Received: 22 September 2018 | Revised: 4 January 2020 | Accepted: 18 June 2020
DOI: 10.1002/ijfe.2028

RESEARCH ARTICLE

WILEY

Peer effects in R&D investment policy: Evidence from China

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Funding information
Accounting Research Project of Guangdong Province in 2019-2020, Grant/Award Number: 19-20*084; Philosophy and Social Science Fund Project of Guangdong Province, Grant/Award Number: GD16XYJ22; Common University Innovation Talents Project (Youth Innovation Talents) of Guangdong Province, Grant/Award Number: 2016WQNCX018; National Natural Science Foundation of China, Grant/Award Number: 71672206

Abstract

Using a typical linear model on a sample of listed firms in China over a period of 10 years (2006–2016), this study empirically attempts proving how peer effects influence corporate research and development (R&D) investment decision. The study goes further to demonstrate that peer effects play a significant and critical role in determining corporate R&D investment policies, and by extension the more important determinant than most traditional firm-specific factors. After dealing with endogeneity bias and conducting further robustness checks, the above conclusions were valid in this study. It has been theorized in contemporary research that both information and market competition are the main channels through which one can best appreciate peer effects and that firms with weak information acquisition ability and in highly uncertain or competitive environment are more likely to be affected by peer groups. We also find evidence that a firm's R&D investment status relative to its peer firms will affect its R&D investment decision. Moreover, the direction of peer effects follows the law of imitation. Thus, firms are more likely to imitate those peers who share similar characteristics. Yet, leading firms and state-owned enterprises (SOEs) are exceptionally different as their R&D decisions are sensitive to both peer-followers and non-SOEs respectively.

KEYWORDS

competition, imitation, industry peers, information, peer effects, R&D investment

1 | INTRODUCTION

Innovation is essential to the survival and evolution of firms in today's highly competitive environment (Kim & Koo, 2018). What makes a firm innovative and what drives firms to engage more in innovative investment are important topics in finance and management which have attracted tremendous attention and research effort from both academic researchers and practitioners alike.[1] It has become increasingly important for both policy makers and academic researchers to understand the determinants of firm R&D investment drive since it is a cornerstone of various R&D-related issues (Lee, 2003). Most empirical research on corporate innovation policy thrives on the assumption that R&D investment choices are made independently of the actions or characteristics of their peers, or at most implicitly assumed to operate through an unmeasured impact on firm-specific determinants (Chen & Ma, 2017; Leary & Roberts, 2014). Yet the environment within which a firm exist greatly influence its behaviour and it plays an integral role in shaping the number of corporate financial policies (Grebel & Nesta, 2017; Joo, Yang, & Yang, 2016; Kaustia & Rantala, 2015; Leary & Roberts, 2014). Research has shown that the actions of peer firms may matter for corporate R&D investment policy choices (see Cockburn &

Henderson, 1994; Dasgupta & Stiglitz, 1980; Grebel & Nesta, 2017).

The contribution of this paper is to examine how peer firms behaviour matters for corporate R&D investment decisions in China. We identify peer groups by three digits industry category and define them as enterprises in the same industry in the same year. Our sample includes 1,837 companies in China stock markets (i.e., Shanghai and Shenzhen Stock Exchange) over a decade (2006–2016). Consistent with peer effects prediction, our empirical results regardless of the estimation approach show that the average R&D investment intensity of peers can positively stimulate enterprises R&D investment. When a firm's peers increase their R&D investment intensity in the previous year, then the firm's R&D investment intensity is bound to increase in the year after. In addition, we also find that these peer effects play a critical role in determining corporate R&D investment policies, and more important than most previously identified determinants. To deal the issue of endogeneity bias, we choose peer firms' idiosyncratic equity return shocks as an instrument for peer firms' R&D investment intensity, and retest our empirical sample based on the instrumental variable (IV) approach.

One of the challenges in testing peer effects is to identify the peer groups. To avoid peer identification bias, we further examined whether the industry peers are really the firm's reference group in making the corporate R&D investment decisions. We focused on the companies that have changed their industry category during the sample period. There were 333 firms and 356 firm-year observations to meet the test requirement. We observed that firm will change its reference groups (or peers) when its industry category has changed. As a result, we found it reasonable to choose peers from the industry perspective due to the likelihood of this phenomenon.

According to Lieberman and Asaba (2006), information-based theories and rivalry-based theories are the main driving mechanisms of peer effects. To examine whether these two mechanisms are the possible channels through which peer firms influence a firm's R&D investment policies, we develop our predictions based on the moderating effects of information and competition variables on the relationship between peer firms' average R&D investment intensity and firm *j*'s R&D investment intensity. We find that the R&D investment policies in firms with poor information acquisition ability and in the years with highly economic policy uncertainty to be more likely to be affected by peer effects. We also find that peer effects in R&D investment policy are more pronounced in a highly competitive market. The above results show that peer effects in enterprise R&D investment decision-making is derived from both information and competitive mechanisms.

In addition, according to Bizjak, Lemmon, and Naveen (2008) and Yang and Yang (2009), a firm's investment status relative to their peer firms may affect its investment decision. Based on this competitive benchmarking mechanism for peer effects, we further examine whether a firm's R&D investment intensity status relative to their peer firms will influence its R&D investment decision. Other evidence gathered showed that peer firms' average R&D investment intensity may be a reference point for firm R&D investment decision. When firm's R&D investment intensity is below the peer firms' average R&D investment intensity in the last year, the firm is more likely to increase its R&D investment in the coming year; and the more it falls behind, the greater it improves. These results prove once again that peer effects matter in enterprise R&D investment decisions.

Finally, we examined the heterogeneity of peer effects in corporate R&D investment decision. We find that, for R&D investment policy, the follower firms are influenced by both follower-peer and leader-peer firms, but the influence from follower-peer firms is larger. Leader firms are only influenced by the follower-peer firms. Firms with less profitability are influenced by both less-profitability-peer and more-profitability-peer firms, but the influence from less-profitability-peer firms are larger. Firms that are more profitability are only influenced by peers that share similar traits (i.e., profitability). Firms with strong innovation ability only pay attention to their kind, whiles those that are weak innovators have a two pronged strategies – focus on both firms with strong and weak-ability, but the influence from weak-ability peer firms are larger. State-owned enterprises (SOEs) attach importance to both SOEs and non-SOEs peer firms, but the influence from non-SOE peer firms are larger. Non-SOE attaches importance to both SOE and non-SOE peer firms, but the influence from non-SOE peer firms are larger. The above results indicated that the influence direction of peer effects in general obey the law of imitation from within to without put forward by Tarde (1903).

Our study is most closely related to those literatures which emphasized on the importance of enterprises cluster (Pouder & Johhn, 1996) and social network (Fracassi, 2017; Patnam, 2011) as R&D investment policy determinant. Broadly speaking, there are two types of mechanisms by which imitating objects can be identified: (a) connection, and (b) observation. The former emphasizes on inter-organizational networks, whiles the latter holds that imitation can occur through the observation of relevant information obtained from a variety of media (McKendrick, 2001; Miner & Haunschild, 1995). Both enterprises cluster and social network in previous studies have emphasized on connection mechanism. However, in this study, we stress the importance of observational learning, in which imitation can occur between companies that may have no real connections. This is what distinguishes our study from previous ones and thus syncs with our contribution to knowledge to stimulate further discourse.

The rest of the paper is organized as follows. Section 2 reviews relevant literature on peer effects and develops the hypotheses. Section 3 describes the methodology and data. Section 4 presents our primary results and robustness checks. Section 5 concludes with some policy recommendations.

2 | LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

2.1 | Literature review

Peer effects exist when an individual's behaviour is affected by his or her interaction with one or more other individual (Winston & Zimmerman, 2003). They are empirically elusive in the social sciences, but critical to policy makers (Aral & Walker, 2012). These influences can create social multiplier effects, whereby a small initial shock can lead to larger changes as individuals are directly influenced by each other's actions (Kaustia & Rantala, 2015). In view of the universality and the important role for solving social problems, peer effects have aroused many researchers interest from the fields of sociology, education, economics, psychology, finance and management.

Corporate actions are a potential domain for such peer effects, as anyone having experience with corporate management knows that firms pay close attention to their peer firms (Kaustia & Rantala, 2015). Information related to the activities of peer firms is indispensable for almost all corporate strategies (Joo et al., 2016). Recent studies have shown that corporate financial policies and behaviour are influenced by their peers, for example, corporate capital structures (Leary & Roberts, 2014), stock splits (Kaustia & Rantala, 2015), dividend payments (Grennan, 2019), cash holdings (Chen, Chan, & Chang, 2019), corporate social responsibility (Cao, Liang, & Zhan, 2019) and so on.

Peer effects are kind of endogenous social effect, wherein the propensity of an individual to behave in some way varies with the prevalence of that behaviour in some reference group containing the individual (Manski, 1993). One of the main manifestations of the peer effects is imitation, which is a very common form of behaviour that arises in a variety of business domains (Leary & Roberts, 2014; Lieberman & Asaba, 2006). Scholars from diverse disciplines have proposed numerous theories to explain why and how business imitation occurs. One of the seminal researches was done by Gabriele Tarde, an outstanding sociologist from France in 19th century. In his famous book "*The Laws of Imitation*," Tarde (1903) thought inter-organizational imitation behaviour will obey the law of logical imitation and the imitation from within to without. The law of logical imitation emphasizes that the appearance of imitated objects and the degree of imitation are intrinsically logical. Those with high efficiency, good performance and high status are more likely to be imitated. The imitation from within to without highlights that the individual's imitation and selection of local culture and its behaviour always takes precedence over foreign culture and its behaviour. That is, the imitator has a congenital tendency to imitate objects similarly to their own cultural attributes. For example, objects that belong to the same cultural space face similar institutional and industrial policies, share common consumer groups and service targets.

Another seminal work was done by Lieberman and Asaba (2006), in the paper "*Why Do Firms Imitate Each Other*," organized numerous theories of business imitation into two broad categories. The first category is information-based theories, where information imperfection is the main cause of imitation and firms will follow others that are perceived as having superior information. The second category is rivalry-based theories, where firms imitate others to limit rivalry or maintain relative position in the market.

It is worth noting that there are some other manifestations for peer effects besides imitation. One of the examples is that information from peer firms may matter for the firm's relevant decisions. Foucault and Fresard (2014) explained that peers' stock prices are significantly associated with corporate investment. Another example is that a firm's status relative to their peer firms in some kind of behaviours may also affect its decision. Based on the competitive benchmarking theory, Yang and Yang (2009) and Bizjak et al. (2008) find that a firm's CEO (or top executive) pays status relative to its peer firms will affect its pay changes. In general, the peer effects are universals and their influences have many kinds of manifestations.

2.2 | Hypotheses development

Through the literature review above, we hold the opinion that peer effects in corporate R&D investment policy can also be explained by information-based theory and rivalry-based theory. We do further explication below on this matter.

R&D activity is a kind of explorative behaviour, which is highly uncertain with some level of ambiguity that makes managers to be unsure of the likelihood of possible outcomes. Managers may find it difficult in recognizing cause-effect relationships and the full range of potential consequences with great confidence. In such environments, managers seek for ways to reduce search uncertainties and costly strategic mistakes through mimetic. They are particularly likely to be receptive to information implicit in the actions of peer firms. Such information, although highly imperfect, can have a strong influence on managerial perceptions and beliefs (see Anand, Mesquita, & Vassolo, 2009; Lieberman & Asaba, 2006). However, under certain circumstances, even if managers have their own private information, they will ignore it and imitate the R&D investment decisions of peer firms. Although this behaviour is inefficient from a social and economic standpoint, it can be rational from the perspective of managers who are concerned about their reputation in the labour market (Scharfstein & Stein, 1990).

Rivalry-based theories argue that firms mimic each other to maintain competitive parity or limit rivalry. Competitor actions can motivate firms to act, even when social pressures are relatively small (Pacheco & Dean, 2015). Firm imitate competitor behaviour as a response designed to mitigate competitive rivalry or risk. When competitors take similar actions, there is less chance that any firm will succeed or fail relative to others. Specifically, in the area of corporate innovation, the first inventor can obtain first mover advantages and some key patent rights of technology. To defuse rivals, the firm will follow the innovation actions of their competitors so that R&D investments among competitors may be positively correlated (Anand et al., 2009; Fracassi, 2017; Lieberman & Asaba, 2006; Patnam, 2011). Based these perspectives, we hypothesis that:

Hypothesis 1 *A firm's R&D investment is significantly affected by its peer firms.*

3 | RESEARCH DESIGN, SAMPLE SELECTION AND SUMMARY STATISTICS

3.1 | Research design and model specification

3.1.1 | Baseline empirical model

To examine the influence of peer effects on the R&D investment, we adopt a typical linear model by Manski (1993) and others (see Joo et al., 2016; Leary & Roberts, 2014) as shown below:

$$y_{i,j,t} = \alpha + \beta\bar{y}_{i,-j,t-1} + \gamma'\overline{X}_{i,-j,t-1} + \lambda' X_{i,j,t-1} + \delta'\mu_i + \varphi'\nu_t + \varepsilon_{i,j,t}. \quad (1)$$

In Equation (1), the indices i, j and t correspond to industry, firm and year, respectively; the indices $-j$ stands for peer firms (excluding firm j). $y_{i,j,t}$ is a measure of corporate R&D investment policy, such as firm R&D investment intensity (i.e., the ratio of R&D to sales), while the covariate $\bar{y}_{i,-j,t-1}$ denotes peer firms (excluding firm j) average outcomes (i.e., the peer firms' average R&D investment intensity). This variable is lagged for two reasons: First, considering R&D investment policy is a business secret, it is possible but very difficult to obtain peer firms' accurate R&D investment information in real time or even in the same year. However, mandatory disclosure of R&D investment information begun in 2007 in China and such information is available in the previous year annual report. Second, the contemporaneous measure will trigger serious reflection problem raised by Manski (1993) which makes it more difficult to identify mimicking behaviour (Leary & Roberts, 2014). Fortunately, time lag measure will reduce part of this reflection problem (Mugerman, Sade, & Shayo, 2014). The vectors $\bar{X}_{i,-j,t-1}$ and $X_{i,j,t-1}$ represent peer firms average characteristics and firm-specific characteristics respectively. This includes ASSET, INCOME, DAR, ROA, CASH, and TOBINQ (see Appendix A for the definition of variables). The notations μ_i and ν_t represent industry and year fixed effects, respectively. $\varepsilon_{i,j,t}$ is the firm-year specific error term assumed to be correlated within firms and heteroskedastic.

According to Manski (1993), $\bar{y}_{i,-j,t-1}$ is endogenous effect factor, $\bar{X}_{i,-j,t-1}$ are exogenous (contextual) effect factors, $X_{i,j,t-1}$, μ_i, and ν_t are correlated effect factors.[2] The coefficients λ',$\delta'$and ϕ' capture the correlated effects; β, γ' capture the peer effects (Leary & Roberts, 2014). However, only endogenous effects can trigger social multiplier effects, and the other two effects could not (Manski, 1993). Thus, this paper focuses on the coefficient β. If β statistically significant, then it means a firm's R&D investment is significantly affected by its peer firms.

3.1.2 | Channel identification model

To identify the main driving mechanisms of peer effects, we adopt a moderate effect model used by Chen and Ma (2017) as shown below:

$$y_{i,j,t} = \alpha + \beta_1 \bar{y}_{i,-j,t-1} + \beta_2 Mode^* \bar{y}_{i,-j,t-1} + \beta_3 Mode + \gamma' \overline{X}_{i,-j,t-1} + \lambda' X_{i,j,t-1} + \delta' \mu_i + \varphi' \nu_t + \varepsilon_{i,j,t}. \quad (2)$$

In Equation (2), variable *Mode* represents the influence channel of peer effects. According to Lieberman and Asaba (2006), information-based theories and rivalry-based theories are the two possible channels through which peer firms influence firm *j*'s R&D investment policies.

Based on the information theory, firms will actively imitate peer firms' R&D investment decisions as they have imperfect information and they believe that their peers' actions can convey some useful information. Thus, we predict that if firms are able to capture the information that making R&D investment decision needed, they will have less incentive to mimic their peer firms' decisions. We test this prediction in two ways. First, we used the market status to measure the informational advantage of a firm. If the firm's market status is higher, it may have the ability to capture more useful information for itself and will be less sensitive to their peer firms' decisions. Following Leary and Roberts (2014), we used a firm's market share to represent its market status. If the firm's market share rank in the upper third among the peer firms, it means the firm's market status is higher. We also used a dummy variable STATUS which we equated to one, or otherwise to zero. If β_2 is statistically negative and significant, then it means that the market status has reverse moderating effects on the relationship between firm's and their peers' R&D investment, and it can be asserted that the peer effects in corporate R&D investment decision-making are partly derived by the information mechanism.

Secondly, according to Lieberman and Asaba (2006), environmental uncertainty is the main cause that makes firms to imitate each other. Managers are more difficult to predict the consequences of R&D action or behaviour in an uncertain environment and raise the likelihood of investment failure. The higher the environmental uncertainty, the more likelihood that the firms will imitate their peer firms. We used the economic policy uncertainty index (EPUI) by Baker, Bloom, and Davis (2016) to capture environmental uncertainty. If β_2 is statistically positive and significant, then it means that the economic policy uncertainty has up-regulated effects on the relationship between firm's and their peers' R&D investment. We can then assert that information mechanism is one of the driving mechanisms for corporate R&D investment peer effects.

Based on the rivalry theory, the reason why firms imitate their peer firms' innovation decisions is that they want to maintain competitive parity or limit rivalry. The fierce competition will encourage companies to respond more aggressively to competitors' innovative behaviour. Therefore, if we can observe that the firms' R&D investment are more likely to be affected by peers in competitive environment, then we can conclude that the peer effects of enterprise R&D investment decision-making is partly derived by the competitive mechanism.

Following Chen and Ma (2017) and Curry and George (1983), we used market structure and the number of peer firms to capture market competition. Thus, market structure is calculated by Herfindahl–Hirschman Index (HHI). If HHI < 0.1, then the market structure belongs to competitive type, the dummy variable HHID equals zero; otherwise if HHI ≥ 0.1, the market structure belongs to monopoly type, the dummy variable HHID equals one. If β_2 is statistically negative and significant, then it means that the market structure has reverse moderating effects on the relationship between firm's and their peers' R&D investment. We can base on this relationship to assert that peer effects in corporate R&D investment decision-making are partly derived by the competitive mechanism.

The number of peer firms also can be used to characterize industry competition. The more the peer firms, the fiercer the competition between firms (Curry & George, 1983). If the number of peer firms (including firm *j*) in one group is bigger than the median of the whole groups in the sample, then the dummy variable PNUM equals one; otherwise if the number of peer firms (including firm *j*) in one group is smaller than the median of the whole groups in the sample, then the dummy variable PNUM equals zero. If β_2 is positive and significant statistically, then it means that the competition has up-regulated effects on the relationship between firm's and their peers' R&D investment, and it can be asserted that the competition mechanism is one of the driving mechanisms for corporate R&D investment peer effects.

The definitions of other variables in Equations (1) and (2) are explained in Appendix A.

3.1.3 | Another manifestation of peer effects

In addition to imitation, there is another manifestation for peer effects. According to Yang and Yang (2009) and Bizjak et al. (2008), a firm's pay status relative to their peer firms will affect it pay decision. This is also a manifestation of peer effects. To examine whether the corporate R&D investment status relative to the peer firms will affect its investment changes after controlling for other factors that are related to R&D investment, we adopt a model which also used by Bizjak et al. (2008) and Yang and Yang (2009) as shown below:

$$\Delta y_{i,j,t} = \alpha + \beta_1 Rdgap_{i,-j,t-1} + \gamma' \overline{X}_{i,-j,t-1} + \lambda' X_{i,j,t-1} + \delta' \mu_i + \varphi' \nu_t + \varepsilon_{i,j,t}. \quad (3)$$

In Equation (3), $\Delta y_{i,\,j,\,t}$ represents the change in R&D investment from year *t*-1 to year *t*. We use two kinds of measures to capture this change. If the change is positive, then variable ΔRD1 takes the value one; otherwise if the change is negative, variable ΔRD1 takes the value zero. Variable ΔRD2 represents the real change in R&D investment from year *t*-1 to year *t*. $Rdgap_{i,\,-j,\,t-1}$ represents the distance from peer firms' mean R&D investment. We also use two variables to capture this gap. Variable RDGAP1 is a dummy variable, if a firm's R&D investment is below the peer firms' mean R&D investment in the prior year, then variable RDGAP1 takes the value one; otherwise, RDGAP1 takes the value zero. RDGAP2 equals the peer firm's mean R&D investment in the prior year minus the firm's R&D investment in the prior year. If RDGAP2 is positive, then it indicates that the firm's R&D investment below the peer firms' mean R&D investment. If β_1 is significant in statistically, then it means that the peer effects are important component in determining R&D investment.

The definitions of other variables in Equation (3) are the same as in Equation (1), see Appendix A.

3.1.4 | The heterogeneity of peer effects

To examine whether some firms within the peer groups are more or less sensitive to their peers' R&D investment policies, we adopt a model as shown below:

$$y_{i,j,t} = \alpha + \beta_1 Psame_{i,-j,t-1} + \beta_2 Pother_{i,-j,t-1} + \gamma' \overline{X}_{i,-j,t-1} + \lambda' X_{i,j,t-1} + \delta' \mu_i + \varphi' \nu_t + \varepsilon_{i,j,t} \quad (4)$$

$Psame_{i,\,-j,\,t-1}$ represents the mean R&D investment of peer firms, which have the same characteristics with firm *j*; $Pother_{i,\,-j,\,t-1}$ represents the mean R&D investment of the rest of the peer firms without these characteristics. Following Leary and Roberts (2014), we classified peer firms into two groups based on firm-specific characteristics such as market share, profitability, innovation ability and ownership property.

First, we categorized peer firms into two groups that we call leader and follower based on the income of the industry for that year. Leaders are those firms in the upper-third of the distribution, and the remaining part in peer groups are called followers. Variable PLEAD represents the mean of R&D investment of peer firms which belong to leader enterprises. Variable PFOLLOW represents the mean of R&D investment of peer firms which belong to follower enterprises.

Second, we categorized peer firms into two groups that we called more-profitable enterprises and less-profitable enterprises based on the firm-year's return of asset (ROA). More-profitable enterprises are those firms in the upper-third of the distribution, and the remaining part in peer groups are called less-profitable enterprises. Variable PPROFIT represents the mean of R&D investment of peer firms which belong to more-profitable enterprises. Variable PNPROFIT represents the mean of R&D investment of peer firms which belong to less-profitable enterprises.

Third, we categorized peer firms into two groups that we called strong enterprises and weak enterprises based on the firm's innovation ability. If a firm listed in "Top 500 Enterprises in Innovation Ability," which produced by ZIJIN MEDIA THINK TANK, then these firms are called strong enterprises; otherwise, the remaining part of the peer groups are called weak enterprises. Variable PSTRONG represents the mean of R&D investment of peer firms which belong to strong enterprises. Variable PWEAK represents the mean of R&D investment of peer firms which belong to weak enterprises.

Fourth, we classified peer firms into two groups that we called SOEs and non-state-owned enterprises (NSOEs) based on the ownership property of actual controller. If a firm's ownership property of actual controller is central or local government, then these firms are called SOEs; otherwise, the remaining part in peer groups are called NSOE. Variable PSOE represents the mean of R&D investment of peer firms which belong to SOE. Variable PNSOE represents the mean of R&D investment of peer firms which belong to NSOE.

In this part, we focused on the coefficient β_1 and β_2. The definitions of other variables in Equation (4) are the same as in Equation (1), see Appendix A.

3.2 | Sample selection

China provides an ideal scenario for studying peer effects due to the following reasons. First, the traditional culture of China is based on the philosophy of "*The Golden Mean*," which emphasizes harmony instead of unconventional attitudes. When people make decisions, they may consider the behaviour of others in advance. Secondly, the Chinese Communist Party pays more attention to "*Keep in Alignment*" or "*orderliness*" which may affect the behaviour of business decision-making.

Following Leary and Roberts (2014), this study defines peer firms as those enterprises in the same industry. Specifically, the industry identification method is based on the industry code published by China Securities Regulatory Commission (CSRC). In our peer groups, industries are defined based on three-digit CSRC industry code. Considering the problem of comparison, the number of companies in the same group is at least two.

Our primary data on R&D expenditure comes from the Wind database (Wind) for the last 9 years (2007–2016). The other financial data were derived from China Stock Market and Accounting Research Database (CSMAR) over the last decade (2006–2016). Our sample was confined to industrial enterprises and related industrial services enterprises, including manufacturing, information technology services, scientific research and technology services. We excluded observations with missing data on any variable. The final unbalanced panel sample contains 13,604 firm-year observations with 1,837 unique firms over the last decade (2006–2016).[3] To mitigate the influence of extreme observations, we winsorized all continuous variables at the 1st and 99th percentiles.

Table 1 presents the descriptive statistics of the main variables in our final sample. In the sample, the mean of R&D investment intensity is 4% almost similar to peer firms' 3.8%. The mean of ΔRD2 (the first differences for R&D investment intensity) is 0.3%, which suggests that firm's R&D investment intensity have been increasing year by year in generally.

TABLE 1 Descriptive statistics (N = 13,604)

Variables	Mean	*SD*	Min.	Max.
RD	0.040	0.050	0.000	0.291
MRD	0.038	0.031	0.001	0.152
ΔRD1	0.491	0.500	0	1
ΔRD2	0.003	0.023	−0.080	0.111
RDGAP1	0.614	0.487	0	1
RDGAP2	0.000	0.0394	−0.186	0.109
MASSET	0.456	0.220	0.114	1.212
MINCOME	0.338	0.220	0.069	1.298
MDAR	0.450	0.137	0.256	1.284
MROA	0.054	0.030	−0.045	0.168
MCASH	0.235	0.079	0.091	0.476
MTOBINQ	0.030	0.014	0.014	0.102
ASSET	0.308	0.418	0.002	2.613
INCOME	0.236	0.354	0.006	2.071
DAR	0.416	0.207	0.044	1.112
ROA	0.055	0.070	−0.202	0.297
CASH	0.236	0.167	0.010	0.770
TOBINQ	0.029	0.023	0.002	0.148
STATUS	0.358	0.480	0	1
EPUI	1.455	0.502	0.733	2.444
HHID	0.381	0.486	0	1
PNUM	0.491	0.500	0	1

Notes: All numeric values are reserved to three decimal places. The unit of ASSET and INCOME is 100 million yuan. Both TOBINQ and EPUI are divided by 100.

4 | RESULTS AND DISCUSSION

4.1 | Main empirical results for baseline model

Table 2 presents the empirical results for the peer effects in R&D investment policy. Before regression, we used Hausman Test to decide which kinds of estimation method (fixed or random effect) is suitable for our panel data. As the Hausman Test result chi-square value equals to 841.68, p-value is .000, so that fixed effect is more appropriate for the estimation of our panel data.

In column (1) of Table 2, the main variable MRD (peer firms' average R&D investment intensity) shows a positive and significant relationship with variable RD (firm j's R&D investment intensity). The coefficient of MRD is 0.308, significant at 1% level. A 1 *SD* increase in peer firms' R&D investment intensity leads to 30.8 percentage point increase in firm j's R&D investment intensity. In addition, variable MCASH, INCOME, CASH, TOBINQ exhibit significant relationship with RD. These results indicate that after controlling the contextual and correlated factors, it still can find that the firm j's R&D investment decision will be significantly affected by its peer firms' R&D investment policies. When peer firms increase their R&D investment intensity in the previous year, the firm j's R&D investment intensity will be increased in the coming year.

Moreover, compared to traditional firm-specific determinants, peer firms' R&D investment policy have a significantly larger effect. For example, in column (1) of Table 2, the next-most impactful variable is TOBINQ, whose scaled coefficient is 0.093 (which is almost 2.4 times smaller). These results lend credence to our hypothesis which suggests that peer effects are one of the most important forces that stimulates corporate innovation investment.

4.2 | Endogeneity bias and treatment

To identify peer effects, one of the challenges is the reflection problem raised by Manski (1993). Peer firms'

TABLE 2 Peer effects on a firm's R&D investment policy

Variables	Panel A: Fixed-effects model RD (1)	Panel B: Instrumental variable model MRD (1) first-stage	RD (2) second-stage
MRD	0.308*** (0.054)		0.257** (0.101)
PIERS		0.009*** (0.000)	
MASSET	−0.001 (0.002)	−0.003*** (0.001)	−0.002 (0.002)
MINCOME	0.002 (0.003)	−0.014*** (0.001)	0.001 (0.003)
MDAR	0.004 (0.004)	−0.014*** (0.001)	0.004 (0.003)
MROA	0.006 (0.014)	−0.001 (0.005)	0.007 (0.014)
MCASH	−0.023**(0.011)	0.086*** (0.004)	−0.020 (0.013)
MTOBINQ	0.051 (0.044)	0.231*** (0.012)	0.068 (0.047)
ASSET	0.001 (0.001)	0.001* (0.000)	0.001 (0.001)
INCOME	−0.024*** (0.004)	0.001 (0.001)	−0.024*** (0.002)
DAR	−0.005 (0.004)	0.001 (0.001)	−0.005* (0.002)
ROA	−0.011 (0.007)	−0.003* (0.002)	−0.011** (0.005)
CASH	0.009** (0.004)	−0.002** (0.001)	0.009*** (0.002)
TOBINQ	0.093*** (0.028)	0.043*** (0.005)	0.096*** (0.016)
_Cons	0.025*** (0.005)	−0.019*** (0.002)	0.024*** (0.005)
Industry FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
No. of obs.	13,604	13,604	13,604
No. of groups	1,837	1,837	1,837
Adj. R^2	0.149	0.777	0.152
F/ Wald chi-square	38.88***	753.71***	35,603.13***

Notes: The sample consists of 1,837 firms listed on Shanghai and Shenzhen Stock Exchanges from the year 2006 to 2016 with non-missing data for all analysis variables (see Appendix A). Peer groups are defined by three-digit CSRC industry code. The dependent variable is indicated at the top of columns. Panel A, column (1), presents the results based on the baseline model. Panel B column (2) and (3) presents the results based on the instrumental variable model (column (2) and (3) presents the results of first-stage and second-stage, respectively). Industry and year fixed effects are all controlled in these models. Robust *SEs* in parentheses. All coefficients are adjusted using company clustering.

*Statistical significance at 10% level.

**Statistical significance at 5% level.

***Statistical significance at 1% level.

behaviour can influence firm *j*'s decision, meanwhile, firm *j*'s behaviour can also affect its peer firms' decision. This simultaneous movements like a man and his reflection in a mirror. It is hard to tell whether this mirror image cause the person's movements or just reflect them. This simultaneity implies that $\bar{y}_{i,-j,t-1}$ is an endogenous variable. Although following Mugerman et al. (2014) approach which allowed us to use a one lagged period model, we observed further that the problem of endogeneity bias was not fully resolved.

To find a lasting solution to the endogeneity bias problem, there was the need for an enhanced robustness check of our results. Thus, following Leary and Roberts (2014), we adopted the instrumental variable (IV) approach and choose peer firms' idiosyncratic equity return shocks (PIERS) as an instrument for peer firms' R&D investment intensity (MRD). Substantial theoretical and empirical evidence shows that corporate innovation relevant for stock returns (see Sood & Tellis, 2009; Vassalou & Apedjinou, 2003). PIERS are serially uncorrelated and cross-uncorrelated (see Chen & Ma, 2017; Leary & Roberts, 2014). PIERS are relevant for peer firms' R&D investment intensity, but not relevant for firm *j*'s R&D investment intensity. These characteristics make the PIERS meet the requirement of IV for our research. More precisely, the data on idiosyncratic equity return shocks comes from Wind database for the period of 9 years (2006–2015).

Columns (2) and (3) of Table 2 displays the results based on the IV regression estimation. The first-stage regression results are shown in column (2), and we can see that the PIERS is strongly and positively correlated with peer firms' average R&D investment intensity (MRD) with a coefficient of 0.009 and significant at 1% level. The second-stage regression results are shown in column (3), and the main variable MRD (peer firms' average R&D investment intensity) shows a positive relationship with RD (firm *j*'s R&D investment intensity) with a coefficient of 0.257 significant at 1% level. These results are consistent with the priori expectations in our baseline model. In addition, the multivariate F-statistic is 1,138.04 in the first-stage, which is much bigger than experience value 10, so that the variable PIERS is not a weak IV. Based on the above analysis, we can argue to some extent that a firm's R&D investment policies are partly driven by a response to their peer firms.

4.3 | Robustness tests

The above results show that peer effects are important determinants of corporate R&D investment decisions and such behaviour is in reference to the industry the firm finds itself. In order to avoid peer identification bias from the current criteria, we do further test to ascertain whether industry peers really matter for firm's R&D investment decisions. The rule of thumb is that, if it does matter then when a firm's industry is changed, it should automatically affect its reference group accordingly. Based on this, we focus on companies that have changed their industry category during the sample period. There were 333 firms who changed their industry code between 2007 and 2016. Among these firms, 311 firms changed their industry one time, and 21 firms changed twice, with the remaining firms having changed thrice.

Table 3 present the test results based on the importance of industry peers from the perspective of the IV regression estimation approach. In Panel A, the identification of the peer groups is based on the industry code before code change, whiles in Panel B, the identification of the peer groups is based on the industry code after changes were made to its code. For instance, if a firm's industry code was C13 in 2007, but in 2008 it changed to C27. This implies that the firm had two kinds of peer groups: (a) firms with industry code C13 (in Panel A) and (b) firms with industry code C27 (in Panel B). We argue that if the industry peers really matter to the firms' R&D investment decision, then the firm will change its reference groups with the ensuing change of industry code and is supposed to be significant in both panels A and B respectively.

In column (1) of Panel A, we can see that the PIERS is strongly and positively correlated with peer firms' average R&D investment intensity (MRD) in the first-stage, the coefficient is 0.03 and significance at 1% level. But the relationship between MRD (peer firms' average R&D investment intensity) and RD (firm *j*'s R&D investment intensity) is not significant in the second-stage, as shown in column (2) of Panel A. In column (1) of Panel B, PIERS is strongly and positively correlated with peer firms' average R&D investment intensity (MRD) in the first-stage, the coefficient is 0.031 and significance at 1% level. At the same time, our main variable MRD (peer firms' average R&D investment intensity) shows a positive relationship with RD (firm's R&D investment intensity) in the second-stage, the coefficient is 0.805 and significance at 1% level, as shown in column (2) of Panel B. In addition, the multivariate F-statistic in first-stage of Panel A and Panel B are 106.854 and 102.037, respectively, which are bigger than experience value 10. This means that our instruments variable is not weak. Thus, peer effects are significant in Panel B, but not significant in Panel A, which means that a firm will change its reference groups when its industry code changed. We can also conclusion that industry peers are really matter for firm's R&D investment decision as assumed and its reasonable for us to choose the peers from the perspective of industry.

4.4 | Channel identification

To further investigate the driving mechanisms of peer effects, we develop our predictions based on the information theory and rivalry theory, and empirically examine the moderating effects of relevant variables on the relationship between peer firms' average R&D investment intensity (MRD) and the firm's R&D investment intensity (RD). Panel A and Panel B in Table 4 report the respective results based on the channel identification model.

In column (1) of Panel A, the coefficient of interaction term STATUS*MRD is −0.084 and significant at 10% level. It means that the lower a firm's market status, the more sensitive it is to its peer firms' R&D investment decisions (the marginal effect can also be observed in Figure 1(1)). In column (2) of Panel A, the coefficient of interaction term EPUI*MRD is 0.050 and significant at 5% level. This implies that the higher the environmental uncertainty, the more likely the firm will imitate peer firms' R&D investment decisions (the marginal effect can also be observed in Figure 1(2)). Both firm's market status and EPUI are relevant to firm's information acquisition

TABLE 3 The test for the importance of industry peers

Variables	Panel A: The identification of peer groups is based on the industry code before its change MRD (1) first-stage	RD (2) second-stage	Panel B: The identification of peer groups is based on the industry code after its change MRD (1) first-stage	RD (2) second-stage
MRD		0.493 (0.312)		0.805*** (0.298)
PIERS	0.030*** (0.003)		0.031*** (0.003)	
MASSET	0.018*** (0.006)	0.044** (0.019)	0.000 (0.007)	0.035 (0.022)
MINCOME	−0.032*** (0.007)	−0.022 (0.024)	−0.004 (0.007)	−0.022 (0.022)
MDAR	−0.020*** (0.006)	0.017 (0.022)	−0.084*** (0.010)	0.026 (0.041)
MROA	−0.027 (0.036)	−0.081 (0.115)	−0.406*** (0.055)	0.195 (0.212)
MCASH	0.243*** (0.013)	0.047 (0.063)	0.363*** (0.017)	−0.082 (0.102)
MTOBINQ	0.029 (0.071)	0.172 (0.228)	0.492*** (0.081)	−0.650* (0.361)
ASSET	0.017*** (0.005)	0.033** (0.016)	0.009* (0.005)	0.044*** (0.016)
INCOME	−0.017*** (0.006)	−0.046** (0.021)	−0.004 (0.006)	−0.058*** (0.020)
DAR	−0.019*** (0.005)	−0.048*** (0.018)	−0.008 (0.006)	−0.052*** (0.017)
ROA	−0.026* (0.014)	−0.009 (0.046)	−0.033** (0.015)	−0.024 (0.046)
CASH	−0.003 (0.007)	0.010 (0.021)	0.010 (0.007)	0.007 (0.020)
TOBINQ	0.073** (0.036)	0.147 (0.121)	0.108*** (0.041)	0.100 (0.136)
_Cons	−0.012* (0.007)	0.006 (0.021)	−0.015* (0.008)	0.038 (0.023)
No. of obs.	356	356	356	356
Adj. R^2	0.715	0.253	0.827	0.236
F/ Wald chi-square	69.50***	118.32***	131.17***	109.08***

Notes: The subsample consists of 333 firms whose industry codes were changed at least once between 2007 and 2016. Peer groups are defined by three-digit CSRC industry code. The dependent variable is indicated at the top of columns. This table presents the results based on the instrumental variable model and choose peer firms' idiosyncratic equity return shocks (PIERS) as the instrument for peer firms' average R&D investment intensity (MRD). In Panel A, the identification of peer groups is based on the industry code before its change, and in Panel B, the identification of peer groups is based on the industry code after its change. Robust *SEs* in parentheses. All coefficients are adjusted using company clustering.
*Statistical significance at 10% level.
**Statistical significance at 5% level.
***Statistical significance at 1% level.

ability. These results indicate further that peer effects in corporate R&D investment decision-making are partly driven by the information mechanism.

In column (1) of Panel B, the coefficient of interaction term HHID*MRD is −0.045 and significant at 10% level. In column (2) of Panel B, the coefficient of interaction term PNUM*MRD is 0.196 and significant at 1% level. Both results imply that firms' R&D investment decision in a fiercer competitive environment is more likely to be affected by peer groups (the marginal effect can also be saw in Figure 1(3) and (4)). Therefore, there is the tendency that peer effects in corporate R&D investment decision-making are partly driven by competitive mechanism.

In summary, both information and competitive mechanisms are the channels of peer effects in corporate R&D investment decisions. These conclusions are consistent with Lieberman and Asaba (2006) and Chen and Ma (2017), who claimed that information and rivalry are the main causes why a firm's behaviour is affected by its peers.

4.5 | Another manifestation for peer effects

To further investigate another manifestation for peer effects, we develop our predictions based on the competitive benchmarking theory and empirically examine whether a firm's R&D investment status relative to peer firms affects its R&D investment decision. The empirical results are shown in Table 5.

TABLE 4 Channel identification of peer effects

	Panel A: Information mechanism		Panel B: Competitive mechanism	
	(1) Market status	(2) Market uncertainty	(3) Market structure	(4) Number of peers
Variables	RD	RD	RD	RD
MRD	0.362*** (0.056)	0.230*** (0.057)	0.331*** (0.055)	0.149*** (0.054)
STATUS* MRD	−0.084* (0.050)			
STATUS	−0.000 (0.002)			
EPUI* MRD		0.050** (0.022)		
EPUI		0.015*** (0.003)		
HHID* MRD			−0.045* (0.025)	
HHID			0.003** (0.001)	
PNUM* MRD				0.196*** (0.063)
PNUM				−0.006** (0.002)
MASSET	−0.001 (0.002)	−0.001 (0.002)	−0.001 (0.002)	−0.001 (0.002)
MINCOME	0.001 (0.003)	0.003 (0.003)	0.001 (0.003)	0.003 (0.003)
MDAR	0.004 (0.004)	0.004 (0.004)	0.005 (0.004)	0.004 (0.004)
MROA	0.006 (0.014)	0.007 (0.014)	0.010 (0.013)	0.018 (0.013)
MCASH	−0.022** (0.011)	−0.026** (0.011)	−0.022* (0.011)	−0.013 (0.011)
MTOBINQ	0.054 (0.043)	0.047 (0.044)	0.037 (0.043)	0.026 (0.043)
ASSET	0.001 (0.001)	0.001 (0.001)	0.001 (0.001)	0.001 (0.001)
INCOME	−0.021*** (0.004)	−0.024*** (0.004)	−0.024*** (0.004)	−0.024*** (0.004)
DAR	−0.004 (0.004)	−0.005 (0.004)	−0.005 (0.004)	−0.005 (0.004)
ROA	−0.009 (0.007)	−0.011 (0.007)	−0.011 (0.007)	−0.010 (0.007)
CASH	0.009** (0.004)	0.009** (0.004)	0.009** (0.004)	0.009** (0.004)
TOBINQ	0.087*** (0.028)	0.094*** (0.028)	0.092*** (0.028)	0.091*** (0.028)
_Cons	0.024*** (0.005)	0.014** (0.006)	0.022*** (0.005)	0.022*** (0.005)
Industry FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
No. of obs.	13,604	13,604	13,604	13,604
No. of groups	1,837	1,837	1,837	1,837
Adj. R^2	0.150	0.149	0.149	0.150
F	38.03***	38.33***	37.64***	38.74***

Notes: The sample consists of 1,837 firms listed on Shanghai and Shenzhen Stock Exchanges from the year 2006 to 2016 with non-missing data for all analysis variables (see Appendix A). Peer groups are defined by three-digit CSRC industry code. The dependent variable is indicated at the top of columns. This table presents the results based on the channel identification model. Industry and year fixed effects are all controlled in these models. Robust *SEs* in parentheses. All coefficients are adjusted using company clustering.
*Statistical significance at 10% level.
**Statistical significance at 5% level.
***Statistical significance at 1% level.

The results in columns (1) and (2) of Table 5 are based on conditional fixed-effects logistic regression model. The results in columns (3) through (6) of Table 5 are based on the fixed-effects (within) regression model. In column (1), the coefficient of RDGAP1 is 1.121 and significant at 1% level. In column (2), the coefficient of RDGAP2 is 29.792 and significant at 1% level. In column (3), the coefficient of RDGAP1 is 0.256 and significant at 1% level. In column (4), the coefficient of RDGAP2 is 5.103 and significant at 1% level. In column (5), the coefficient of RDGAP1 is 0.019 and significant at 1% level. In column (6), the coefficient of RDGAP2 is 0.468 and significant at 1% level. These results imply that if a firm's R&D investment intensity is below the peers' average

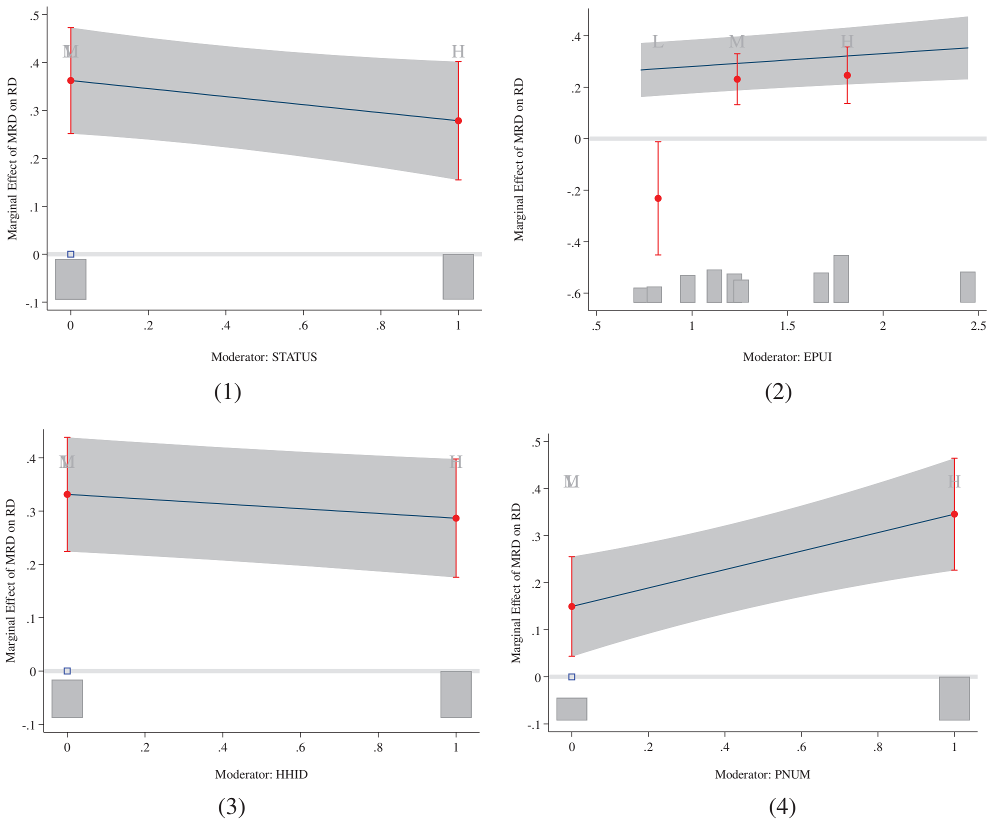

FIGURE 1 The marginal effect of MRD on RD based on different moderators [Colour figure can be viewed at wileyonlinelibrary.com]

R&D investment intensity in the year past, then the firm is more likely to increase its R&D investment in the year ahead. The more the firm falls behind, the greater it improves in the coming year. Firm which temporarily fell behind will continuously improve its R&D investment intensity to the level that would make it more competitive. Because of this competitive benchmarking between the peer firms, the R&D investment level is getting higher and higher.

4.6 | The heterogeneity of peer effects

Table 6 reports the results about the heterogeneity of peer effects in corporate R&D investment decision. Panel A presents the difference between follower and leader. In column (1), the coefficient of PFOLLOW is 0.219 and significant at 1% level, the coefficient of PLEAD is 0.026 and significant at 10% level. In column (2), the coefficient of PFOLLOW is 0.326 and significant at 1% level, but the coefficient of PLEAD is not significant. These results show that peer-follower R&D investment intensity are influenced by both their follower and leader-peer firms, but the follower-peer rivals have a greater impact (0.219 > 0.026). However, the R&D investment decisions of leaders are only affected by follower-peer firms. This result is consistent with the findings of Ross and Sharapov (2015) who explained that a leader imitates the action of a follower in order to avoid dethronement. This they further indicated is an effective competitive strategy.

Panel B presents the difference between more-profitable firms and less-profitable firms. In column (3), the coefficients of PLESS and PMORE are significant at 1% ($\beta = 0.115$ and 0.035 respectively). That notwithstanding, in column (4), the coefficient of PMORE is still significant at 1% ($\beta = 0.045$), whiles that of PLESS is insignificant. These results indicate that less-profitable firms' R&D investment decision are influenced by both less-profitable peers and more-profitable peers, yet less-profitable peer rivals have a greater impact (0.115 > 0.035). However more-profitable firms' R&D investment decision is only affected by more-profitable peers.

Panel C presents the difference between firms with strong innovation ability and firms with weak innovation ability. In column (5), the coefficient of PWEAK is 0.163 and significant at 1% level. PSTRONG is also significant at 5% ($\beta = 0.030$). In column (6), the coefficient of PSTRONG is 0.136 and significant at 5% level, whiles that of PWEAK is insignificant. These results imply that the R&D investment decision in firms which with weak innovation ability are influenced by both weak-ability peers and strong-ability peers, but the weak-ability peer rivals have a greater impact (0.163 > 0.030). However,

TABLE 5 Another test for peer effects

Variables	Panel A: Conditional fixed-effects logistic regression model		Panel B: Fixed-effects (within) regression model			
	ΔRD1 (1)	ΔRD1 (2)	ΔRD1 (3)	ΔRD1 (4)	ΔRD2 (5)	ΔRD2 (6)
RDGAP1	1.121*** (0.058)		0.256*** (0.012)		0.019*** (0.001)	
RDGAP2		29.792*** (1.198)		5.103*** (0.264)		0.468*** (0.019)
MASSET	−0.212 (0.165)	−0.175 (0.167)	−0.049 (0.037)	−0.039 (0.037)	−0.001 (0.001)	−0.000 (0.001)
MINCOME	0.224 (0.233)	0.188 (0.239)	0.037 (0.053)	0.038 (0.053)	0.003 (0.002)	0.004 (0.002)
MDAR	0.413 (0.261)	0.426 (0.264)	0.084 (0.057)	0.070 (0.057)	0.007*** (0.003)	0.007*** (0.002)
MROA	−1.434 (1.121)	−1.859 (1.154)	−0.272 (0.264)	−0.415 (0.261)	0.009 (0.012)	−0.005 (0.011)
MCASH	0.807 (0.961)	−0.517 (0.981)	0.154 (0.212)	−0.135 (0.214)	0.001 (0.009)	−0.027*** (0.009)
MTOBINQ	−6.017** (2.710)	−8.323*** (2.832)	−1.148* (0.659)	−1.307** (0.665)	−0.110*** (0.036)	−0.126*** (0.035)
ASSET	−0.018 (0.075)	0.017 (0.076)	−0.005 (0.017)	0.001 (0.016)	−0.001 (0.001)	0.000 (0.001)
INCOME	−1.650*** (0.206)	−1.686*** (0.210)	−0.347*** (0.049)	−0.343*** (0.049)	−0.018*** (0.002)	−0.018*** (0.002)
DAR	−0.422** (0.211)	−0.428** (0.218)	−0.112** (0.047)	−0.105** (0.047)	−0.010*** (0.003)	−0.009*** (0.002)
ROA	−0.828** (0.407)	−0.591 (0.424)	−0.222** (0.087)	−0.160* (0.087)	−0.026*** (0.005)	−0.018*** (0.005)
CASH	0.949*** (0.204)	0.949*** (0.210)	0.205*** (0.047)	0.187*** (0.047)	0.014*** (0.003)	0.013*** (0.003)
TOBINQ	−2.100 (1.321)	−0.215 (1.390)	−0.595** (0.292)	−0.191 (0.303)	0.002 (0.020)	0.035* (0.020)
_Cons	N/A	N/A	0.140* (0.081)	0.446*** (0.081)	−0.005 (0.004)	0.020*** (0.003)
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
No. of obs.	12,987[4]	12,987	13,604	13,604	13,604	13,604
No. of groups	1,670	1,670	1,837	1,837	1,837	1,837
Adj. R^2	N/A	N/A	0.094	0.122	0.111	0.258
LR chi-square/F	1,167.13***	1,648.21***	22.48***	30.22***	26.97***	75.60***

Notes: The sample consists of 1,837 firms listed on Shanghai and Shenzhen Stock Exchanges from the year 2006 to 2016 with non-missing data for all analysis variables (see Appendix A). Peer groups are defined by three-digit CSRC industry code. The dependent variable is indicated at the top of columns. Industry and year fixed effects are all controlled in these models. Robust *SEs* in parentheses. All coefficients are adjusted using company clustering.

*Statistical significance at 10% level.

**Statistical significance at 5% level.

***Statistical significance at 1% level.

TABLE 6 The heterogeneity of peer effects

	Panel A: Follower vs. leader		Panel B: More-profitable firms vs. less-profitable firms		Panel C: Firms with strong innovation ability vs. firms with weak innovation ability		Panel D: SOE vs. non-SOE	
	Follower	Leader	Less-profitable firms	More-profitable firms	Weak	Strong	Non-SOE firms	SOE firms
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	RD	RD	RD	RD	RD	RD	RD	RD
PFOLLOW	0.219*** (0.055)	0.326*** (0.098)						
PLEAD	0.026* (0.014)	0.007 (0.012)						
PLESS			0.115*** (0.035)	0.007 (0.066)				
PMORE			0.035*** (0.013)	0.045** (0.021)				
PWEAK					0.163*** (0.039)	0.002 (0.060)		
PSTRONG					0.030** (0.015)	0.136** (0.068)		
PNSOE							0.125** (0.050)	0.248*** (0.068)
PSOE							0.021* (0.012)	0.061** (0.025)
MASSET	−0.000 (0.003)	−0.004* (0.002)	−0.006* (0.003)	−0.001 (0.003)	0.002 (0.002)	−0.017** (0.007)	−0.003 (0.003)	−0.001 (0.003)
MINCOME	0.004 (0.005)	0.006* (0.004)	−0.001 (0.004)	−0.003 (0.006)	0.003 (0.003)	0.003 (0.009)	−0.003 (0.005)	0.003 (0.004)
MDAR	0.008 (0.006)	−0.007** (0.003)	0.005 (0.005)	−0.006 (0.004)	0.001 (0.004)	0.001 (0.014)	0.006 (0.005)	−0.006 (0.004)
MROA	−0.009 (0.021)	−0.007 (0.020)	0.029* (0.016)	−0.044* (0.023)	0.017 (0.014)	−0.044 (0.040)	0.008 (0.020)	0.011 (0.017)
MCASH	−0.052*** (0.018)	−0.017 (0.014)	−0.033** (0.015)	−0.003 (0.020)	−0.009 (0.013)	−0.040 (0.032)	−0.004 (0.016)	−0.030* (0.016)
MTOBINQ	0.088 (0.070)	0.079 (0.054)	0.037 (0.061)	0.131 (0.081)	0.129** (0.052)	−0.122 (0.117)	0.094 (0.062)	0.100 (0.081)
ASSET	−0.001 (0.002)	0.001 (0.001)	−0.000 (0.001)	0.001 (0.001)	0.001 (0.001)	−0.000 (0.002)	0.000 (0.001)	0.001 (0.001)
INCOME	−0.103*** (0.017)	−0.017*** (0.004)	−0.024*** (0.005)	−0.013** (0.005)	−0.028*** (0.004)	−0.024*** (0.008)	−0.031*** (0.006)	−0.022*** (0.005)
DAR	−0.007 (0.005)	−0.000 (0.004)	−0.011* (0.006)	−0.001 (0.007)	−0.004 (0.004)	−0.004 (0.012)	−0.009 (0.005)	0.004 (0.007)
ROA	−0.013 (0.009)	0.016** (0.008)	0.001 (0.011)	−0.009 (0.016)	−0.007 (0.007)	−0.026 (0.021)	−0.020** (0.010)	−0.008 (0.011)
CASH	0.009** (0.004)	−0.002 (0.006)	0.006 (0.006)	0.010* (0.006)	0.005 (0.004)	0.025** (0.012)	0.005 (0.004)	0.002 (0.007)
TOBINQ	0.092*** (0.032)	0.029 (0.051)	0.140*** (0.049)	0.063* (0.038)	0.096*** (0.030)	0.138* (0.081)	0.104*** (0.034)	0.077 (0.051)
_Cons	0.033*** (0.007)	0.016** (0.006)	0.027*** (0.006)	0.004 (0.011)	0.017*** (0.005)	0.028* (0.014)	0.028*** (0.008)	0.017** (0.007)
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
No. of obs.	8,719	4,867	8,822	4,764	10,927	2,599	8,478	5,013
No. of groups	1,531	852	1,588	1,450	1,496	338	1,325	609

TABLE 6 (Continued)

	Panel A: Follower vs. leader		Panel B: More-profitable firms vs. less-profitable firms		Panel C: Firms with strong innovation ability vs. firms with weak innovation ability		Panel D: SOE vs. non-SOE	
	Follower	Leader	Less-profitable firms	More-profitable firms	Weak	Strong	Non-SOE firms	SOE firms
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	RD	RD	RD	RD	RD	RD	RD	RD
Adj. R^2	0.139	0.213	0.138	0.121	0.147	0.164	0.115	0.207
F	22.23***	20.95***	22.35***	9.10***	30.43***	10.91***	17.77***	10.81***

Notes: The sample consists of 1,837 firms listed on Shanghai and Shenzhen Stock Exchanges from the year 2006 to 2016 with non-missing data for all analysis variables (see Appendix A). Peer groups are defined by three-digit CSRC industry code. The dependent variable is indicated at the top of columns. This table presents the results based on the fixed-effects (within) regression model. The total number of samples in Panel A, Panel B, Panel C and Panel D, are 13,586, 13,586, 13,526 and 13,491, respectively, slightly less than 13,604. This is mainly because we require at least two companies in the same peer group. If the group only have one company, then it will be automatically deleted. Industry and year fixed effects are all controlled in these models. Robust *SEs* in parentheses. All coefficients are adjusted using company clustering.

*Statistical significance at 10% level.

**Statistical significance at 5% level.

***Statistical significance at 1% level.

R&D investment decision in firms with strong innovation ability is only affected by peers with strong-ability.

Panel D presents the difference between SOE and NSOEs. In column (7), the coefficient of PNSOE is 0.125 and significant at 5% level. PSOE is significant at 10% ($\beta = 0.021$). In column (8), we find disparities in the coefficients of PNSOE and PSOE ($\beta = 0.248$, 0.061 respectively $p < .05$). These results indicate that R&D investment decision in non-SOE are influenced by both non-SOE peers and SOE peers, but non-SOE peer rivals have a greater impact (0.125 > 0.021). The R&D investment decision in SOEs are influenced by both SOEs peers and non-SOE peers, but non-SOE peer rivals have a greater impact (0.248 > 0.061). In generally, non-SOE is more innovative than SOE in China. This result means that SOEs are getting better in innovation year by year through lifelong learning from non-SOE peer rivals.

The above results indicate that peer effects in corporate R&D investment decision are heterogeneous in nature and scope, yet they tend to obey the law of imitation from within to without as advanced by Tarde (1903). The R&D investment decision of a firm is more likely to be affected by peers it shares similar characteristics.

5 | CONCLUSION AND POLICY RECOMMENDATION

In this paper, we examine the influence of peer effects in corporate R&D investment policy decision based on a decade data (2006–2016) of listed firms in China. Our result shows that firms do not make R&D investment decisions in isolation and that there is an imminent influence from the peers it belongs. Indeed, compared to traditional firm-specific determinants, the R&D investment policy of peer firms are remarkably robust with larger impact on corporate R&D investment decision. In general, these impacts are in line with the law of imitation (i.e., from within to without). Thus, for firms to make R&D investment decision, there is the likelihood of those firms imitating peers who share similar characteristics. Yet in all these scenarios, there may be some exceptional cases where leader-peers R&D investment decision may be more sensitive to their follower-peers. Similarly, SOEs R&D investment decision may be more sensitive to their non-SOE-peers.

The most interesting implication of our study has to do with the emergence of the presence of R&D investment externalities. Thus, peer effects have the propensity to encourage similar ones to follow suit and thus exacerbate investment in R&D decisions. Therefore, to increase corporate enthusiasm for R&D investment activities and stimulate enterprise creativity, the government should take advantage of this externality. As information and competitive mechanism are potential channels for these peer effects, one of the possible measures is to standardize and strengthen the disclosure of R&D investment information and the other is to increase the degree of competition in the industry.

ACKNOWLEDGEMENTS

This study was supported by National Natural Science Foundation of China (No. 71672206), Philosophy and Social Science Fund Project of Guangdong Province (No. GD16XYJ22), Common University Innovation Talents Project (Youth Innovation Talents) of Guangdong Province (No. 2016WQNCX018), Accounting Research Project of Guangdong Province in 2019-2020 (No.19-20*084).

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ENDNOTES

[1] See the survey papers, for example, He and Tian (2018) and Belloc (2012).

[2] Endogenous effect means the propensity of an individual to behave in some way varies with the behavior of the group; exogenous (contextual) effect means the propensity of an individual to behave in some way varies with the exogenous characteristics of the group; correlated effect means individuals in the same group tend to behave similarly because they have similar individual characteristics or face similar institutional environment (Manski, 1993).

[3] Considering the data availability, our sample period starts from the year in 2006. Because the Ministry of Finance of China implemented a policy that listed companies need to disclose the amount of research and development expenditures since January 1th, 2007. Before this, we cannot obtain the data of R&D investment.

[4] One hundred and sixty-seven groups (617 observations) are dropped because of all positive or all negative outcomes, so that in conditional fixed-effects logistic regression model, the number of observations (12,987) and the number of groups (1,670) are a little smaller than the fixed-effects (within) regression model.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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How to cite this article: Peng Z, Lian Y, Forson JA. Peer effects in R&D investment policy: Evidence from China. *Int J Fin Econ*. 2020;1–18. https://doi.org/10.1002/ijfe.2028

APPENDIX A.: DEFINITION OF VARIABLES

Variables	Definition
RD	The ratio of R&D expenses to last year's sales (R&D investment intensity)
MRD	Peer firms' average R&D investment intensity
ASSET	Natural logarithm of total asset
INCOME	Natural logarithm of income
DAR	The ratio of total debt to total assets
ROA	The ratio of net income to total assets
CASH	The ratio of cash asset to total assets
TOBINQ	Tobin's Q ratio, equals total market value/(total assets − net intangible assets − net goodwill)
MASSET	Peer firms' average ASSET
MINCOME	Peer firms' average INCOME
MDAR	Peer firms' average DAR
MROA	Peer firms' average ROA
MCASH	Peer firms' average CASH
MTOBINQ	Peer firms' average TOBINQ
ALPHA	Idiosyncratic equity returns, calculated by CAPM
MALPHA	Peer firms average ALPHA
STATUS	Dummy variable, if a firm's market share rank in the upper third among the peer firms, then STATUS equals one, otherwise equals zero
EPUI	The economic policy uncertainty index constructed by (Baker et al., 2016)
HHID	Dummy variable, if HHI < 0.1, HHID equals zero; otherwise equals one
PNUM	Dummy variable, if the number of peer firms in one group is bigger than the median of the whole groups in the sample, then PNUM equals one; otherwise equals zero
ΔRD1	Dummy variable, if the change in R&D investment from year *t*-1 to year *t* is positive, then ΔRD1 equals one, otherwise equals zero
ΔRD2	The first differences for R&D investment intensity

(Continues)

Variables	Definition
RDGAP1	Dummy variable, if a firm's R&D investment intensity is below the mean of peer firms' R&D investment intensity in the prior year, then equals one, otherwise equals zero
RDGAP2	Equals the peer firms' mean R&D investment intensity minus the firm's R&D investment intensity in the prior year
PLEAD	Leader-peer firms' average R&D investment intensity
PFOLLOW	Follower-peer firms' average R&D investment intensity
PPROFIT	More-profitable-peer firms' average R&D investment intensity
PNPORFIT	Less-profitable-peer firms' average R&D investment intensity
PSTRONG	With strong innovation ability-peer firms' average R&D investment intensity
PWEAK	With weak innovation ability-peer firms' average R&D investment intensity
PSOE	State-owned-peer firms' average R&D investment intensity
PNSOE	Non-state-owned-peer firms' average R&D investment intensity
Industry FE	Industry controlled
Year FE	Year controlled