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A paradoxical view of speed and quality on operational outcome: An empirical investigation of innovation in high-tech small and medium-sized enterprises

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ABSTRACT

Recently, there has been increasing attention on the speed versus quality paradox in operations and innovation management literature. This study examines the innovation speed-quality paradox on operational performance in small and medium-sized enterprises (SMEs) from high-tech industries. Specifically, we seek to understand how R&D investment with organizational risk influences the innovation speed-quality paradox and how this paradox further influences a firm's operational performance. Based on a panel data of 247 firms (1782 firm-year observations), the empirical results show that R&D investment positively affects innovation speed and quality, and organizational risk positively moderates the relationship between R&D investment and innovation quality. Also, both the innovation speed and quality are positively related to firm's operational performance, while the interaction of speed and quality is negatively related to firm's operational performance. The theoretical and practical implications of our research are also discussed.

1. Introduction

With the development of economics and intensification of competition, innovation is recognized as a key facilitator to a firm's survival and development (Boh et al., 2020; Cadwallader et al., 2010; Santos-Vijande et al., 2016). In general, innovation speed and quality are two major dimensions in firm operation (Carbonell et al., 2009; Miner and Glomb, 2010; Wang et al., 2018). "Innovation speed" refers to the pace of innovation progress, from the conception and initial development to the ultimate commercialization (Carbonell et al., 2009; Wang et al., 2016). "Innovation quality" means the process and the results of innovation with the criteria, such as reliability creativity, standardization, and systematic procedures (Carbonell et al., 2009; Haner, 2002; Wang et al., 2018). In firm's operation, innovation speed and innovation quality are deemed as trade-off and paradoxical (Guo et al., 2019b; Kostami and Rajagopalan, 2013; Yeung et al., 2019). On the one hand, the relationship between innovation speed and innovation quality is contradictory and conflicted due to time constraints and limited resources (Guo et al., 2019b; Kostami and Rajagopalan, 2013; Santos-Vijande et al., 2016); on

the other hand, innovation speed and quality are interdependent due to the fact that speed enhances focus and discipline in innovation for quality, and quality triggers effectiveness for speed (Caulkins et al., 2017; Santos-Vijande et al., 2016). In other words, innovation speed and quality are elements of persistent contradiction between interdependence, which is called a paradox in the management field (Schad et al., 2016). Innovation speed-quality paradox is a critical characteristic in firms' operation. Consequently, it is critical to better understand the role of speed and quality in order to find the balance between the two to improve operational performance (Guo et al., 2019b; Kostami and Rajagopalan, 2013; Wang et al., 2018). Thus, it is of theoretical and practical relevance to explore the innovation speed-quality paradox.

Previous studies on the innovation speed-quality paradox mainly focus on two streams (i.e., antecedents and outcomes). One stream explores the predictors of innovation speed and quality from a resource and knowledge perspective. For example, Taghizadeh et al. (2018) investigates how knowledge from the customer, for the customer, and about the customer influences innovation speed and quality. However, they ignore the role of R&D investment, which is key to a firm's

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innovation (Frenz and Ietto-Gillies, 2009; Wu et al., 2019). Additionally, the effect of R&D investment on firm's innovation speed and quality may be contingent on the riskiness in which an organization is embedded (e.g., organizational risk) (Boh et al., 2020; Hasan et al., 2018), which has been also ignored in previous studies. Organizational risk reflects firms' income stream uncertainty (Palmer and Wiseman, 1999) and can act as an external environmental factor affecting the efficiency in resource allocation for innovation (Godfrey et al., 2009; Hasan et al., 2018). Thus, it may have an impact on the R&D investment concerning innovation speed and quality. As a result, organizational risk deserves further investigations along with the paradoxical view of innovation speed and quality.

In terms of outcomes of the speed-quality paradox, previous studies examine how innovation speed and quality separately influence firm performance (Carbonell et al., 2009; Santos-Vijande et al., 2016; Wang et al., 2018). Nevertheless, they fail to explore a potential interaction effect between innovation speed and quality on firm performance because overlooked the trade-off between innovation speed and quality on performance outcomes have been overlooked (Guo et al., 2019b; Kostami and Rajagopalan, 2013; Miner and Glomb, 2010). Moreover, the trade-off between innovation speed and quality can be even more critical for small and medium-sized enterprises (SMEs) in high-tech industries because these SMEs are innovation-oriented while resource-constrained (Guo et al., 2020; Wang et al., 2018). They are confronted with the survival pressure and competition imposed by large firms. Accordingly, they have to effectively transform their limited R&D resources to innovation outcomes at a fast (speed) and steady (quality) pace (Mei et al., 2019; Wang et al., 2018). Therefore, we study the innovation speed-quality paradox in the context of high-tech SMEs. To this end, this study incorporates both the antecedents and outcomes associated with the innovation speed-quality paradox in high-tech SMEs. More specifically, we answer the following three research questions:

- (1) How does R&D investment influence the innovation speed-quality paradox in high-tech SMEs' operation?
- (2) What role does organizational risk play in the above relationship?
- (3) How does the innovation speed-quality paradox influence firm performance in high-tech SMEs' operation?

We argue that R&D investment is indicative to resource commitment (Shan et al., 2016), absorptive capability (Cohen and Levinthal, 1989; Wu et al., 2019), risk tolerance (Ehie and Olibe, 2010; Lee et al., 2014), and high-quality knowledge creation and combination (Czarnitzki and Hottenrott, 2011), which can significantly accelerate innovation speed and quality in high-tech SMEs. Meanwhile, organizational risk reflects income uncertainty and uncertain expectations (Freeman et al., 2007; Hasan et al., 2018). In our research context, firms tend to slow down the pace of innovation (speed) and improve the reliability and stability of innovation (quality) by investing in R&D. Consequently, this hinders the effect of R&D investment on innovation speed and facilitates innovation quality. In addition, innovation speed enables firms to benefit from first-mover advantage (Shan et al., 2016; Wang and Wang, 2012), while innovation quality may guarantee long-term values and create barriers for preventing products and services being imitated (Santos-Vijande et al., 2016; Wang and Wang, 2012), thereby improving SMEs' operational performance. Furthermore, the scarcity of R&D resource in high-tech SMEs impedes them to simultaneously accelerate innovation speed and quality (Guo et al., 2020; Zhu et al., 2019), and therefore the interplay between innovation speed and quality may be negatively related to firm performance in high-tech SMEs' operation.

The analysis in this study uses 247 firms (1782 firm-year observations) from high-tech SMEs. The empirical results show that within the high-tech SMEs, R&D investment is conducive to both innovation speed and quality; organizational risk amplifies the positive effect of R&D investment on innovation quality. Both innovation speed and innovation quality lead to higher operational performance; however, the

interaction of innovation speed and quality inhibits operational performance.

This study contributes to the current literature in several aspects. First, this study theorizes the speed-quality paradox in operations management and empirically examines this paradox on operational performance in high-tech SMEs. Meanwhile, this study contributes to the multi-disciplinary literature, i.e., innovation and operations management by revealing a positive effect of R&D investment on innovation speed and innovation quality in high-tech SMEs' operations. Finally, this study suggests that there is a contingent effect of organizational risk on the relationship between R&D investment and innovation quality in high-tech SMEs.

2. Theoretical background and hypothesis

2.1. Innovation speed-quality paradox in firms' operations

Innovation in operational processes has two dimensions: innovation speed and innovation quality (Carbonell et al., 2009; Wang and Wang, 2012). Innovation speed reflects the extent to which innovative products or services can be created from initial development (i.e., the conception or an idea of an innovation) to the commercial introduction of products or services to the market (Kessler and Bierly, 2002; Taghizadeh et al., 2018; Wang and Wang, 2012). Innovation quality, on the other hand, focuses on adding more value to customers—for instance, by improving product effectiveness, reliability, complexity, and so forth (Taghizadeh et al., 2018; Wang and Wang, 2012). However, innovation speed and innovation quality are considered contradictory and interdependent. In terms of contradiction, high speed emphasizes greater output and less delay, which may result in more errors and lower quality; high quality underlines stability and standard processes, thereby resulting in more time-consumption and lower speed (Guo et al., 2019b; Kostami and Rajagopalan, 2013). In terms of interdependence, speed enhances focus and discipline in the development efforts and the quality is reinforced; quality reduces errors and mistakes, which is beneficial to speed (Kostami and Rajagopalan, 2013; Santos-Vijande et al., 2016). In other words, innovation speed and innovation quality can be a pair of persistent contradiction between interdependence, which is called a paradox in the management literature (Schad et al., 2016).

As such, innovation speed and quality may compete for time and resources, leading to a paradoxical decision that the firms should make (Kessler and Bierly, 2002; Shan et al., 2016). This is particularly relevant for high-tech SMEs, given that they are innovation-orientation and resource-constrained compared to larger firms (Guo et al., 2020; Zhu et al., 2019). However, recent studies on innovation speed-quality paradox in high-tech SMEs have neglected how innovation speed-quality paradox determines operational performance.

In general, resources include both tangible and intangible assets controlled or owned by a firm that enable firms to implement strategies aiming at improving efficiency and effectiveness (Barney, 2001). The resource-based view suggests that the possession of valuable, scarce, inimitable, and non-substitutable resources contributes to sustainable competitive advantages (Barney, 1991, 2001; Kraaijenbrink et al., 2010). Meanwhile, Grant (1996) indicates that the competitive advantages can be achieved not only by a firm owning valuable resources, but also by the managerial capabilities of deployment and integration of the resources. In this vein, the utilization of resources is very important to firms' operation and performance (Henard and McFadyen, 2012). Among various resources, R&D resources—including R&D capital expenditure, human resources, and related training R&D activities—are characterized as rare and hard-to-imitable (Frenz and Ietto-Gillies, 2009; Wu et al., 2019). R&D resources have direct and vital effects on firms' innovation in operational processes (Wu et al., 2019). Additionally, the effect of R&D investment on firms' innovation in operation may be contingent on a dynamic organizational context, such as organizational risk (Boh et al., 2020; Hasan et al., 2018). As such, the effects of

R&D investment on firms' innovation (innovation speed and innovation quality) in operation could be contingent on organizational risk. Unfortunately, previous studies failed to investigate how R&D investment impacts the innovation speed-quality paradox and ignored the roles of organizational risk played in the course of R&D investment on innovation speed-quality paradox.

This study, based on a paradoxical view, aims to examine the innovation speed-quality paradox in high-tech SMEs' operation and explore how R&D investment with organizational risk influences innovation speed-quality paradox and how the innovation speed-quality paradox impacts operational performance in high-tech SMEs.

2.2. R&D investment, innovation speed, and innovation quality

According to the innovation literature, investments in R&D enable innovation (Czarnitzki and Hottenrott, 2011). Research shows that R&D investment is positively related to firms' innovation (Wu et al., 2019). We argue that R&D investment can accelerate innovation speed in high-tech SMEs. Financial and human resource commitments in R&D activities facilitate the high-tech SMEs to surmount obstacles in the process of new product development (Shan et al., 2016). Consequently, firms' innovation pace can speed up. Moreover, R&D investment can increase an organization's absorptive capacity to promote knowledge assimilation and exploitation from the external environment (Cohen and Levinthal, 1989; Wu et al., 2019). Thus, effective utilization of external knowledge can overcome the scarcity of internal resources in high-tech SMEs, thereby speeding up innovation. Finally, innovation activities tend to be risky, meaning that firms need to invest plenty of resources for experimentation while the outcomes could be highly uncertain (Ehie and Olibe, 2010; Guo et al., 2020). The availability of R&D resources may increase firms' risk tolerance in innovation (Ehie and Olibe, 2010; Lee et al., 2014), thereby positively influencing innovation speed. In other words, R&D investment, which is indicative of resource commitment, absorptive capability, and greater risk tolerance, is likely to accelerate innovation speed. We, therefore, propose that:

H1. R&D investment (RDI) is positively related to innovation speed.

R&D investment not only can influence innovation speed in firms, but also may impact innovation quality. A high level of innovation quality reflects the high effectiveness of innovation (Wang and Wang, 2012). More R&D investment implies more resources commitment to innovation (Cohen and Levinthal, 1989; Frenz and Ietto-Gillies, 2009; Wu et al., 2019), which can be used in experimentation or in trial-and-error activities for different new ideas, which in turn, can increase high-tech SMEs' possibilities of developing potential advanced technology to improve innovation quality. Furthermore, R&D activities can be considered as investments in the creation of new knowledge (Czarnitzki and Hottenrott, 2011). Hence, more R&D investment could incrementally trigger knowledge creation. More innovative knowledge combinations can add more value to innovation, which further enhances the quality of innovation. Consequently, R&D investment improves innovation quality. Based on these arguments, we propose the following hypothesis.

H2. R&D investment (RDI) is positively related to innovation quality.

2.3. The moderating effects of organizational risk

Given that firms are operating in a competitive and dynamic environment (Boh et al., 2020; Hasan et al., 2018), they will inevitably encounter risk and uncertainty. In particular, high-tech SMEs face high organizational risk, where the support of human and financial resources is sparsely available when compared with larger firms (Guo et al., 2020; Zhu et al., 2019). In this study, we treat organizational risk as a contextual variable and define it as income stream uncertainty (Palmer and Wiseman, 1999). It indicates firms' risk exposure as a consequence of managerial decisions and external environmental factors (Godfrey

et al., 2009; Hasan et al., 2018).

We predict that organizational risk will negatively moderate the relationship between R&D investment and innovation speed. The income stream uncertainty implies that there are more uncertain and risky factors in firms' operational processes (Hasan et al., 2018). Thus, when high-tech SMEs face organizational risks, regardless of the R&D resources committed to the innovation process, the failure rate of innovation will rise. Therefore, it will lead to a decrease in innovation speed. Furthermore, when firms are confronted with organizational risks, it is less likely that they can make the right managerial decisions (Godfrey et al., 2009; Palmer and Wiseman, 1999). As such, the absorbed knowledge from the environment may not be proper for innovation, due to inappropriate decision-making in organizational risks, thereby slowing down their innovation speed. Finally, organizational risks imply the existence of uncertainties in firms' operational processes (Hasan et al., 2018; Palmer and Wiseman, 1999). As we know, innovation activities are influenced by uncertainties and risks (Ehie and Olibe, 2010; Wu et al., 2019); the risks of innovation combined with organizational risk may exceed SMEs' tolerance and confidence to accelerate innovation speed. Accordingly, we propose the following hypothesis.

H3. Organizational risk (OR) negatively moderates the relationship between R&D investment (RDI) and innovation speed (IS).

In contrast, we predict that organizational risk positively moderates the relationship between R&D investment and innovation quality. Firms, when exposed to organizational risks, are more likely to experience negative events, such as products with unreliable quality (Freeman et al., 2007; Hasan et al., 2018). To this end, high-tech SMEs tend to excel more discreetly on different innovative ideas so the technology novelty and product newness can be improved (Howell, 2015; Liegl et al., 2016). Consequently, R&D investment could lead to a higher quality of innovation. In addition, when faced with organizational risk in creating knowledge by utilizing R&D investment, high-tech SMEs can be cautious in selecting more valuable knowledge that is compatible with the existing knowledge stock (Czarnitzki and Hottenrott, 2011), thereby triggering innovation quality improvement. In other words, R&D investment can lead to higher innovation quality in the context of higher rather than lower organizational risk. We, therefore, propose the following hypothesis.

H4. Organizational risk (OR) positively moderates the relationship between R&D investment (RDI) and innovation quality (IQ).

2.4. Innovation speed, innovation quality, and firm performance

New product development literature has demonstrated that innovation speed accelerates the introduction of new products to market (Kessler and Bierly, 2002), and it enables firms to accumulate time-based competition, such as quickly introducing new products or services to seize markets (Shan et al., 2016; Wang and Wang, 2012). On the one hand, innovation speed is likely to enable high-tech SMEs to gain first-mover advantage in the marketplace (Kessler and Bierly, 2002; Shan et al., 2016; Wang and Wang, 2012). On the other hand, innovation speed guarantees a timely reaction to sense market changes quickly via innovation, especially in dynamic and competitive environments (Boh et al., 2020; Wang and Wang, 2012). Hence, firms can respond to customers' changing demands and competitors' new strategies more quickly. Therefore, the fast reaction enabled by rapid innovation speed can increase the opportunities for them to boost sales and eventually improve operational performance (Rodriguez and Nieto, 2016). We proposed the following hypothesis.

H5. Innovation speed (IS) is positively related to a firm's operational performance (OP).

A high level of innovation quality indicates decent product or service quality perceived by customers (Atuahene-Gima, 2003; McNally et al., 2011). High quality leads to high reputation of the focal firm (Parker

et al., 2019), which can further help retain and attract more customers. Thus, SMEs can enhance operational performance due to increased profits or market shares, et cetera. On the other hand, high quality of innovation requires firms to integrate various resources and coordinate cross-sectional activities in organizations, making the innovation even more difficult to copy and imitate (Wang and Wang, 2012). High-tech SMEs, therefore, are able to build up barriers for rivals or followers in the market. Overall, firms' operational performance can be increased. Therefore, we propose the following hypothesis.

H6. Innovation quality (IS) is positively related to a firm's operational performance (OP).

Speed and quality are important dimensions of innovation in firms' operation (Carbonell et al., 2009; Kostami and Rajagopalan, 2013). It should be the case that firms are less likely to excel in speed and quality simultaneously because managers always need to balance the tradeoff between these two dimensions of innovation in firms' operation (Guo et al., 2019b; McNally et al., 2011). On the one hand, high-speed-accompanied deadline pressure tends to reduce the checks on the process of innovation, which hinders firms' innovation quality; on the other hand, high quality and newness of an innovation require more time and effort, which restricts an organization in speeding up a new product development process (Kostami and Rajagopalan, 2013; Santos-Vijande et al., 2016). Therefore, the relationship between speed and quality makes it difficult for firms to make trade-offs from a time consumption perspective.

In addition, SMEs have typical characteristics of constrained and limited resources (Guo et al., 2020; Zhu et al., 2019). No matter whether one is improving innovation speed or innovation quality in an operational process, a considerable amount of investment commitments, including both human and capital resources, are required (Lukas et al., 2002; Santos-Vijande et al., 2016). Therefore, when innovation speed and innovation quality influences are both high, the effects of this combination may exert a negative force on firm performance in operation from the resource-limited perspective. Based on the above arguments, we proposed the following hypothesis.

H7. The interaction of innovation speed (IS) and quality (IS) is negatively related to a firm's operational performance (OP).

In summary, we propose the research model in Fig. 1.

Fig. 1. Research model.

3. Method

3.1. Data collection

High-tech SMEs, as an important entity of the Chinese economy, play an increasingly important role in economic development in China (Mei et al., 2019; Wang et al., 2018). The high-tech SMEs are innovation orientated because they face survival pressure and intense competition from large firms, and they have to effectively apply their R&D resources to innovate quickly (speed) and steadily (quality); thus, high-tech SMEs are appropriate for exploring the innovation speed-quality paradox. The sample for this study was the SME Board and Growth Enterprise Board of listed firms in the *Shanghai Stock Exchange* over the period from 2009 to 2018. In order to focus on high-tech SMEs engaging in innovation activities, according to the suggestions of Ren et al. (2015), we selected firms in the sectors of engineering, machinery, information technology, and pharmaceuticals. The firm-level data (e.g., firm age, industries, financial slack, operational performance, R&D investment, and industrial risk) was collected from the *Wind* database. We obtained patent information (e.g., granted patents and cited patents) from the *Incopat* database. The data on the regional economic development (e.g., per-capita GDP) was collected from the *National Bureau of Statistics of China* (NBS). In order to measure the organizational risk with five-year forward statistics, the observation period was from 2005 to 2018.

We merged the data set of Wind, Incopat, and GDP per capita from NBS; there are 247 firms with ten years' worth of observations. Given that this study aims to examine the antecedents and outcomes of the innovation speed-quality paradox on SMEs' operational outcomes, we endeavored to avoid possible endogenous problems in our analysis. Specifically, according to the approaches of Bichescu et al. (2018) and Boh et al. (2020), we adopted the method of the lag mode. We eliminated some firms with incomplete data and retained 247 firms, which corresponds to 1782 firm-year observations. Out of these 1782 firm-year observations, 288 are from material engineering, 665 are from industrial manufacturing, 582 are from information technology, 141 are from pharmaceuticals, and 106 are from home applications and others.

3.2. Measures

3.2.1. Dependent variables

Operational performance (OP) was measured by the operating profit,

which is commonly used in previous studies (Bradley et al., 2011; Guo et al., 2020; Tan and Peng, 2003). Given the effect of the magnitudes and signs of profits, we followed the approach of Bradley et al. (2011) and Guo et al., 2020 to measure firms' operational performance, as the index that a firm's profit divides the mean profits of all firms.

Innovation speed (IS) describes the efficiency of the new product development, and it was measured by the number of granted patents in the given year (Boh et al., 2020; Chin et al., 2009; Shan et al., 2016).

Innovation quality (IQ) reflects the significance and impact of an innovation, which is measured by the forward citations of the patents (Boh et al., 2020; Chin et al., 2009; Nerkar and Paruchuri, 2005).

3.2.2. Independent variables

R&D investment (RDI) describes the expenditures in R&D activities, and it was measured by the natural logarithm of R&D expenditures (Mazzola et al., 2019).

Organizational risk (OR) reflects the firms' income stream uncertainty (Hasan et al., 2018; Palmer and Wiseman, 1999). This study adopted the approach by Hasan et al. (2018) and measured industrial risk using the standard deviation of return on assets over the past five years on a rolling basis in our sample firms.

3.2.3. Control variables

Previous studies indicated that financial slack, current ratio, local economic development, firm age, and industry may influence firms' innovation and performance (Boh et al., 2020; Guo et al., 2020; Lee et al., 2014), thus we chose them as control variables.

Financial slack (FS) represents the cash reserves in a firm for a given year and provides the freedom in allocation for various uses (Bradley et al., 2011). Following Bradley et al. (2011), we measured financial slack by the index that a firm's cash reserves divide all firm's mean cash reserves. *Current ratio (CR)* reflects the liquidity of a firm's assets, and it was measured by the current assets divided by current liabilities (Boh et al., 2020). Local economic development was measured by *per-capita GDP (PGDP)* of each region in a respective year based on the study of Sun et al. (2019); we took a natural logarithm to avoid skewing the data (Lee et al., 2014). *Firm age* was measured by the number of operation years. Because our sample firms across five industries, namely material engineering, industrial manufacturing, information technology, pharmaceutical and biological engineering, home applications, and others, we used four industry dummy variables.

3.3. Data analysis

In order to mitigate possible endogenous problems and ensure the reliability of our statistical results, we adopted a panel data analysis approach (Bichescu et al., 2018; Boh et al., 2020). We specify the following three models to test the hypotheses developed in the previous section:

$$IS_{it} = \alpha_0 + \alpha_1 Age_{it} + \alpha_2 industry1_{it} + \alpha_3 industry2_{it} + \alpha_4 industry3_{it} + \alpha_5 industry4_{it} + \alpha_6 FS_{it} + \alpha_7 CR_{it} + \alpha_8 PGDP_{it} + \alpha_9 RDI_{it-1} + \alpha_{10} OR_{it-1} + \alpha_{11} RDI_{it-1} \times OR_{it-1} + \mu_{it}$$

$$IQ_{it} = \beta_0 + \beta_1 Age_{it} + \beta_2 industry1_{it} + \beta_3 industry2_{it} + \beta_4 industry3_{it} + \beta_5 industry4_{it} + \beta_6 FS_{it} + \beta_7 CR_{it} + \beta_8 PGDP_{it} + \beta_9 RDI_{it-1} + \beta_{10} OR_{it-1} + \beta_{11} RDI_{it-1} \times OR_{it-1} + \epsilon_{it}$$

$$OP_{it+1} = \gamma_0 + \gamma_1 Age_{it+1} + \gamma_2 industry1_{it+1} + \gamma_3 industry2_{it+1} + \gamma_4 industry3_{it+1} + \gamma_5 industry4_{it+1} + \gamma_6 FS_{it+1} + \gamma_7 CR_{it+1} + \gamma_8 PGDP_{it+1} + \gamma_9 IS_{it} + \gamma_{10} IQ_{it} + \gamma_{11} IS_{it} \times IQ_{it} + \phi_{it+1}$$

where $i = 1, 2, 3, \dots, N$ indicate the numbers of observations; α_0 to α_6 , β_0

to β_{10} , γ_0 to γ_{11} are the parameters to be estimated in the three equations; μ_{it} , ϵ_{it} , ϕ_{it} stand for error terms in the three equations.

Previous studies pointed out that the ordinary least squares regression model is inefficient and subject to estimation bias if the time effects are excluded from the analysis (Guo et al., 2020; Lee et al., 2014). Following a method of panel data analysis in Samila and Sorenson (2010) and Lee et al. (2014), we adopted a fixed-effect model to investigate the relationship between the explanatory and dependent variables.

Following recent studies (Balducci et al., 2018; Hasan et al., 2018; Yang et al., 2019), we conducted a hierarchical polynomial regression to test the hypotheses. According to Brambor et al. (2006) and Hayes and Matthes (2009), mean-centered data may not be helpful in overcoming multicollinearity issues, so we did not mean center explanatory variables.

4. Results

4.1. Regression analysis

Given that we used panel data in the analysis, we followed the approach of Bichescu et al. (2018) for a panel data analysis. Table 1 shows the descriptive statistics and pairwise correlations of key variables in this study. Table 2 presents the results of regression analysis.

We regressed innovation speed on R&D investment (RDI) to test the main effect (see Model 1) and found that R&D investment shows a significant and positive effect on innovation speed ($b = 3.384$, $p < 0.001$). Therefore, H1 is supported. In order to test the moderating effects of organizational risk (OR), following the procedure suggested by Aiken et al. (1991) and Cohen et al. (2003), we computed the interaction term between R&D investment (RDI) and organizational risk (OR) and then included it in the regression equation at second stage (Model 2). In Model 2, the coefficient of interaction term ($RDI \times OR$) is statistically insignificant ($b = -0.049$, $p > 0.050$). Therefore, H3 is not supported. Other control variables are insignificant except that current ratio and industry 1 and industry 2 dummies are significant.

In order to test the main effect, we regressed innovation speed and R&D investment (RDI) on innovation quality (IQ) in Model 3. The results show that R&D investment positively and significantly influences innovation quality ($b = 7.023$, $p < 0.001$); thus, H2 is supported. To test the moderating effect of organizational risk (OR), the interaction term between R&D investment (RDI) and organizational risk (OR) was computed and entered into the regression equation at the next stage (Model 4). The results from Model 4 indicate that the coefficient of the interaction term ($RDI \times OR$) is statistically significant ($b = 0.211$, $p < 0.050$), suggesting that when organizational risk increases, the slope of the relationship between R&D investment and innovation quality becomes steeper. Following Meyer et al. (2017), we plotted the marginal effect of R&D investment on innovation quality at different levels of organizational risk (see Fig. 2). The results indicate that when the value of organizational risk increases from 0.13 to 64.77, the impact of R&D investment on innovation quality becomes significantly stronger. As a result, H4 was further supported. All control variables are insignificant except for the dummy-industry 3.

Table 1
Descriptive statistics and correlation matrix.

	1	2	3	4	5
1. Operational performance	1.00				
2. Innovation speed	.133***	1.00			
3. Innovation quality	.119***	.497***	1.00		
4. R&D Investment	.376***	.238***	.177***	1.00	
5. Organizational risk	-.026	-.034	.052*	-.078**	1.00
Mean	1.123	17.500	23.370	17.339	5.307
Std. Deviation	2.584	16.793	26.137	.971	4.902

Notes: * $p < 0.050$, ** $p < 0.010$, *** $p < 0.001$ (2-tailed test).

Table 2

Results from regression analyses (N = 1782).

Variables	Innovation speed (IS)		Innovation quality (IQ)		Operational performance (FP)	
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Intercept	−19.444 (15.677)	−25.319 (17.002)	−73.008** (24.587)	−51.144 (26.637)	−3.939* (1.764)	−4.079* (1.763)
Firm age	.072 (.077)	.070 (.078)	.094 (.120)	.109 (.122)	−.014 (.010)	−.014 (.010)
Industry 1	−5.013** (1.814)	−4.991** (1.815)	.576 (2.846)	.500 (2.844)	.409 (.229)	.433 (.229)
Industry 2	3.988* (1.672)	4.062* (1.674)	3.469 (2.622)	3.198 (2.623)	.234 (.211)	.259 (.211)
Industry 3	2.954 (1.694)	2.982 (1.701)	8.475** (2.656)	8.311** (2.664)	.050 (.214)	.056 (.214)
Industry 4	−4.020 (2.052)	−3.982 (2.057)	−2.064 (3.219)	−2.249 (3.222)	.761** (.260)	.806** (.260)
Financial slack (FS)	−.151 (.134)	−.152 (.134)	.085 (.210)	.085 (.210)	.462*** (.015)	.461*** (.015)
Current ratio (CR)	−.208* (.089)	−.212* (.091)	.037 (.139)	.042 (.142)	.003 (.011)	.003 (.011)
Per-capita GDP (PGDP)	−2.096 (1.229)	−2.097 (1.234)	−2.801 (1.927)	−2.843 (1.934)	.375* (.156)	.375* (.156)
R&D investment (RDI)	3.385*** (.448)	3.719*** (.584)	7.023*** (.703)	5.797*** (.915)		
Organizational risk (OR)		1.014 (1.149)		−3.685*** (1.800)		
RDI × OR		−0.058 (.065)		0.211* (.101)		
Innovation speed (IS)					.009* (.003)	.015*** (.004)
Innovation quality (IQ)					.007*** (.002)	.013*** (.003)
IS × IQ						−.0002* (.0001)
R ²	.104	.105	.052	.055	.389	.390

Note 1: * $p < 0.050$, ** $p < 0.010$, *** $p < 0.001$ (2-tailed test); the numbers in brackets indicate standard errors.

Note 2: Industry 1: material engineering, Industry 2: industrial manufacturing, Industry 3: information technology, Industry 4: pharmaceutical and biological engineering.

Fig. 2. Moderating effect of organizational risk (OR) on the relationship between R&D investment (RDI) and innovation speed (IS).

We regressed innovation speed and innovation quality on operational performance to test the main effect (see Model 5). The results indicate that both innovation speed ($b = 0.009$, $p < 0.050$) and innovation quality ($b = 0.007$, $p < 0.001$) positively and significantly influence operational performance. Therefore, H5 and H6 are supported. To test the interaction effect, we computed the interaction terms of innovation speed (IS) and innovation quality (IQ), and then entered them into the regression equation after the main effect (Model 6). In Model 6, the coefficient of interaction term (IS × IQ) is negative and significant ($b = -0.0002$, $p < 0.050$). We also plotted the interaction effect of innovation speed (IS) and innovation quality (IQ) on operational performance (see Figs. 3 and 4). Fig. 3 displays the marginal effects of innovation quality on operational performance at different levels of innovation speed, while Fig. 4 presents the marginal effects of innovation speed on operational performance at different levels of innovation quality. For example, Fig. 3 shows that when the value of innovation quality increases from 0 to 77.10 (accounting for the 95.06% of the total sample size), the effect of innovation speed on operational performance becomes significantly weaker. Fig. 4 indicates that when the value of innovation speed increases from 0 to 77.10 (accounting for the 98.71% of the total sample size), the effect of innovation quality on operational performance becomes significantly weaker. In other words, when innovation speed increases, the slope of the relationship between innovation quality and operational performance becomes flatter; when innovation quality increases, the slope of the relationship between innovation speed and operational performance becomes flatter. To sum up, the results suggest that the relationship between innovation

Fig. 3. Moderating effect of innovation quality (IQ) on the relationship between innovation speed (IS) and operational performance (OP). **Fig. 4.** Moderating effect of innovation speed (IS) on the relationship between innovation quality (IQ) and operational performance (OP).

speed and innovation quality are substitutes (Titah and Barki, 2009; Zhang et al., 2014). Therefore, H7 is further supported. Financial slack and per-capita GDP are positively related to operational performance, which is consistent with previous studies (Guo et al., 2020; Kim and Hemmert, 2016; Sun et al., 2019). Other control variables turn out to be statistically insignificant except the industry 4.

4.2. Supplementary analyses

To address the potential problems of partial coefficient distortion in our moderating effect and interaction effect, we followed the residual centering procedure demonstrated by Heavey and Simsek (2017) and Lance (1988). To test the moderating effect of organizational risk (OR) on the relationship between R&D investment (RDI) and innovation speed (IS), innovation quality (IQ), we first regressed the interaction term ($RDI \times OR$) on their components (RDI and OR). We then applied the resulting residuals of these interaction terms in our hypothesis testing models (we refer to Model 2 and Model 4 in Table 2) to replace the interaction terms, which had the effect of reducing the extent of collinearity between the main effect and the interaction. The results revealed that the coefficient of the residual of the $RDI \times OR$ interaction ($b = -0.057, p > 0.050$) in innovation speed (IS) was insignificant, while the coefficient of the residual of the $RDI \times OR$ interaction ($b = 0.211, p < 0.050$) in innovation speed (IS) was positive and significant. To test the interaction effect of innovation speed (IS) and innovation quality (IQ) on operational performance, we also applied the residuals of these interaction term to replace the interaction term, and the result indicated that coefficient of the residual of the $IS \times IQ$ interaction ($b = -0.0002, p < 0.050$) was negative and significant. Comparing residual centering procedure results with the original hypothesis testing results in Table 2, these two sets of results are consistent with each other, which demonstrates the robustness of our analyses.

In order to further test the robustness of our regression results, we replaced profit with sales to operate firm performance in operation. The volume of sales is an important indicator to reflect firm performance (DeGroot and Marx, 2013; Koskela, 2015), and we applied the natural logarithm of sales to measure firm performance in operation. We regressed the natural logarithm of sales on innovation speed (IS), innovation quality (IQ), and their interaction ($IS \times IQ$). The results showed that the coefficients of innovation speed ($b = 0.006, p < 0.001$) and innovation quality ($b = 0.002, p < 0.050$) were positive and significant; the coefficients of the interaction term ($IS \times IQ$) were negative and significant ($b = -0.0001, p < 0.050$). The results of sales as the indicator of firm performance in operation are the same as the results of profit as the indicator of operational performance. Therefore, our analysis and results are robust.

5. Discussion

This study aims to examine the antecedent and outcome of the innovation speed-quality paradox in high-tech SMEs' operation. Based on a total number of 1782 firm-year observations of high-tech SMEs, we find that R&D investment facilitates innovation speed and quality; organizational risk strengthens the positive effect of R&D investment on innovation quality; and both innovation speed and quality are beneficial for firms to improve performance in operation. The interaction between innovation speed and quality hinders firms in reaping performance. However, the hypothesis stating that organizational risk negatively moderates the relationship between R&D investment and innovation speed is not supported. One plausible explanation is that the high-tech SMEs are small and flexible, and they can cope with the dynamics and uncertainties in the process of innovation (De et al., 2020; Rodríguez and Nieto, 2016; Wang et al., 2018). Thus, the effect of R&D investment on innovation speed appears to be not affected by organizational risk. The theoretical contributions, practical implications, limitations, and future research are discussed in the following sections.

5.1. Theoretical contributions

This study makes several contributions to operations and innovation literature. First of all, this study extends our understanding of the speed-quality paradox in operations management by revealing the effect of this paradox on firm's operational performance in high-tech SMEs. The

relationships between innovation dimensions (i.e., speed and quality) on firm performance have been discussed in the academic literature (Carbonell et al., 2009; Taghizadeh et al., 2018). However, to the best of our knowledge, there is no literature in operations management empirically investigating the speed-quality paradox (Kostami and Rajagopalan, 2013). In this study, we provide empirical evidence to show that both innovation speed and innovation quality are beneficial for operational performance in high-tech SMEs. Meanwhile, we also offer additional insights into the speed-quality paradox and uncover that the interaction of innovation speed and innovation quality is detrimental to operational performance. The findings of the significant role of innovation speed-quality paradox in high-tech SMEs' operation offer a novel perspective in understanding innovation in firms' operations. More specifically, this study empirically confirms the innovation speed-quality paradox and uncovers the mechanism of innovation speed-quality paradox on operational performance in high-tech SMEs, which enriches the studies of speed-quality paradox in operations management.

Second, this study enriches the literature of innovation in operation by revealing the positive effect of R&D investment on innovation speed and innovation quality in high-tech SMEs' operations. According to the resource-based view, R&D investment drives firms to engage in innovation activities, which is crucial to firms' innovation (Czarnitzki and Hottenrott, 2011; Wu et al., 2019). It is worthwhile to note that innovation in firms' operations consists of two dimensions—speed and quality (Carbonell et al., 2009; Taghizadeh et al., 2018). We argue that high-tech SMEs with R&D investment can improve resource commitment, absorptive capability, risk tolerance, and high-quality knowledge creation and combination, thereby accelerate innovation speed and quality in high-tech SMEs. In other words, this study reveals that R&D investment positively impacts innovation speed and innovation quality in high-tech SMEs' operations, which makes contributions to innovation in operations.

Finally, this study extends the literature of the R&D-innovation relationship in operation by uncovering the boundary condition of organizational risks. High-tech SMEs are operating in a competitive dynamic environment and are confronted with uncertainties and risks from the dynamic environment, e.g., organizational risk (Boh et al., 2020; Hasan et al., 2018; Wang et al., 2018). In order to answer the above research calls and understand whether and how the effect of R&D investment on innovation depends on broader environmental contingencies, this study reveals that organizational risk strengthens the positive effect of R&D investment on innovation quality. To encounter organizational risk, high-tech SMEs tend to excel more discreetly on choosing stable and reliable innovative ideas by applying R&D resources, and tend to be cautious to invest R&D resources in selecting more valuable knowledge that is compatible with the existing knowledge stocks. Thus, the efficiency of R&D investment on innovation quality can be improved. In other words, this study uncovers differing contingency effects of organizational risk on innovation speed and quality, which extends the literature regarding the relationship between R&D and innovation in operations management.

5.2. Practical implications

Our study also offers several useful insights for operations managers, board members, and policy-makers in high-tech SMEs. For high-tech SMEs' managers and board members in high-tech SMEs, they should be aware of the innovation speed-quality paradox in firms' operations. On the one hand, both innovation speed and innovation quality are conducive to the improvement of operational performance. On the other hand, their interaction is detrimental to operational performance. The managers and board members who allocate innovation-related resources should take advantage of the benefits of the innovation speed-quality paradox and avoid its negative effects. For example, they may need to find a balance in trading-off between innovation speed and

innovation quality. For instance, operations managers are advised to give priority to either innovation speed or quality in carrying out innovation activities by sticking to the strategies they have made at the upper-echelon level (board members). Also, our research findings indicate that R&D investment is beneficial for innovation speed and innovation quality in high-tech SMEs' operation such that the managers and board members in high-tech SMEs should make the best use of R&D investments to improve innovation speed and innovation quality. For instance, they can allocate more resources to R&D activities and regulate the R&D investment based on the firms' requirements to improve firms' innovation speed and quality. Furthermore, managers should pay careful attention to organizational risk. Since organizational risk strengthens the positive effect of R&D investment on innovation quality, they may need to increase the R&D investment aiming for improving innovation quality when the firm encounters high organizational risk. For example, they can allocate more resources (e.g., financial and human resources capital) to improve high-quality patents and products.

Our research findings also inform policy-makers in high-tech SMEs. To begin with, they are recommended to introduce a policy to encourage R&D and innovation since R&D investments and innovation are positively related to operational performance. On the one hand, since dedication to innovation speed and quality both lead to higher operational performance in high-tech SMEs, the policy-makers can implement some schemes to motivate firms to engage in innovation activities. For example, policy-makers can administer incentive schemes (e.g., tax reduction) to the firms which have been granted a high number of and high-quality patents. On the other hand, policy-makers should encourage firms to allocate more resources in R&D activities given that R&D investment triggers innovation speed and innovation quality. For instance, the policy-makers may offer subsidies or make certain funds available in support of firms' R&D activities. In particular, policy-makers should be able to encourage the high-tech SMEs to allocate more R&D investments to improve innovation quality when confronted with organizational risk due to that organizational risk enhances the effect of R&D investment on innovation quality. Specifically, the policy-makers may provide subsidies and tax reductions for firms to develop promising patents and introduce high-margin products in the context of high organizational risk. These policy initiatives, in the long run, are likely to better help high-tech SMEs improve operational performance by implementing effective innovation management strategies and therefore these SMEs can outperform in the ever increasingly competitive business environment.

5.3. Limitations and future research

Although this study makes several contributions to literature and practices, several limitations also emerge in our research. First, the context of this study is China, which may constrain the generalizability of the results to other national contexts. It is desirable and interesting to apply similar research in other nations in the future. Second, this study focuses on high-tech SMEs, and the results may not be generalized to other industries. Since high-tech SMEs are innovation-oriented and resources are relatively scarce (Boso et al., 2017; Wang et al., 2018), the innovation speed-quality paradox may be stronger in this setting than in other industries. It is recommended to collect data from other industries' samples to test the study's validity in the future. Finally, this study only considers the contingent effects of organizational risk. Organizational risk is an important contingency factor in firms' operation (Boh et al., 2020; Hasan et al., 2018; Wang et al., 2018); meanwhile, other contextual factors—for example, competitive intensity, environmental turbulence, and market supporting institutions—are also important and interesting in firms' operation (Carbonell et al., 2009; Cui et al., 2018). It is worthwhile to consider these contingency factors to further confirm and extend our research in the future.

Declaration of competing interest

The authors hereby declare that there are no other conflicts of interest.

CRediT authorship contribution statement

Feng Guo: Conceptualization, Methodology, Writing - original draft. **Qingwen Bo:** Data curation, Investigation, Writing - original draft. **Xun Tong:** Writing - review & editing, Supervision. **Xiaofei Zhang:** Conceptualization, Writing - review & editing.

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