	Mean	7.795	7.650	8.150	
	Median	7.714	7.570	8.143	0.500^{***}
	SD	1.151	1.088	1.222	
	N	12134	8606	3528	

Column 1 is for the full sample, column 2 is for the young firm subsample, and column 3 is for the mature firm subsample. In the last column 4, we show the standard t-test results to compare the mean difference between the two subsamples in columns 2 and 3. The p value of the t-test results are all significant with 3 asterisks, that is, $^{***}p$ significant at the 1.0% level. It is evident that young firms are significantly different from matured firms in all of the dimensions. * Significant at the 1.0% level. ** Significant at the 0.5% level. *** Significant at the 0.1% level.

instruments [3]. The tests shows that the validity of the instruments cannot be rejected in Table 4.

In Table 4, the coefficients for rd_{t-1} are significantly positive, indicating the persistence of R&D. However, the coefficients for rd_{t-1} are always smaller than 1; the coefficients for rd_{t-1}^2 are often negative; and the coefficients for $sales_t$ are negative but not always significant. Hence, these results reject the null hypothesis of the Euler equation, which could be explained by the financial constraints of the firms in imperfect capital markets [9]. The coefficients for cfo_{t-1} and cfi_{t-1} are always nonsignificant. In addition, the coefficients for cff_{t-1} are always negatively significant.

These results suggest that firms with greater CFO and CFI may not have spent more money on R&D, and firms with greater CFF tend to invest less in innovation. The results align exactly with hypothesis 1. Since R&D

TABLE 4: Dynamic R&D regressions for full sample.

	(1)	(2)
rd_{t-1}	0.433*	0.907***
	(0.247)	(0.169)
rd_{t-1}^2	0.007	−3.603***
	(1.850)	(1.398)
cfo_{t-1}	0.022	−0.011
	(0.024)	(0.018)
cfi_{t-1}	0.012	0.001
	(0.011)	(0.010)
cff_{t-1}	−0.022**	−0.025***
	(0.009)	(0.010)
$sales_{t-1}$	−0.011***	−0.002
	(0.004)	(0.003)
$tobinq_t$		−0.003
		(0.002)
$\Delta\,cashholdings_t$		0.019*
		(0.011)
$size_t$		−0.003
		(0.003)
Time dummies	Yes	Yes
Firm dummies	Yes	Yes
AR(1)	0.000	0.000
AR(2)	0.955	0.062
Hansen	0.538	0.137
Obs.	7,176	6,261
Firms	1,898	1,826

Note. Robust standard errors are in parentheses; $^{***}p < 0.01$, $^{**}p < 0.05$, and $^{*}p < 0.1$. Estimation is by first-difference GMM. Time and firm fixed effects are included in both regressions. Lagged values dated from t-3 to t-5 are utilised as instruments for all explanatory variables.

investment can have long-term risk, unpredictability, and irreversibility, firm managers and external investors may be reluctant to invest largely in R&D, even if CFO, CFI, and CFF are sufficiently available.

Moreover, the results show that R&D spending is more sensitive to financing cash flow than the other two types of cash flow. That is, an increase in CFO and CFI does not necessarily lead to an increase in firm R&D investment, but an increase in CFF can be significantly associated with a decrease in R&D investment. Hence, hypothesis 2 is partially supported. This can be explained by the high adjustment costs of R&D investment [3, 18], which make firms sustain a relatively stable R&D level instead of changing their R&D significantly with the increase/decrease in CFI and CFO. In addition, it is highly possible that firms that need more CFF are generally firms whose CFO and CFI are insufficient, indicating that these firms are in relatively poor operational conditions. Therefore, they tend to invest less in R&D.

For other control variables, the coefficient for $\Delta\,cashholdings_t$ is positive and slightly significant. In addition, the coefficients for $tobinq_t$ and $size_t$ are nonsignificant. This is possibly because the growth opportunity and size of firms have already been selected, as we utilise listed firms to construct our sample. In China, for instance, a firm is required to have sustainable growth ability and a minimum of 30,000,000 RMB capital stock with over 25% publicly issued shares to be listed on the ChiNext Board

market (http://www.szse.cn/disclosure/notice/company/t20120420_508712.html).

Since there can be significant variations between young and mature firms [2, 9], we split the full sample into young and mature firm subsamples based on the firms' age to further check the findings.

2.2. Firm Maturity, Cash Flow Sources, and R&D Investment.
Table 5 provides the dynamic regressions for the young and mature firm subsamples. All explanatory variables in these regressions are treated as potentially endogenous, and we refer to Brown and Peterson [9]; Sasaki [37]; and Tori and Onaran [34] to use lagged values dated t-3 to t-5 as instruments. The p values for the AR(1) statistics indicate first-order autocorrelation in the errors, and the p values for the AR(2) statistics do not reject the null hypothesis of no second-order autocorrelation. Moreover, the Hansen tests cannot reject the instruments' validity [3].

In Table 5, columns 1 and 3 document the results for the young firm subsample, and columns 2 and 4 report the results for the mature firm subsample. Past R&D is always significantly and positively associated with current R&D. Similar to the results of the full sample, the coefficients for $tobinq_t$ and $size_t$ are nonsignificant. The coefficients for cfo_{t-1} and cfi_{t-1} in the regression specifications are always nonsignificant, which indicates that the lagged CFO and the lagged CFI do not have a significant relationship with contemporaneous R&D for both young and mature firms. The coefficients for cff_{t-1} are only negatively significant in columns 1 and 3, showing that an increase in lagged CFF is significantly related to a decrease in contemporaneous R&D for young, but not mature, firms. Hence, the result confirms hypothesis 3 only for CFF. The R&D investment of both young and mature firms is less likely to be influenced by the availability of CFO and CFI, while an increase in CFF leads to a more significant decrease in R&D investment by young Chinese firms than by mature firms.

The finding on CFF is different between young and mature firms in this study. Mature firms are more capable of relying on their internal funds to finance R&D because they have accumulated more profits over the years [38]. In contrast, young firms always lack internal funds. Hence, young firms are more likely to rely on CFF than mature firms are [39]. Since investors in CFF are normally inclined to pursue short-term and low-risk investments, they are less likely to support R&D investment, which has a long-term risk [40, 41]. In addition, as discussed above, firms tend to sustain a relatively stable R&D level with changes in CFI and CFO and are reluctant to invest more in R&D when CFF increases, which can be explained by the high adjustment costs and high uncertainty of R&D investment [42].

2.3. Intentions of Financing Activities and R&D Investment.
Based on the analyses above, it is found that firms with available CFO, CFI, and CFF may not spend more on R&D. Moreover, young firms may spend significantly less on R&D when they have more CFF. Hence, this section verifies the

Table 5: Dynamic R&D regressions for young and mature firm subsamples.

	Young (1)	Mature (2)	Young (3)	Mature (4)
rd_{t-1}	0.455**	0.359	0.854***	0.503**
	(0.253)	(0.307)	(0.211)	(0.233)
$rd_{t-1}{}^2$	−0.599	0.119	−3.958**	−1.071
	(1.879)	(2.761)	(1.626)	(2.630)
cfo_{t-1}	0.016	0.030	−0.002	−0.003
	(0.023)	(0.028)	(0.019)	(0.016)
cfi_{t-1}	0.007	−0.004	−0.002	−0.012
	(0.012)	(0.014)	(0.012)	(0.013)
cff_{t-1}	−0.027***	−0.012	−0.027**	−0.012
	(0.009)	(0.010)	(0.011)	(0.010)
$sales_{t-1}$	−0.008*	−0.005	−0.001	−0.001
	(0.005)	(0.006)	(0.004)	(0.003)
$tobinq_t$			−0.002	−0.003
			(0.003)	(0.003)
$\Delta\,cashholdings_t$			0.019	0.001
			(0.014)	(0.011)
$size_t$			−0.005	0.001
			(0.005)	(0.004)
Time dummies	Yes	Yes	Yes	Yes
Firm dummies	Yes	Yes	Yes	Yes
AR(1)	0.000	0.012	0.000	0.003
AR(2)	0.603	0.627	0.218	0.846
Hansen	0.573	0.208	0.538	0.289
Obs.	4,778	2,398	4,160	2,101
Firms	1,406	713	1,347	674

Note. Robust standard errors are in parentheses; ***$p < 0.01$, **$p < 0.05$, and *$p < 0.1$. Estimation is by first-difference GMM. Time and firm fixed effects are included in all regressions. Lagged values dated from t-3 to t-5 are utilised as instruments for all explanatory variables. Columns 1 and 3 are regressions for the young firm subsample, and columns 2 and 4 are regressions for the mature firm subsample.

intentions for firms to acquire CFF to further support these findings.

Financing activities basically involve issuing or taking debt or equity. To verify the intentions behind financing activities, we examine the disclosed records of Chinese listed firms in the CSMAR database during the period 2010 to 2017. The results are shown in Table 6. It is acknowledged that only few firms disclose the intentions behind their financing activities, but the statistics can provide an overview of possible trends for firms in raising funds. We classify the intentions of financing activities into six groups: innovation, capital investment, operation, funding, debt repayment, and others.

Column 1 of Table 6 presents the analysis of all the disclosed intentions relating to stock issuance or reissuance. A total of 2,777 out of 5,410 observations disclosed intentions. Of these observations, approximately 6.80% of funds are raised for innovation. Column 2 of Table 6 provides the analysis of all the disclosed intentions for borrowing bank loans, which is a main source of debt finance. A total of 1,334 out of 2,179 observations disclosed intentions. Of these observations, only 0.29% of loans are borrowed for innovation. These statistics show that firms spend merely a small portion of funds from financing activities on innovation, which supports our findings that firms with more CFF do not necessarily invest more in R&D.

TABLE 6: Disclosed intents of financing activities.

Intents	Activities	Stock issues (1) (%)	Bank loans (2) (%)
Innovation	Research and development, technical reform, and new product development	6.80	0.29
Operation	Enlarging firm size, merger and acquisition, and purchasing fixed assets	35.26	69.62
Capital investment	Operation maintenance and projects	22.73	9.01
Debt repayment	Adding liquid funds	3.90	4.76
Funding	Paying for debt	29.69	10.90
Others	All other purposes such as advertising, training, and export security	1.62	5.43

Based on the intentions disclosed on the CSMAR, the study classifies them into six groups: innovation, capital investment, operation, funding, debt repayment, and others. Details of the activities for each group are presented. The statistics are reported for the disclosed records of Chinese listed firms on the CSMAR during the period 2010 to 2017. Column 1 provides the percentage of the funds utilised for different intentions, obtaining from stock issues. Column 2 provides the percentage of the funds utilised for different intentions, obtaining from borrowing bank loans.

We further examine the mean values of cash flow and R&D for the disclosed observations and present the results in Table 7. Compared with Table 3, the mean values of cfo_t are quite close, showing that the operational state of firms that obtained finance by issuing stock is similar to the average level for listed firms. The mean R&D spending is 0.029 for young firms and 0.018 for mature firms, which is quite close to the values of 0.027 and 0.018 in Table 3. However, the absolute mean values of cfi_t in Table 7 are much larger than those in Table 3. This suggests that firms in good operating conditions can raise more funds by issuing and reissuing stocks, but they tend to conduct more capital investment than R&D investment. The results can be explained by the conservative attitude of Chinese listed firms due to the high uncertainty of innovation investment. In addition, we find that firms that need bank loans have a much smaller mean cfo_t, indicating that these firms are in a relatively poor operational condition and find it more difficult to sustain their business by operational profits. These firms are less likely to invest in R&D, even if they obtain funding through bank loans.

According to the statistics from the CSMAR database, the mean value of net debt issuance is approximately three times greater than that of the net stock issuance. However, the analyses show that the firms are more likely to support R&D by equity financing than bank loans. One explanation is that the firms that can raise funds from stocks are in better operational condition than the firms that need loans; hence, even if more funds are acquired from debt issuance, the funds are used for purposes such as maintenance and debt repayment. Previous studies on innovation finance have suggested that a large amount of stock or debt issuance may be a main source of R&D spending [3, 9], which is consistent with the previous research conclusions in this paper. It is necessary to verify the intentions of financing activities. The results confirm that firms may not invest in innovation even if they can obtain additional funds from financing activities.

2.4. Robustness. To check the stability of our findings, we conduct the following analyses. The results are shown in Tables 8–13. First, in columns 1–3 of Table 8, we employ the alternative Tobin's Q measure and firm size measure [31] and obtain consistent results. Second, in columns 4–6 of

TABLE 7: Analysis of the disclosed observations.

	Stock issues			Bank loans		
	Full (1)	Young (2)	Mature (3)	Full (4)	Young (5)	Mature (6)
cfo_t	0.049	0.047	0.054	0.026	0.029	0.018
cfi_t	−0.152	−0.171	−0.091	−0.077	−0.075	−0.082
cff_t	0.255	0.280	0.171	0.068	0.059	0.087
rd_t	0.027	0.029	0.018	0.011	0.012	0.010

The mean values of cash flow and R&D for the disclosed observations are analysed in this table.

Table 8, we add return on assets (roa) to control for profitability [1] and tax-to-asset ratio (tax) to control for the firm tax environment [43]. The results are consistent when additional control variables are added. Third, we adjust the instrument set to include lagged values dated from t-2 to t-5 and lagged values dated from t-3 to t-4. The results are presented in Table 9 and are consistent with the findings in Table 5.

Fourth, the sample utilised above includes firms with at least one R&D observation. Since some relevant studies construct their samples with at least three R&D observations [37], this paper analyses the regressions using an alternative sample with at least three R&D observations as well in Table 10. The results are invariant with the sample selection criterion for the number of R&D observations.

Fifth, while we drop observations with no R&D in the analyses above, we set missing R&D values to zero as in Pang & Wang [44] to check the robustness. The results are shown in Table 11, which are verified to be robust.

In addition, we employ 10 years as an alternative firm age selection criterion, referring to Brown et al. [9]; Haltiwanger et al. [45]; and Coad et al. [46]. The results, presented in Table 12, show that the findings are robust when firm age selection criterion is different. Further, to verify that the effects of various types of cash flow on R&D investment are significantly different among young and mature firms, we also interact CFO, CFI, and CFF with firm age variables (Age_a_t, Age_b_t, and Age_c_t), respectively, for the full sample, following the research of Howell [47]. The results are reported in Table 13, which corroborate the significant effects of CFF on R&D investment for young firms.

TABLE 8: Additional controls and alternative controls.

	Alternative control			Additional controls		
	Full	Young	Mature	Full	Young	Mature
	(1)	(2)	(3)	(4)	(5)	(6)
rd_{t-1}	0.926***	0.877***	0.503**	0.796***	0.774***	0.556**
	(0.165)	(0.201)	(0.210)	(0.163)	(0.202)	(0.219)
rd_{t-1}^2	−3.829***	−4.052**	−1.095	−3.290**	−3.701**	−1.824
	(1.359)	(1.576)	(2.330)	(1.432)	(1.629)	(2.616)
cfo_{t-1}	−0.009	−0.001	−0.002	−0.019	−0.010	−−0.006
	(0.018)	(0.020)	(0.017)	(0.015)	(0.016)	(0.017)
cfi_{t-1}	−0.001	−0.004	−0.015	0.004	−0.002	−0.015
	(0.010)	(0.012)	(0.014)	(0.011)	(0.011)	(0.013)
cff_{t-1}	−0.021**	−0.028***	−0.008	−0.019**	−0.019*	−0.016
	(0.010)	(0.010)	(0.011)	(0.010)	(0.010)	(0.010)
$sales_{t-1}$	−0.002	−0.000	−0.001	−0.003	−0.003	−0.000
	(0.003)	(0.004)	(0.003)	(0.003)	(0.005)	(0.003)
$tobinq_t$	−0.002	−0.001	−0.002	−0.004	−0.004	−0.003
	(0.002)	(0.003)	(0.003)	(0.002)	(0.003)	(0.003)
$\Delta\,cashholdings_t$	0.024**	0.015	0.013	0.014	0.022*	-0.011
	(0.011)	(0.012)	(0.012)	(0.010)	(0.013)	(0.009)
$size_t$	−0.003	−0.003	−0.001	−0.001	−0.005	0.005
	(0.003)	(0.004)	(0.005)	(0.003)	(0.004)	(0.004)
roa_t				0.001**	0.001**	0.001***
				(0.000)	(0.000)	(0.000)
tax_t				0.039	0.071	-0.020
				(0.064)	(0.080)	(0.089)
Time dummies	Yes	Yes	Yes	Yes	Yes	Yes
Firm dummies	Yes	Yes	Yes	Yes	Yes	Yes
AR(1)	0.000	0.000	0.001	0.000	0.000	0.003
AR(2)	0.059	0.252	0.476	0.444	0.769	0.465
Hansen	0.114	0.262	0.566	0.239	0.756	0.450
Obs.	6,316	4,190	2,126	6,043	4,044	1,999
Firms	1,835	1,354	676	1,800	1,329	653

Note. Robust standard errors are in parentheses; ***$p < 0.01$, **$p < 0.05$, and *$p < 0.1$. Estimation is by first-difference GMM. Time and firm fixed effects are included in all regressions. Lagged values dated from t-3 to t-5 are utilised as instruments for all explanatory variables. Columns 1–3 are regressions with alternative control variables. Columns 4–6 are regressions with additional control variables. Among them, regressions in columns 1 and 4 are for the full sample; regressions in columns 2 and 5 are for the young firm subsample; and regressions in columns 3 and 6 are for the mature firm subsample.

TABLE 9: Other instruments.

	Full	Young	Mature	Full	Young	Mature
	(t-2, t-5)	(t-2, t-5)	(t-2, t-5)	(t-3, t-4)	(t-3, t-4)	(t-3, t-4)
	(1)	(2)	(3)	(4)	(5)	(6)
rd_{t-1}	0.800***	0.751***	0.621***	1.028***	1.112***	0.618***
	(0.133)	(0.169)	(0.180)	(0.205)	(0.257)	(0.236)
rd_{t-1}^2	−3.193***	−2.702**	−2.591	−4.328***	−5.742***	−1.841
	(1.078)	(1.359)	(1.576)	(1.592)	(1.973)	(2.654)
cfo_{t-1}	−0.005	−0.005	0.001	−0.003	−0.002	−0.014
	(0.004)	(0.006)	(0.006)	(0.022)	(0.023)	(0.019)
cfi_{t-1}	−0.001	−0.001	0.001	−0.004	−0.008	−0.015
	(0.003)	(0.003)	(0.006)	(0.013)	(0.013)	(0.015)
cff_{t-1}	−0.010***	−0.012***	−0.003	−0.031***	−0.027**	−0.012
	(0.003)	(0.004)	(0.004)	(0.011)	(0.012)	(0.012)
$sales_{t-1}$	−0.003	−0.004	−0.001	−0.000	−0.000	−0.001
	(0.002)	(0.004)	(0.002)	(0.003)	(0.004)	(0.003)
$tobinq_t$	0.001	−0.002	0.002	−0.002	−0.002	−0.003
	(0.003)	(0.004)	(0.004)	(0.003)	(0.003)	(0.004)
$\Delta\,cashholdings_t$	0.017	0.029	0.006	0.012	0.019	-0.005
	(0.015)	(0.025)	(0.015)	(0.013)	(0.014)	(0.011)
$size_t$	−0.004	−0.009	0.001	−0.001	−0.003	0.003

TABLE 9: Continued.

	Full (t-2, t-5)	Young (t-2, t-5)	Mature (t-2, t-5)	Full (t-3, t-4)	Young (t-3, t-4)	Mature (t-3, t-4)
	(0.004)	(0.006)	(0.006)	(0.004)	(0.005)	(0.004)
Time dummies	Yes	Yes	Yes	Yes	Yes	Yes
Firm dummies	Yes	Yes	Yes	Yes	Yes	Yes
AR(1)	0.000	0.000	0.000	0.000	0.000	0.005
AR(2)	0.098	0.215	0.924	0.066	0.232	0.892
Hansen	0.743	0.696	0.501	0.073	0.219	0.386
Obs.	6,261	4,160	2,101	6,261	4,160	2,101
Firms	1,826	1,347	674	1,826	1,347	674

Note. Robust standard errors are in parentheses. *Significant at the 1.0% level. **Significant at the 0.5% level. ***Significant at the 0.1% level. Estimation is by first-difference GMM. Time and firm fixed effects are included in all regressions. Columns 1-3 are regressions with instruments lagged twice to five times. Columns 4-6 are regressions with instruments lagged three to four times. Among them, regressions in columns 1 and 4 are for the full sample; regressions in columns 2 and 5 are for the young firm subsample; and regressions in columns 3 and 6 are for the mature firm subsample.

TABLE 10: Alternative sample selection criterion: at least three R&D observations.

	Full (1)	Young (2)	Mature (3)	Full (4)	Young (5)	Mature (6)
rd_{t-1}	0.433*	0.455*	0.359	0.907***	0.854***	0.503**
	(0.247)	(0.253)	(0.307)	(0.169)	(0.211)	(0.233)
rd_{t-1}^2	0.007	−0.599	0.119	−3.603***	−3.958**	−1.071
	(1.850)	(1.879)	(2.761)	(1.398)	(1.626)	(2.630)
cfo_{t-1}	0.022	0.016	0.030	−0.011	−0.002	−0.003
	(0.024)	(0.023)	(0.028)	(0.018)	(0.019)	(0.016)
cfi_{t-1}	0.012	0.007	−0.004	0.001	−0.002	−0.012
	(0.011)	(0.012)	(0.014)	(0.010)	(0.012)	(0.013)
cff_{t-1}	−0.022**	-0.027***	−0.012	−0.025***	−0.027**	−0.012
	(0.009)	(0.009)	(0.010)	(0.010)	(0.011)	(0.010)
$sales_{t-1}$	-0.011***	−0.008*	−0.005	−0.002	−0.001	−0.001
	(0.004)	(0.005)	(0.006)	(0.003)	(0.004)	(0.003)
$tobinq_t$				−0.003	−0.002	−0.003
				(0.002)	(0.003)	(0.003)
Δ cashholdings$_t$				0.019*	0.019	0.001
				(0.011)	(0.014)	(0.011)
$size_t$				−0.003	−0.005	0.001
				(0.003)	(0.005)	(0.004)
Time dummies	Yes	Yes	Yes	Yes	Yes	Yes
Firm dummies	Yes	Yes	Yes	Yes	Yes	Yes
AR(1)	0.000	0.000	0.012	0.000	0.000	0.003
AR(2)	0.955	0.603	0.627	0.062	0.218	0.846
Hansen	0.538	0.573	0.208	0.137	0.538	0.289
Obs.	7,176	4,778	2,398	6,261	4,160	2,101
Firms	1,898	1,406	713	1,826	1,347	674

Note. Robust standard errors are in parentheses; ***$p < 0.01$, **$p < 0.05$, and *$p < 0.1$. Estimation is by first-difference GMM. Time and firm fixed effects are included in all regressions. Lagged values dated from t-3 to t-5 are utilised as instruments for all explanatory variables. An alternative sample with at least three R&D observations is executed. Regressions in columns 1 and 4 are for the full sample; regressions in columns 2 and 5 are for the young firm subsample; and regressions in columns 3 and 6 are for the mature firm subsample.

TABLE 11: Replacement of all missed R&D values as zero.

	Full (1)	Young (2)	Mature (3)	Full (4)	Young (5)	Mature (6)
rd_{t-1}	1.816***	1.267**	1.891***	1.497***	1.025**	1.343***
	(0.417)	(0.541)	(0.538)	(0.340)	(0.416)	(0.492)
rd_{t-1}^2	−12.199***	−6.483	−15.365***	−9.425***	−5.015	−10.037***
	(3.862)	(5.084)	(4.490)	(2.778)	(3.644)	(3.583)
cfo_{t-1}	−0.027	0.024	0.014	−0.002	−0.004	0.008

TABLE 11: Continued.

	Full (1)	Young (2)	Mature (3)	Full (4)	Young (5)	Mature (6)
	(0.025)	(0.026)	(0.028)	(0.025)	(0.021)	(0.021)
cfi_{t-1}	0.017	0.031	0.006	0.005	−0.008	0.012
	(0.022)	(0.022)	(0.028)	(0.014)	(0.016)	(0.013)
cff_{t-1}	−0.039***	−0.032**	−0.010	−0.023**	−0.034***	−0.007
	(0.015)	(0.015)	(0.018)	(0.010)	(0.013)	(0.008)
$sales_{t-1}$	−0.012**	−0.013**	0.001	−0.005*	−0.003	0.002
	(0.005)	(0.006)	(0.006)	(0.003)	(0.004)	(0.003)
$tobinq_t$				0.001	0.003	−0.003
				(0.002)	(0.003)	(0.004)
$\Delta\,cashholdings_t$				0.012	0.031**	−0.009
				(0.015)	(0.014)	(0.015)
$size_t$				−0.007*	−0.008*	0.004
				(0.004)	(0.004)	(0.006)
Time dummies	Yes	Yes	Yes	Yes	Yes	Yes
Firm dummies	Yes	Yes	Yes	Yes	Yes	Yes
AR(1)	0.000	0.000	0.005	0.000	0.000	0.003
AR(2)	0.368	0.646	0.210	0.921	0.215	0.065
Hansen	0.553	0.727	0.740	0.529	0.582	0.869
Obs.	9,490	5,553	3,937	8,186	4,822	3,364
Firms	2,347	1,626	1,057	2,255	1,557	995

Note. Robust standard errors are in parentheses; ***$p < 0.01$, **$p < 0.05$, and *$p < 0.1$. Estimation is by first-difference GMM. Time and firm fixed effects are included in all regressions. Lagged values dated from t-3 to t-5 are utilised as instruments for all explanatory variables. All missing R&D values are set to zero. Regressions in columns 1 and 4 are for the full sample; regressions in columns 2 and 5 are for the young firm subsample; and regressions in columns 3 and 6 are for the mature firm subsample.

TABLE 12: Alternative firm age selection criterion.

	Young (1)	Mature (2)	Young (3)	Mature (4)
rd_{t-1}	0.794***	0.191	0.824***	0.717***
	(0.283)	(0.316)	(0.242)	(0.177)
rd_{t-1}^2	−3.035	1.492	−4.300**	−2.850
	(1.998)	(2.692)	(1.715)	(1.930)
cfo_{t-1}	0.015	0.006	−0.018	−0.012
	(0.025)	(0.031)	(0.023)	(0.018)
cfi_{t-1}	0.010	0.005	0.004	−0.005
	(0.013)	(0.015)	(0.010)	(0.012)
cff_{t-1}	−0.022**	−0.012	−0.025**	−0.014
	(0.009)	(0.010)	(0.010)	(0.010)
$sales_{t-1}$	0.001	−0.015***	0.009**	−0.005*
	(0.004)	(0.005)	(0.004)	(0.003)
$tobinq_t$			0.001	−0.002
			(0.003)	(0.003)
$\Delta\,cashholdings_t$			0.018	0.017
			(0.012)	(0.013)
$size_t$			−0.004	0.003
			(0.004)	(0.004)
Time dummies	Yes	Yes	Yes	Yes
Firm dummies	Yes	Yes	Yes	Yes
AR(1)	0.000	0.016	0.000	0.000
AR(2)	0.140	0.979	0.840	0.122
Hansen	0.697	0.533	0.539	0.366
Obs.	3,533	3,643	3,063	3,198
Firms	1,116	1,005	1,073	954

Note. Robust standard errors are in parentheses; ***$p < 0.01$, **$p < 0.05$, and *$p < 0.1$. Estimation is by first-difference GMM. Time and firm fixed effects are included in all regressions. Lagged values dated from t-3 to t-5 are utilised as instruments for all explanatory variables. An alternative firm age selection criterion is executed. The firms with less than 10 years' listed experience are categorised as young firms, and the remaining firms are counted as mature firms. Regressions in columns 1 and 4 are for the full sample; regressions in columns 2 and 5 are for the young firm subsample; and regressions in columns 3 and 6 are for the mature firm subsample.

TABLE 13: Interactions.

	(1)	(2)	(3)
rd_{t-1}	0.903***	0.922***	0.893***
	(0.168)	(0.166)	(0.173)
rd_{t-1}^2	−3.595**	−3.953***	−3.463**
	(1.432)	(1.423)	(1.428)
$sales_{t-1}$	−0.002	−0.003	−0.003
	(0.003)	(0.003)	(0.003)
$tobinq_t$	−0.003	−0.002	−0.002
	(0.002)	(0.002)	(0.002)
$\Delta\,cashholdings_t$	0.021**	0.025**	0.019*
	(0.010)	(0.010)	(0.011)
$size_t$	−0.003	−0.001	−0.004
	(0.003)	(0.004)	(0.003)
$cfo_{t-1} \times Age$	−0.006	0.007	−0.005
	(0.020)	(0.027)	(0.007)
$cfi_{t-1} \times Age$	−0.001	−0.002	0.002
	(0.013)	(0.014)	(0.005)
$cff_{t-1} \times Age$	−0.033***	−0.030**	−0.009***
	(0.012)	(0.013)	(0.004)
Time dummies	Yes	Yes	Yes
Firm dummies	Yes	Yes	Yes
AR(1)	0.000	0.000	0.000
AR(2)	0.086	0.125	0.071
Hansen	0.183	0.188	0.133
Obs.	6,266	6,266	6,237
Firms	1,827	1,827	1,823

Note. Robust standard errors are in parentheses; ***$p < 0.01$, **$p < 0.05$, and *$p < 0.1$. Estimation is by first-difference GMM. Time and firm fixed effects are included in all regressions. Regressions in columns 1 and 3 are for the full sample. Here, Age represents the firm age variables, which are Age_a_t, Age_b_t, and Age_c_t in columns 1,2, and 3, respectively.

3. Conclusions

R&D is an important driver of firms' competitiveness and economic growth. Using firm-level dynamic panel data for 2,401 Chinese listed firms from 2010 to 2017, this study investigates whether firms' R&D spending would increase when more cash flows from different business activities became available. In addition, the differential impacts of the cash flow sources of firms with different levels of maturity on R&D investment are discussed.

The findings concern mainly two aspects. First, it is found that Chinese firms will not necessarily spend more cash on R&D even if funds are available. In contrast, they would rather use funds for projects that are more profitable in the short term. This explanation can be supported by the disclosure information on financing activities presented above. Second, the findings suggest that CFO and CFI are nonsignificantly related to R&D spending for both young and mature firms, and CFF has a significantly negative impact on R&D spending for young, but not mature, firms.

With regard to implications, this study provides new insight into financing availability for innovative investment. In China and other emerging economies, financial markets are imperfect, and many firms lack funds [14]. Since continuous R&D investments require a great amount of cash, firm CFO and CFF may not be sufficient to meet such needs. Furthermore, even if cash is abundant, firm managers and external investors may be unwilling to invest in R&D due its

high uncertainty. Hence, alleviating financing constraints may not lead to greater innovation investments. Measures should be implemented to increase the willingness of firm managers to invest in R&D.

In addition, this paper clarifies the influencing mechanism between different cash flow sources and R&D investment. Firms are suggested to plan and manage CFO, CFI, and CFF as an organic unified system. According to the characteristics of the cash flow throughout the whole process of R&D, based on the differential management of firm cash flow, the investment management of CFO, CFF, and CFI on R&D should be integrated into an organic and unified management system. The differential management of CFF minimises financial costs while providing start-up funds for R&D investment. The differential management of CFI offers an important guarantee for R&D financing. The differential management of CFO would maximise the benefits of R&D investment by increasing R&D efficiency and reducing fees. In turn, the differential management of CFO would promote the steady progress of R&D financing and thus realise the integration of all aspects and the whole process of R&D activities.

Finally, this study explains the heterogeneous impacts of the cash flow sources of firms with different levels of maturity on R&D investment. Compared with the R&D investment of mature firms, the R&D investment of young firms is more significantly and negatively influenced by CFF. This is because young firms that need more CFF are generally in relatively poor operational condition. In addition, external investors are inclined to pursue short-term and low-risk investments and are less likely to support R&D investment, which has high uncertainty. To ensure the investment in R&D for young firms, policies and measures to stimulate innovation funds from external investors are suggested.

Since this study uses a different categorisation of finance from the perspective of business activities, future research might analyse the impact of funds from specific business activities (e.g., instrument investments, mergers, and acquisitions) on innovation activities. As for the study limitations, since a certain number of listed firms did not disclose their financing intents, we acknowledge that we only analysed the disclosed firms' intents regarding stock issuing, reissuing, and bank loan borrowing in this study. Therefore, it is recommended that these results are used only as support.

Data Availability

The sample of this study includes all Chinese firms from the Main Board, Small and Medium Enterprise (SME) Board, and ChiNext Board listed on the Shanghai Stock Exchange and the Shenzhen Stock Exchange. These listed firms cover 18 industries, and the details are presented in Table 1. The majority of statistics and disclosed information on financing activities used to support the findings of this study were, respectively, supplied by Wind (https://www.wind.com.cn/newsite/about.html) and China Stock Market & Accounting Research Database (CSMAR, https://cn.gtadata.com) under

license and so cannot be made freely available without permission. The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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