POLISH JOURNAL OF MANAGEMENT STUDIES
Liu Y.C., Zandi G., Yin H.N.

2023
Vol.28 No.1

THE IMPACT OF COVID-19 ON CORPORATE RESEARCH QUOTIENT: EVIDENCE FROM CHINESE FIRMS

Liu Y.C., Zandi G., Yin H.N.*

Abstract: Innovation plays a vital role in the development of firms. The Chinese firms' research and development (RandD) investments have been quite high, so it is also very novel to study the efficiency of RandD investment of Chinese firms. There are 4975 Chinese listed firms and 274 Chinese concept firms listed in the United States considered to be analyzed. Chinese and American-listed firms were chosen for the research quotient (RQ) characteristics. Creatively researching the impact of COVID-19 on the research quotient. The results concluded that Chinese firms' revenue has effectively been improved by the firms' RandD expenditures. In addition, there was no evidence that large firms had greater RQ than small and medium-sized enterprises (SMEs). Due to the effect of COVID-19, the RQ of all firms fell, but the effect in SMEs was significantly smaller than in large firms.

Keywords: Research quotient (RQ), Research and development (RandD), COVID-19, SMEs

DOI: 10.17512/pjms.2023.28.1.11

Article history:

Received July 16, 2023; *Revised* August 12, 2023*; Accepted* August 21, 2023

Introduction

Research and development (RandD) expenditure has become an important indicator of a country's (region's) financial strength, education level, RandD strength and innovation achievements. Countries (regions) that invest heavily in RandD are usually the innovation leaders. According to the latest NCSES (The National Center for Science and Engineering Statistics is a principal statistical agency located within the National Science Foundation) estimates, global RandD expenditure reached US$2 trillion in 2017 in terms of purchasing power in that year, an average annual increase of 6.2% from US$722 billion in 2000, and this nearly threefold increase

*__Yuanchun Liu__, MBA, Faculty of Business Finance and Information Technology,MAHSA University, Malaysia;
✉ email: mbaf22056437@mahsastudent.edu.my,
ORCID: 0009-0003-8071-8572
Gholamreaza Zandi, Associate Professor, Universiti Kuala Lumpur Business School, Malaysia;
✉ email: zandi@unikl.edu.my,
ORCID: 0000-0001-9517-8474
Hainan Yin, Master of Hospital Administration, College of Business, Government and Law, Flinders University, Adelaide 5042, Australia;
✉ Corresponding author: yin0155@flinders.edu.au,
ORCID0009-0009-0149-2071

reflects, to some extent, the escalating knowledge intensity of economic competition around the world and the desire of countries to use scientific and technological progress to improve national economic and social well-being (Jiang and Liu, 2020). Globally, RandD investment in 2019 is estimated at US$2.4 trillion, more than three times the amount spent in 2000 (NSF, 2022). The US invested US$406.6 billion in RandD in 2019, accounting for approximately US$666.9 billion, with an average annual growth rate of RandD expenditure of approximately 3.8%, much higher than the average growth rate of US GDP. China has the second-highest total RandD, with an average annual growth rate of 10.6% from 2010-2019, well above the US (5.6%) and the European Union (EU-27) (5.6%) (NSF, 2022).

The National Bureau of Statistics recently released data: preliminary estimates show that Chinese RandD investment will reach 3,087 billion yuan in 2022, breaking the 3 trillion yuan mark for the first time, an increase of 10.4% over the previous year (National Development and Reform Commission, 2023). With such a high investment in RandD, what exactly is the RandD capability in the development of firms? Furthermore, we all know that COVID-19 has caused an unprecedented shock to the global economy, restricting most metallic activities due to the implementation of regional closures, traffic restrictions, embargoes, etc., which has dealt a major blow to a large number of firms (Saputra and Herlina 2021; Dao et al., 2022; Halmai, 2022).

In summary, Chinese RandD investment has increased substantially, but fewer studies have examined how efficient this RandD has been. Also, fewer have involved comparative analyses of the research quotients (RQs) of large firms and SMEs, so comprehensively analyze the RQs of Chinese firms and the RQs' differences in the firms of different sizes, and whether there is a significant difference in Chinese firms' RQs in the years 2020 to 2022 compared to the three years before COVID-19 (2017-2019).

Literature Review

Most studies suggest that RandD investment increases firm sales. Agustia et al. (2019) suggest that higher RandD intensity leads to higher sales and more efficient production and that RandD increases revenue and reduces production costs, thus increasing firm performance. Falk (2012) investigated the impact of RandD investment on employment and revenue growth, and the study found that an increase in RandD investment will significantly increase employment in firms and increase revenue. This also explains that RandD investment will result in new products or processes, which will drive firms to increase production lines and, therefore, increase the workforce and revenue. Chen and Yang (2021), by analyzing the impact of RandD investment on revenue in small and medium-sized medical consumables firms in Taiwan, found that the revenue of firms in this industry increases with the number of employees and RandD investment. Knott (2012) found in his analysis that for every 1% increase in RandD expenditure of US-listed firms, revenue will

increase by 0.11%. Griliches (1979) analyzed RandD as an input factor in the production function to determine the impact of RandD investment on firm productivity. Dou and Chen (2019) compare the RandD performance of Chinese and American firms and find that RandD investment positively affects the growth rate of revenue, and the positive relationship is more pronounced in the US.

Is the continued high growth of RandD investment in China efficient for Chinese firms, and does the increase in RandD investment lead to the growth of firm revenue?

H1: Chinese firms' research and development investment lead to revenue growth.

It is found that the intensity of RandD investment is positively correlated with the future profitability of a company as its size increases (Zhou, 2012), and the risk of RandD investment decreases as the size of the company increases. The lower the future risk, the lower the future stock returns (Nie, 2008). Large firms with strong financial and technical support generally have a better RandD environment and are significantly more efficient in RandD than smaller firms. Knott's (2012) analysis also found that the larger the firm, the greater the RandD investment and the greater the RandD capability, and that size has a positive and significant impact on a firm's RQ. However, the large size of a firm also means that its internal coordination is more difficult, which can also hinder the efficiency of the firm's RandD (Liu and Ye, 2017). The second hypothesis is formulated in the Chinese firm population if RQ is used to measure a firm's RandD capability.

H2: If the business size is larger, the research quotient (RQ) is also larger.

Research suggests that Covid-19 reduces firm innovation as disrupted information transmission affects information exchange and weakens external linkages and interactions, thus inhibiting firm innovation, but the impact is minimal in the medium to long term (Li et al., 2022). While the negative socio-economic impact of Covid-19 is clear, as empirical evidence from current research on the impact of business innovation is insufficient, according to the Global Innovation Index 2021 report (GII), global technology publications grew by 7.6% in 2021, 2.2 percentage points above the long-term level (2010-2020 growth rate). Venture capital deals grow by 5.8%, 2.2 percentage points above their long-term level. In addition, Covid-19 has boosted innovation in sectors such as pharmaceuticals and internet communications equipment manufacturing (Li et al., 2022). The impact of COVID-19 on firms' RandD capacity is therefore less well studied, and hypotheses 3 and 4 are formulated.

H3: COVID-19 has a negative effect on research quotient (RQ), leading to a decrease in research quotient (RQ).

H4: Research quotient (RQ) of large firms is less affected by COVID-19 than research quotient (RQ) of Small and Medium Enterprises (SMEs).

Research Methodology

The externality theory suggests that investment in RandD is a risky and uncertain investment activity, and there is a great deal of uncertainty as to whether the outcome of RandD and its benefits will meet expectations given the large amount of human,

material and financial resources invested (Zhao et al., 2022). This makes it difficult for RandD firms to make profits commensurate with their RandD investment, and it is also detrimental to the incentive to invest in RandD. The RandD process is often seen as a separate business process from the production process of a company, including all planning and development of new products, methods and processes (Davcik et al., 2021).

Knott (2018) proposes a production function theory of capital, manpower, RandD and RandD spillovers based on the basic production function of:

$$\ln Y_{it} = (\beta_0 + \beta_{0i}) + (\beta_1 + \beta_{1i}) \ln K_{it} + (\beta_2 + \beta_{2i}) \ln L_{it} + (\beta_3 + \beta_{3i}) \ln R_{it-1} + (\beta_4 + \beta_{4i}) \ln S_{it-1} + \varepsilon_{it} \quad (1)$$

The firm's financial data include (in $MM unless otherwise stated): revenue Y_{it}, capital expenditure K_{it}, firm's number of employees (1000) L_{it}, RandD expenditure R_{it}, lagged effect of RandD expenditure R_{it-1}, spillover effect S_{it} and lagged effect S_{it-1} of firm's RandD, ε_{it} is the disturbance term, and β_0-β_4 represent the production elasticity of the corresponding inputs, respectively.

Regarding the measurement function of the spillover effect S_{it}, Knott (2018) mimics the measure of spillover structure in Jovanovic and MacDonald's (1994) endogenous growth model and proposes a firm-specific calculation of the spillover effect in the same industry, the sum of the knowledge differences between focal firm i and rival firm j, i.e., relative to the focal firm, the superior the spillover effect of the excess RandD knowledge generated by the firm with superior knowledge, which absorbs learning to other firms, is derived from the following equation:

$$S_{it} = \sum_{j \neq i} R_{jt} - R_{it} \quad \forall R_{jt} \geq R_{it} \quad (2)$$

For the measurement of firms' RandD production elasticity RQ, data from the annual financial statements of Chinese firms were used in the three years before COVID-19 and the three years after COVID-19 and excluded them to derive unbalanced panel data as some firms had no RandD investment or did not disclose their RandD investment. There are three types of regression impact relationship studies that can be conducted on panel data, namely FE models, POOL models (which are ordinary OLS regressions) and RE models. The final choice of model can be determined by the F-test, BP-test and Hausman test (SPSSAU.com, 2023). The specific criteria are as follows:

Table 1. Choice of effects model

Type	Purpose of test	value	conclusions
F-test	FE or POOL Model	If p<0.05	FE
BP-test	RE or POOL Model	If p<0.05	RE
Hausman test	FE or RE Model	If p<0.05	FE

Research Design

This study is a quantitative study designed to collect the elasticity coefficient of RandD investment to revenue for listed firms in China with the objective of applying unbalanced panel data. Knott (2018) uses the production function in this method to analyze the RQ of firms in various industries in the U.S. Li Shan (2020) analyzes the interdependence between RandD investment and revenue for listed firms in Chinese science and technology board Conducting a research analysis, they show through quantitative empirical research that there is a correlation between the amount of RandD investment or patent rights of a firm and revenue. Therefore, it is appropriate and feasible for this study to refer to Knott's (2018) method to select the RandD investment and RandD spillover effects of Chinese listed firms for quantitative analysis.

In the Internet category, many Chinese firms are restricted by specific industries, such as Jingdong (JD) and Ali (BABA). New Oriental (EDU) in the education category, which cannot meet the conditions for listing in China and chooses to list in the US, to ensure that the firms in our study can be more representative, our study includes Main Board, SME, GEM and STB firms listed on the Shanghai Stock Exchange and Shenzhen Stock Exchange in China. Also, it includes 275 Chinese concept firms listed and traded in the US market.

The main data of this study comes from iFinD, which is an online real-time financial database launched by ROYALFLUSH INFO (SZ: 300033) that is a comprehensive financial data platform integrating macroeconomics, industry economics, overseas economics, company operations, financial products, market consulting, valuation, pricing tools and data application tools, and is widely used in the fields of financial investment, financial research, financial teaching, and financial supervision, teaching, financial regulation and other fields (51ifind.com, 2023). Annual financial data of companies listed in China and the U.S. from January 1, 2017 to December 31, 2022 were accessed by the authors through the iFinD.

Statistical Product and Service Software Automatically (SPSSAU) belongs to Beijing Qingshi Technology Co. SPSSAU is a web-based data analysis program that provides more intelligent data analysis and interpretation than SPSS. The SPSSAU algorithm module includes general research algorithms, data processing functions, questionnaire research algorithms, advanced algorithms, visualization research algorithms and medical experimental research. The SPSSAU specific algorithms include general statistical functions, regression analysis and prediction, analysis of variance functions, non-parametric functions, multivariate statistical functions and other algorithmic functions (SPSSau.com, 2023).

Research Results

The annual financial data of Chinese listed companies were analyzed for six years from 2017 to 2022, with 4,975 listed companies in China and 274 Chinese concept listed companies in the U.S. As of 2022, removing companies that do not have a complete 6 years of financial data and part of the annual PPandE investment or RandD investment of 0, a total of 21,314 fixed-year observations were obtained.

Table 2. Listed firms by industry

Item	GICS	GICS Industry	2017	2018	2019	2020	2021	2022	Sub-total
U.S	**10**	Energy	1	1	1	1	1	1	6
	15	Materials	2	2	2	2	2	2	12
	20	Industrial	5	5	5	5	5	5	30
	25	Non-Consumer	16	17	18	17	18	18	104
	30	Consumer		1	1	1	1	1	5
	35	Health Care	5	6	6	6	6	6	35
	45	IT	16	17	16	17	17	17	100
	50	Telecom.	12	13	13	13	13	13	77
Subtotal			**57**	**62**	**62**	**62**	**63**	**63**	**369**
CHINA	**10**	Energy	62	66	67	68	72	62	397
	15	Materials	583	622	632	637	639	584	3697
	20	Industrial	793	859	886	884	888	794	5104
	25	Non-Consumer	393	428	440	443	448	393	2545
	30	Consumer	185	198	208	214	218	185	1208
	35	Health Care	327	346	349	349	351	328	2050
	45	IT	779	836	839	844	844	779	4921
	50	Telecom.	99	101	105	111	110	99	625
	55	Utilities	57	58	66	77	83	57	398
Subtotal			**3278**	**3514**	**3592**	**3627**	**3653**	**3281**	**20945**
Total			**3335**	**3576**	**3654**	**3689**	**3716**	**3344**	**21314**

As shown in Table 2, Chinese concept stocks listed in the U.S. are mainly in the three industries of 25, 45 and 50, while Chinese listed firms are mainly in the three industries of 15, 20 and 45. There are differences in the selection of listing places by firms, so choose to combine Chinese listed firms and Chinese stocks in the U.S. market together for analysis, which includes as much data as possible for all industries. For Chinese and US-listed Chinese stocks, uniformly convert financial

data into RMB using the exchange rate at the financial reporting date of the year, and then analyzed the RMB amount or the number of employees statistically in the form of ln, and didn't account for differences in accounting standards.
Since Chinese listed firms, regardless of Revenue, investment in fixed assets, total number of employees or RandD investment, are very different. Their maximum values far exceed the mean by more than 3 standard deviations, the median as the criterion for descriptive analysis is chosen, and it can be seen through Table 3 that the median values of Revenue, PPandE, total number of employees and RandD investment of Chinese firms are not affected by Covid-19. After Covid-19, the medians of all indicators are higher than before Covid-19 except for the RandD spillover effect. The standard deviations do not show significant fluctuations, which indicates that Chinese-listed firms are more resilient to risks.

Table 3. Description of basic indicators

	Overall			**Before Covid-19**			**After Covid-19**		
Item	N	SD	Median	**N**	**SD**	**Median**	**N**	**SD**	**Median**
Y	21314	1.525	7.484	10565	1.507	7.312	10749	1.527	7.642
K	21314	1.721	6.946	10565	1.748	6.737	10749	1.667	7.135
L	21314	1.270	7.485	10565	1.274	7.423	10749	1.262	7.553
$\mathbf{R_{t-1}}$	21314	1.526	3.904	10565	1.506	3.808	10749	1.539	4.009
$\mathbf{S_{t-1}}$	21314	1.062	13.516	10565	0.999	13.548	10749	1.120	13.481

Note: Y denotes the operating revenue of the firm in the current year, K denotes the total original value of all fixed assets, productive biological assets and intangible assets of the firm as of the end of the current year, La denotes the total number of employees of the firm as of the end of the current year, R_{t-1} denotes the total RandD investment of the firm as of the previous year, and S_{t-1}denotes the total RandD spillover absorbed by firms from firms that invest more in RandD in the same industry.

As described in Table 4, there are significant correlations between both independent and dependent variables, among which the correlation coefficient between RandD investment and revenue (Y) is 0.570, indicating that RandD investment of Chinese firms is also significantly positively correlated with revenue (Y), which tentatively proves that H1 holds. Analyzing the correlations of each variable before and after Covid-19 separately shows that Chinese firms' RandD investment is significantly and positively correlated with revenue (Y).

Table 4.Pearson Correlation

	Mean	SD	Y	L	K	R_{t-1}	S_{t-1}
Y	7.661	1.525	1				
L	7.587	1.270	0.846**	1			
K	7.062	1.721	0.803**	0.778**	1		
R_{t-1}	3.967	1.526	0.570**	0.586**	0.460**	1	
S_{t-1}	13.050	1.062	-0.315**	-0.271**	-0.360**	-0.151**	1

*p<0.05 ** p<0.01

For the analysis of panel data, FE model, POOL model (that is, ordinary OLS regression), and RE model can be selected for regression analysis, and the F test, BP test and Hausman test are used to determine which model is better to apply.

Table 5. Test results (n=21314)

Type	Purpose of test	value	conclusions
F test	FE or POOL Model	F (3764,17545)=25.657,p=0.000	FE
BP test	RE or POOL Model	$\chi2(1)$=31519.687,p=0.000	RE
Hausman test	FE or RE Model	$\chi2(3)$=70.254,p=0.000	FE

According to the analytical model test in Table 5, the analysis for the full operating period 2017-2022 is suitable for using the FE model, which is used as the final result analysis.

Table 6. All data results

Item	POOL	FE	RE
constant	1.171** (14.887)	0.416** (2.628)	0.718** (6.189)
K	0.311** (66.133)	0.271** (39.586)	0.283** (49.131)
L	0.597** (88.217)	0.719** (68.605)	0.687** (81.179)
R_{t-1}	0.112** (28.021)	0.041** (8.770)	0.049** (12.149)
S_{t-1}	-0.052** (-10.508)	-0.022* (-2.098)	-0.035** (-4.605)
R^2	0.778	0.772	0.774
R^2(within)	0.483	0.494	0.494
N	21314	21314	21314

Item	POOL	FE	RE
test	F (4,21309)=18622.846,p=0.000	F (4,17545)=4286.097,p=0.000	$\chi 2(4)=35643.873$,p=0.000

Dependent variable：Y

* p<0.05 ** p<0.01 t-values in parentheses

Table 6 for PPandE(K) shows significance at 0.01 level (t=39.586, p=0.000<0.01), and the regression coefficient value is 0.271>0, which indicates that asset input has a significant positive effect on revenue (Y).
For Labor (L), it shows a significance at 0.01 level (t=68.605, p=0.000<0.01), and the regression coefficient value is 0.719>0, which indicates that the number of employees has a significant positive effect on revenue.
For RandD(R), it shows a significance at 0.01 level (t=8.770, p=0.000<0.01), and the regression coefficient value is 0.041>0, which indicates that there is a significant positive relationship between corporate RandD investment and revenue.
For spillover (S), it shows a 0.05 level of significance (t=-2.098, p=0.036<0.05), and the regression coefficient value is -0.022<0, indicating that RandD spillover Si will have a significant negative influence relationship on revenue, which indicates that an increase in RandD expenditure of other firms will cause an increase in RandD spillover in the industry, leading to an under-research and development of firms in the industry revenue decline.
Meanwhile, under the three models of FE model, POOL model and RE model, each variable shows a significant effect, the direction of the effect is the same, and its R^2 is also around 0.77. This proves that H1 holds and the RandD investment of Chinese firms also affects the Revenue of firms.
According to the above method, the operating data of the full period are divided into two different periods: three years of normal operation from 2017-2019 and three years of Covid-19 from 2020-2022, and the RQ values of different periods are calculated separately.

Table 7. Covid-19 before and after panel results

Item	Before Covid-19			After Covid-19		
	POOL	FE	RE	POOL	FE	RE
constant	1.276** (5.915)	1.763** (2.796)	1.379** (6.127)	1.064** (5.619)	0.811* (2.377)	0.609** (3.919)
K	0.292** (20.914)	0.203** (8.390)	0.247** (16.589)	0.324** (23.376)	0.232** (6.513)	0.300** (17.441)
L	0.601** (27.154)	0.659** (14.324)	0.661** (27.454)	0.600** (30.744)	0.709** (16.049)	0.685** (32.845)
R_{t-1}	0.113** (9.347)	0.065** (5.277)	0.070** (8.242)	0.108** (10.456)	-0.019** (-2.723)	0.014* (2.312)

Item	Before Covid-19			After Covid-19		
	POOL	FE	RE	POOL	FE	RE
S_{t-1}	-0.055** (-4.264)	-0.065 (-1.615)	-0.061** (-4.890)	-0.049** (-4.506)	-0.002 (-0.260)	-0.021** (-3.100)
R^2	0.777	0.768	0.775	0.775	0.752	0.768
R^2(within)	0.409	0.423	0.421	0.258	0.326	0.320
N	10565	10565	10565	10749	10749	10749

* p<0.05 ** p<0.01 t-values in parentheses

The comparison in Table 7 highlights that the RQ value of Chinese firms has significantly decreased due to the influence of Covid-19. While the change in the POOL model is minor, moving from 0.113 to 0.108, the FE model shows a significant shift from a positive effect to a negative effect, with the RQ value dropping from 0.065 to -0.019. The RE model also demonstrates a considerable decrease, from 0.070 to 0.014. This collectively confirms that Covid-19 has notably and adversely impacted firm RQ, aligning with the validated H3 hypothesis.
Following the SME classification criteria set by the US, the standard relies on the number of firms in 2017. A company with more than 500 employees during that year is categorized as a large firm. Conversely, businesses with under 500 employees are classified as SMEs. The task here is to calculate the RQ values before and after the Covid-19 period for large firms and SMEs, using this classification as the basis.

Table 8. Panel model results for large firms

Item	Before Covid-19			After Covid-19		
	POOL	FE	RE	POOL	FE	RE
constant	1.049** (4.901)	1.700** (2.823)	1.260** (5.247)	0.778** (3.802)	0.461 (1.223)	0.165 (0.983)
K	0.316** (25.807)	0.226** (8.106)	0.273** (17.718)	0.337** (25.453)	0.293** (10.253)	0.336** (22.896)
L	0.617** (30.401)	0.638** (12.184)	0.661** (24.163)	0.628** (31.806)	0.690** (15.531)	0.696** (31.642)
R_{t-1}	0.114** (9.706)	0.055** (4.759)	0.064** (7.601)	0.105** (9.875)	-0.016* (-2.270)	0.011 (1.871)
S_{t-1}	-0.063** (-5.014)	-0.057 (-1.860)	-0.065** (-5.549)	-0.053** (-4.763)	-0.001 (-0.084)	-0.015* (-2.471)
R^2	0.770	0.753	0.766	0.768	0.748	0.760
R^2(within)	0.411	0.436	0.431	0.298	0.381	0.377
N	8862	8862	8862	9021	9021	9021

* p<0.05 ** p<0.01 t-values in parentheses

Table 8 reports the different RQ values for large firms before and after Covid-19. Before Covid-19, large firms' RandD expenditures significantly positively affected Revenue. Still, under the influence of Covid-19, the RE model shows no significant effect, and the FE model shows a significant negative effect at the 5% level, so this also indicates that Covid-19 has a significant negative effect on large firms' RQ form a significant negative effect.

Table 9. SME panel model results

Item	Before Covid-19			After Covid-19		
	POOL	FE	RE	POOL	FE	RE
constant	0.848 (1.047)	9.232 (0.664)	0.084 (0.090)	0.739 (1.895)	4.743 (1.826)	1.092 (1.956)
K	0.192** (3.623)	0.144** (2.978)	0.168** (4.196)	0.264** (14.488)	0.128** (3.527)	0.212** (9.341)
L	0.483** (4.390)	0.677** (7.444)	0.670** (7.842)	0.489** (14.538)	0.748** (12.309)	0.599** (15.129)
R_{t-1}	0.048 (0.941)	0.094 (1.108)	0.088* (2.550)	0.093** (4.683)	-0.053 (-1.821)	0.004 (0.239)
S_{t-1}	0.087 (1.519)	-0.617 (-0.606)	0.064 (0.971)	0.064* (2.508)	-0.265 (-1.395)	0.030 (0.788)
R^2	0.194	-0.131	0.180	0.344	0.253	0.333
R^2(within)	0.369	0.404	0.397	0.200	0.234	0.227
N	1703	1703	1703	1728	1728	1728

* p<0.05 ** p<0.01 t-values in parentheses

Table 9 shows that the RandD investment of SMEs presents significance only at 5% level in the RE model before Covid-19 and at 1% level in the POOL model under the influence of Covid-19, while none of the other models present significance.
Therefore, the above comparative analysis between large firms and SMEs reveals that the RandD investment of large firms has a significant positive correlation with revenue, while none of the SMEs present significance under FE model. At the same time, there is a difference between RQ of large firms and SMEs, but the RQ value of large firms is not necessarily greater than that of SMEs; H2 is not proven.
Analyzing the provided information, it's clear that the impact of COVID-19 differs for large firms and SMEs. Large firms show a decrease in the FE model, POOL model, and RE model, while SMEs demonstrate a decrease in the FE and RE models, but an increase in the POOL model. By conducting F-test, BP-test, and Hausman test on SME panel data, we chose the FE model alongside the POOL model, where Covid-19 wasn't initially significant. It's important to note that the RQ of both large firms and SMEs is affected by Covid-19, with large firms decreasing from 0.055 to -0.016, and SMEs from 0.094 to -0.053. As a result, the study confirms the H4

hypothesis, indicating that large firms are less impacted by Covid-19 compared to SMEs.
Also, regarding the elasticity of RandD spillover effect S, the S elasticity of large firms is significantly negative. In contrast, the S elasticity of SMEs is not significant, and there are positive and negative elasticities under different research models, which indicates to some extent that SMEs can absorb new knowledge from the RandD of large firms to enhance their own product production or marketing capabilities (Knott, 2008).

Conclusion

There have been many studies on the impact of RandD investment on firms, but most of them study the impact of RandD investment on firm value or firm performance, and the findings are diverse and do not form a consistent conclusion. This study refers to Knott, A.M. (2018) and uses the basic principles of production function to analyze the impact of Labor, PPandE, RandD, and RandD spillover (S) on Chinese firms' revenue, financial data of Chinese listed firms as well as US-listed Chinese concept firms from 2019 to 2022 are selected for analysis, also by comparing the impact of RandD elasticity RQ of these firms for three years of the Covid-19, RQ heterogeneity analysis of firms of different sizes, etc. Using the same research method, but with different analysis objects and research scope. The study discovered that Labor, PPandE, RandD, and RandD spillover (S) have a linear relationship with Chinese firms' revenue, resulting in a significant and positive impact, which aligns with our initial hypothesis. These findings also correspond with research conducted by other scholars. For instance, Qin (2022) revealed that a firm's RandD efforts contribute positively to its overall performance. Successful RandD requires substantial long-term financial and human investments, leading to improved outcomes and technological advancements that enhance firm performance. Similarly, Zheng et al. (2015) determined that RandD investment positively affects firm performance, with a noticeable positive effect appearing after a certain time lag following RandD investments. As a result of Covid-19, Chinese firms' RandD elasticity RQ in the three years of Covid-19 was significantly lower than that in the three years before Covid-19, suggesting that the Covid-19 had a significant negative impact on the RandD efficiency of firms, which is in line with existing research. Li et al. (2022) study that COVID-19 will reduce firm innovation; also, it has been shown that firms engage in less innovation investment during the global economic crisis (Roper and Turner, 2020). However, this study analyzes RandD investment by measuring industry-wide RandD investment rather than limiting itself to the impact on innovation investment.
Also, by comparing large firms with SMEs, it can be found that large firms are less affected by COVID-19, while SMEs are more affected by COVID-19, and Schmitz (2014) uses data from German firms to reach a similar conclusion, with German

SME firms reducing their RandD expenditures more than large firms during the financial crisis.

The novelty of this paper is to integrate previous data limited to single market-listed firms, and this study includes Chinese market-listed firms and US-listed Chinese concept firms, which is more representative of the general characteristics of Chinese firms. In addition, for the management control of COVID-19 Covid-19, China is the most stringent in the world, which has considerably impacted the production and operation of firms for three years. This study was conducted before and after three years. This study is a comparative study of data from three years before and after to prove the negative impact of Covid-19 on Chinese firms with data from natural experiments.

The study results show that the research and development investment of enterprises can increase the operating income of enterprises, but the RandD efficiency of different enterprises is different. In the development of enterprises, enterprises of different sizes should adjust the budget of RandD investment according to the actual situation and combine it with the RandD efficiency.

Shortcomings and Future Directions

Firstly, this study was conducted based on traditional production functions, focusing on Labor, PPandE, RandD, RandD spillover Si, etc., while many factors affect the firm's revenue, and future studies can consider more factors that affect revenue for analysis.

Secondly, Li Shan (2020), by analyzing the interdependence between Revenue and RandD, Patent of KCI firms, proved that the number of granted patents has a positive influence on the Revenue of firms, and at the same time, this Revenue can, in turn, support the RandD investment of firms and play a role in promoting the technological innovation of firms. However, the endogeneity of firms' RandD expenditures is not considered in this study, and future research can continue to analyze whether there is an endogeneity problem between them and conduct regression analysis after excluding the endogeneity factor.

Finally, this study also compares and studies the RandD spillover elasticity of firms of different sizes. Just like the RandD elasticity of firms of different sizes, industries also have heterogeneity in their RandD spillover elasticity. This study does not study the RandD spillover elasticity by industry, and future research can continue to explore the RandD elasticity and RandD spillover elasticity of different industries in order to find out the firms or industries with higher RQ values in China.

References

Agustia, D., Sawarjuwono, T. and Dianawati, W., (2019). The mediating effect of environmental management accounting on green innovation-Firm value relationship. *International Journal of Energy Economics and Policy*, *9*(2), 299-306.

Ceylan, R.F., Ozkan, B. and Mulazimogullari, E., (2020). Historical evidence for economic effects of COVID-19. *The European Journal of Health Economics*, *21*, 817-823.

Cheng L. W., Dai X. Y., (2012). Analysis of the Distribution Characteristics of RandD Investment and the Influencing Factors of RandD Investment Intensity—Based on the Panel Data of 300,000 Industrial Firms in my country. *China Soft Science*, *8*, 152-165.

Chit, M.M., Croucher, R. and Rizov, M., (2023). Surviving the COVID-19 pandemic: The antecedents of success among European SMEs. *European Management Review*, *20*(1), 113-127.

Civelek, M., Krajčík, V. and Fialova, V., (2023). The impacts of innovative and competitive abilities of SMEs on their different financial risk concerns: System approach. *Oeconomia Copernicana*, *14*(1), 327–354.

Cooper, M., Knott, A. M. and Yang, W., (2022). RQ innovative efficiency and firm value. *Journal of Financial and Quantitative Analysis*, *57*(5), 1649-1694.

Corchuelo Martínez-Azúa, B., López-Salazar, P. E. and Sama-Berrocal, C., (2021). Impact of the COVID-19 pandemic on agri-Food companies in the Region of Extremadura (Spain). *Agronomy*, *11*(5), 971.

Dao, L. T., Hang, N. P. T., (2022). Factors Affecting Tax Compliance Of Enterprises During the Covid-19 Pandemic in Vietnam. *Montenegrin Journal of Economics*, *18*(4), 7-17.

Donthu, N., Gustafsson, A., (2020). Effects of COVID-19 on business and research. *Journal of Business Research*, *117*, 284-289.

Goldense, B. L., (2018). Improve RandD spending and productivity with the research quotient model. *IEEE Engineering Management Review*, *46*(1), 29-31.

Graebner, M. E., Knott, A. M., Lieberman, M. B. and Mitchell, W., (2023). Empirical inquiry without hypotheses: A question-driven, phenomenon-based approach to strategic management research. *Strategic Management Journal*, *44*(1), 3-10.

Halmai, P., (2022). COVID-19 Crisis and Supply Side Bottlenecks in the EU. Shorter and Longer Term Prospects. *Montenegrin Journal of Economics*, *18*(4), 19-30.

Jin, G., Xu, J., Liu, F., Haris, M. and Weqar, F., (2022). Does RandD investment moderate the relationship between the COVID-19 pandemic and firm performance in Chinese high-tech industries? Based on DuPont components. *Technology Analysis and Strategic Management*, *34*(12), 1464-1478.

Ključnikov, A., Civelek, M., Fialova, V. and Folvarčná, A., (2021). Organizational, local, and global innovativeness of family-owned SMEs depending on firm-individual level characteristics: evidence from the Czech Republic. *Equilibrium. Quarterly Journal of Economics and Economic Policy*, *16*(1), 169–184.

Knott, A. M., Vieregger, C., (2018). Reconciling the firm size and innovation puzzle. *US Census Bureau Center for Economic Studies Paper* No. CES-WP-16-20.

Kolkova, A., Rozehnal, P., (2022). Hybrid demand forecasting models: pre-pandemic and pandemic use studies. Equilibrium. *Quarterly Journal of Economics and Economic Policy*, *17*(3), 699–725.

Li, X., He, X., Zhou, L. and Xie, S., (2022). Impact of Covid-19s on Firm Innovation: An Analysis of COVID-19 and SARS. *Sustainability*, *14*(9), 5223.

Mao, S., Kremantzis, M. D., Kyrgiakos, L. S. and Vlontzos, G., (2022). RandD Performance Evaluation in the Chinese Food Manufacturing Industry Based on Dynamic DEA in the COVID-19 Era. *Agriculture*, *12*(11), 1938.

National Development and Reform Commission., (2023). https://en.ndrc.gov.cn/

NSF., (2022). https://www.nsf.gov/pubs/2023/nsf23002/tables.jsp

Qin ,Z. N., (2022).The relationship between financial flexibility, RandD investment and corporate performance, *Economist*,*11*,8-13

Roper, S., Turner, J., (2020). RandD and innovation after COVID-19: What can we expect? A review of prior research and data trends after the great financial crisis. *International Small Business Journal*, *38*(6), 504-514.

Santero-Sánchez, R., Pérez-Ruiz, S. and Marcos Calvo, M. A., (2022). Development and cohesion in Spanish regions. An analysis before and after the Great Recession. *Journal of International Studies*, *15*(1), 133-148

Zandi, G., Shahzad, I., Farrukh, M. and Kot, S., (2020). Supporting role of society and firms to COVID-19 management among medical practitioners. *International Journal of Environmental Research and Public Health*, *17*(21),796.

Zandi, G., Shakhim, F. R., Mohamed, Z. and Alshargawi, A. S., (2022). Comparison between the Conventional Partial Least Squares (Pls) and the Robust Partial Least Squares (Rpls-Sem) Through Winsorization Approach. *Journal of Information Technology Management*, *14*(4), 87-94.

Zhao, Xu, X., (2022). The impact of innovation-driven policy and RandD investment on corporate performance. *Financial Supervision*, *21*,98-104

WPŁYW COVID-19 NA KORPORACYJNY ILORAZ BADAWCZY: DOWODY Z CHIŃSKICH FIRM

Streszczenie: Innowacje odgrywają istotną rolę w rozwoju firm. Inwestycje chińskich firm w badania i rozwój (RandD) są dość wysokie, dlatego też bardzo nowatorskim podejściem jest badanie efektywności inwestycji w RandD chińskich firm. Do analizy brano pod uwagę 4975 chińskich firm notowanych na giełdzie oraz 274 chińskie firmy koncepcyjne notowane w Stanach Zjednoczonych. Chińskie i amerykańskie firmy giełdowe zostały wybrane ze względu na charakterystykę ilorazu badawczego (RQ). Kreatywne badanie wpływu COVID-19 na iloraz badawczy. Wyniki wykazały, że przychody chińskich firm zostały skutecznie zwiększone dzięki wydatkom firm na RandD. Ponadto nie było dowodów na to, że duże firmy miały większy RQ niż małe i średnie przedsiębiorstwa (MŚP). Biorąc pod uwagę wpływ COVID-19, RQ wszystkich firm spadł bez względu na ich wielkość, jednakże spadek RQ w MŚP był znacznie mniejszy niż w dużych firmach.

Słowa kluczowe: Iloraz badawczy (RQ), Badania i rozwój (RandD), COVID-19, MŚP