



Article R&D Investments and Firm Value: Evidence from China

Woo Sung Kim¹, Kunsu Park^{1,*}, Sang Hoon Lee¹ and Hongyoung Kim^{2,*}

- ¹ Bang College of Business, KIMEP University, Abay Ave 2, Almaty 050010, Kazakhstan; woosung@kimep.kz (W.S.K.); shlee@kimep.kz (S.H.L.)
- ² Strategy Center for R&D Coordination, Korea Institute of S&T Evaluation and Planning, 60 Mabang-ro Seocho-gu, Seoul 06775, Korea
- * Correspondence: kunsu.park@kimep.kz (K.P.); kimhy@kistep.re.kr (H.K.); Tel.: +7-702-172-4096 (K.P.); +82-2-589-2883 (H.K.)

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Abstract: This study examines whether R&D investments are non-linearly related to firm value. Using a sample of 563 Chinese listed firms between 2005 and 2013, we find that R&D investments have an inverted U-shaped relationship with firm value. This finding indicates that as R&D investments increase, firm value increases to a certain level and then decreases. We further find the presence of an inverted U-shaped relationship in firms with low state ownership. However, we find no evidence of a non-linear relationship in firms with high state ownership. These results suggest that the inverted U-shaped relationship is more pronounced for firms with low state ownership than for firms with high state ownership. Moreover, we find that there is an inverted U-shaped relationship between R&D investments and firm value in firms with high growth opportunities. In contrast, for firms with low growth opportunities, their relationship has a U-shaped pattern. These results are robust to robust standard errors clustered at the firm level, controlling for industry fixed effects, and omitting variable biases. Overall, our empirical evidence extends and complements the literature on the R&D investments-firm value relationship by considering their non-linear pattern. This study provides important implications for stakeholders, such as investors, policy makers, standard-setters, state owners, and regulators. Specifically, our findings can be useful to policy makers who pursue long-term performance objectives.

Keywords: R& D investments; firm value; non-linearity; China

1. Introduction

It is well-documented that research and development (R&D) investments play a crucial role in enhancing firm value [1]. High-growth firms, such as Huawei, Apple, Google, and Samsung Electronics, have continued to increase R&D investments so as to improve the quality and attractiveness of their main products. In this context, one of the main concerns among from academics and practitioners is how R&D investments affect firm value. Prior research has provided mixed evidence on the association between R&D investments and firm value. Some studies find that R&D investments have the potential to generate high future profits and thus increase firm value [2–6]. Other studies show that R&D investments have a differential impact on firm value, depending on a firm's structural characteristics, such as size, the industry firms belong to, and risk [7–9]. In particular, recent studies attempt to explore the non-linear relationship between R&D investments and firm market valuation [10–12].

In this study, we extend this growing literature by showing that R&D investments are non-linearly related to firm value in the context of China. The reasons we study the relationship in the China setting are as follows. First, R&D investments in Chinese firms have been rapidly growing, which promotes

the growth of new industries. China's total spending on research and development is estimated to have been 1.76 trillion yuan (around \$279 billion) in 2017 [13]. R&D growth in Chinese firms had led the global market in its scale and scope by capitalizing their advantages in competitive costs to promote innovation and reap the technological capabilities for success in the world market [14]. Second, in China, both state-owned enterprises (SOEs) and private firms coexist. In particular, SOEs account for a substantial proportion of China's economy and their political connection with the Chinese government likely facilitate investment financing [15,16], enabling them to invest in more R&D. Similarly, Wu [17] points out that SOEs are likely to engage in more R&D investments.

We test a non-linear relationship between R&D investments and firm value using a sample of 563 Chinese listed firms between 2005 and 2013. In our analyses, we employ three estimation specifications, such as pooled ordinary least squares (OLS) regressions, fixed-effect panel regressions, and dynamic panel generalized method of moments (GMM) estimators. We find that R&D investments have an inverted U-shaped relationship with firm value. As an additional analysis, we also examined the association between R&D investments and firm value in terms of high and low state ownership. We find that there is an inverted U-shaped pattern between R&D investments and firm value in firms with low state ownership. However, we find no evidence of a non-linear relationship in firms with high state ownership. These findings indicate that the extent of state ownership has a distinct impact on the R&D investments–firm value relationship. We further investigate the R&D investments–firm value relationship in the context of firms' growth opportunities. We find an inverted U-shaped relationship between R&D investments and firm value in firms with high growth opportunities. In contrast, for firms with low growth opportunities, their relationship has a U-shaped pattern. Our empirical results are robust to robust standard errors clustered at the firm level, controlling for industry fixed effects, and omitted variable biases.

Our study contributes to the literature concerning the relationship between R&D investments and firm value by providing evidence that the relationship is non-linear in China. Bae et al. [8] show, using a sample of U.S. manufacturing firms, that the R&D investments–firm performance relationship is not monotonic. They argue that its relationship changes with the extent of firms' multinationality. In their recent works, Naik et al. [10] and Pantagakis et al. [11] show that R&D investments are non-linearly associated with the market value of the firm. Our study complements these studies by showing an inverted U-shaped pattern between R&D investments and firm value in the Chinese setting.

Our study also contributes to the literature examining the effect of state ownership on the relationship between R&D investments and firm value. In particular, our study extends and complements a recent paper by Ruiqi et al. [18], which documents the positive impact of state ownership on the association between R&D expenditures and future firm performance. A study by Ruiqi et al. [18] appears to be similar to ours; however, our study is different in several ways. First, unlike in their study, we identify the existence of a non-linear relationship between R&D investments and firm value by providing evidence of an inverted U-shaped pattern. Second, we find that the extent of state ownership has a different effect on the relationship between R&D investments and firm value in the presence of non-linearity. Thus, our finding provides different insights and perspectives regarding the effect of state ownership on the R&D investments-firm value relationship. Likewise, we expand our understanding of how state ownership has an impact on the relationship. Finally, they use the subsequent three years' average firm performance, measured as the net income divided by lagged market value of equity, as well as operating income. On the other hand, we use Tobin's Q and industry-adjusted Tobin's Q as proxies for firm value. These two proxies used as a measure of long-term firm performance may better explain the relationship between R&D investments and firm value because R&D spending is closely linked to firms' long-term oriented strategies and objectives.

Our study further provides important implications for stakeholders, such as investors, policy makers, standard-setters, state owners, and regulators. Specifically, our findings can be useful to policy makers who pursue long-term performance objectives. Evidence from this study can also help state owners and regulators better understand R&D investments and firm value in light of state ownership.

The remainder of this paper is organized as follows: Section 2 provides a review of the prior literature and hypothesis development; Section 3 presents the data and empirical model; Section 4 presents the empirical results; Section 5 provides the additional analysis; Section 6 discusses robustness checks; and Section 7 concludes the study.

2. Literature Review and Hypothesis Development

Since Schumpeter [19] argues that an innovation in technology is crucial for firm growth, a number of prior studies have explored whether R&D investments serve as a vehicle for influencing firm value. Previous research provides mixed evidence regarding the link between R&D investments and firm value. For example, several studies find that R&D investments are positively associated with firm value [1–4,6,20–23]. Lev and Sougiannis [4] show that R&D investments increase future firm profitability and thus positively affect firm value. Bae and Kim [20] examine the effect of R&D investments on the market value of firms in the U.S., Germany, and Japan. They document that the market places a higher value on the R&D investments of firms in the U.S. than those in Germany and Japan. Eberhart et al. [21] find that the U.S. firms have experienced significantly positive abnormal operating performance following an increase in R&D expenditures. Ehie and Olibe [24] show that R&D investments in the service sector during the pre-9/11 period. More recently, using a sample of Chinese firms, Rao et al. [23] investigate whether an investment in R&D is associated with firm value from the perspective of long-term persistence. They find that R&D investments positively affect firm performance; however, its effect becomes weaker and even disappears as time goes on.

On the other hand, prior literature shows that R&D investments have a non-linear relationship with firm performance [8,10–12]. Using a sample of the U.S. manufacturing firms, Bae et al. [8] document that the relationship between R&D investments and firm performance in multinational firms is not monotonic, but the relationship varies with the phase of firms' multinationality. Specifically, they show that the relationship is negative at the initial stage, followed by a positive relationship, which then again reverts to a negative one when they use both accounting- and market-based measures as proxies for firm performance. Naik et al. [10] examine the association between R&D intensity and firm market valuation using Indian manufacturing firms. They find that the R&D intensity-firm value relationship is inverted U-shaped. Pantagakis et al. [11] investigate the link between R&D investments and firm performance based on 39 European firms. They show that R&D intensity is non-linearly associated with market value of the firm. Booltink and Saka-Helmhout [12] examine the relationship between R&D intensity and firm performance using a sample of non-high-tech small and medium-sized enterprises (SMEs). They find that there is an inverted U-shaped relationship between R&D intensity and firm performance. In the context of Chinese firms, prior studies further suggest that R&D investments have either a positive or negative impact on firm performance [25–27]. Choi and Williams [25] find that innovation intensity is positively related to sales growth. Specifically, they show that while the depth of innovation has a U-shaped relationship with sales growth, the diversity of innovation has an inverted U-shaped relationship. In another study, Xu and Jin [26] find no evidence that R&D investments affect current firm performance, but the cumulative effect of R&D investments are negatively associated with firm performance in China's Internet of Things (IoT) industry. In a more recent study, Xu and Sim [27] show that R&D intensity positively affect firm performance based on emerging market countries such as China and South Korea. However, these recent studies using Chinese data suggest that the relationship between R&D investments and firm value is far from simple, and it is significant to note that existing studies reveal mixed results in terms of R&D investments [23,25]. Based on the above mixed evidence regarding the relationship between R&D investments and firm value, we conjecture that their relationship in Chinese firms may be non-linear.

The rationale for the existence of non-linear relationship is also summarized as follows. First, according to the real option theory, R&D investments may be considered as a firm's growth option value [28,29]. Specifically, firms' R&D investments positively contribute to growth option value [30].

This is due to the fact that the higher volatility (uncertainty) of the expected return on R&D investments is related to higher market value [31]. Moreover, from the resource-based view, firms' competitive advantages in their markets are derived from their unique resources [32]. Based on this argument, R&D investments may have a positive relationship with firm value. Second, the degree of information asymmetry associated with R&D investments is larger than that of tangible assets because the investments have higher firm-specific risk. R&D investments can contribute to information asymmetry between managers and investors. Cui and Mak [33] and Honore et al. [34] argue that asymmetric information between investors and managers is severe in firms with high R&D intensity. Consequently, it is likely that a higher level of R&D investments aggravates information asymmetry, thereby adversely affecting firm value. Third, from the technological standpoint, the S-curve theory and technological limits can be applied to explain the association between R&D and the firm value. The S-curve theory suggests that the diffusion trend in innovations changes as an S-curve shape over time [35–37]. According to the theory, the value of R&D investments may be subject to the diminishing of marginal returns given the limits of technology. Prior studies show that the link between R&D investments and firm value depends on diminishing marginal returns [38–40]. Thus, the diminishing marginal return to R&D investments suggests that as R&D investments increase, firm value increases until a certain level and, beyond the certain level, it decreases.

Given the above empirical evidence and reasoning, it is expected that the relationship between R&D investments and firm value is non-monotonic, that is, a non-linear pattern of the relationship. Thus, we predict that the positive and negative effect of R&D investments on firm value coexist; that is, the dominance of the positive or negative effect on firm value depends on the extent of R&D investments.

We therefore propose the first hypothesis:

Hypothesis 1. There is a non-linear relationship between R&D investments and firm value.

3. Materials and Methods

3.1. Data and Sample Selection

We collect the data from the Bloomberg database covering annual financial data between 2005 and 2013. The procedures for sample selection are as follows. First, we obtain 1000 firms among 2000 firms listed on the Shanghai and Shenzhen Exchange in terms of their market capitalizations. Second, we delete firms with incomplete data, negative equity, or negative assets. Third, we remove financial institutions and real estate firms that are not related to R&D investments. Finally, we exclude missing values as well as extreme firm-year observations. Our final sample contains 563 Chinese listed firms and 5067 firm-year observations.

Table 1 presents the sample distribution of R&D intensity (%) and state ownership (%) by industry groups. Regarding the R&D intensity, Household and Personal Products has the highest percentage (0.24%), followed by Materials (0.22%), Capital Goods (0.19%), Automobiles and Components (0.17%), and Utilities (0.17%). Interestingly, some industries with high R&D intensity also tend to have high state ownerships. For example, state ownership in Automobiles and Components and Household and Personal Products is 31.58% and 41.84%, respectively.

Industry	State Ownership (%)	R&D Intensity (%)
Automobiles & Components	31.58	0.17
Capital Goods	27.87	0.19
Commercial & Professional Services	44.88	0.001
Consumer Durables & Apparel	7.19	0.1
Consumer Services	9.43	0.09
Energy	36.68	0.03
Food & Staples Retailing	21.54	0.06
Food Beverage & Tobacco	20.17	0.11
Health Care Equipment & Services	2.44	0.14
Household & Personal Products	41.84	0.24
Materials	29.82	0.22
Media	36.59	0.13
Pharmaceuticals, Biotechnology & Life Sciences	16.01	0.1
Retailing	23.93	0.1
Semiconductors & Semiconductor Equipment	28.65	0.03
Software & Services	15.21	0.16
Technology Hardware & Equipment	9.02	0.15
Transportation	39.89	0.13
Utilities	45.53	0.17
Industry Average	25.7	0.16

Table 1. Distribution of R&D intensity and state ownership by industry groups.

3.2. Empirical Model

To test the non-linearity of the relationship between R&D investments and firm value, we estimate Equation (1) with a dynamic panel generalized method of moments (GMM) estimator, proposed by Arellano and Bond [41]. The dynamic GMM estimation basically differentiates the model to eliminate firm-specific effects or any time invariant firm-specific variable. This estimation also mitigates endogeneity concerns due to the possible correlation between these firm-specific effects and explanatory variables. As alternative estimation specifications, we further run the pooled ordinary least squares (OLS) and fixed-effects panel regressions. The quadratic regression model is as follows:

Firm Value_{it}

$$= \beta_0 + \beta_1 R \& D \ intensity_{it} + \beta_2 R \& D \ intensity_{it}^2 + \beta_3 State \ ownership_{it} + \beta_4 Leverage_{it} + \beta_5 Assetgr_{it} + \beta_6 Lnasset_{it} + \beta_7 Profitability_{it} + \varepsilon_{it}$$
(1)

Regarding a dependent variable, we use Tobin's Q as a proxy for firm value. Tobin's Q is defined as the book value of total assets minus the book value of equity, plus the market value of equity, divided by the book value of total assets. Following Cheng [42], we also use the industry-adjusted Tobin's Q as an alternative proxy. The industry-adjusted Tobin's Q (IndAdjTobin's Q) is the difference between a firm's Q and the average Q in the firm's industry in the observation year.

Our main independent variables of interest are R&D intensity and the square of R&D intensity. We use R&D intensity as a proxy for the level of R&D investments, measured as R&D expenditures divided by total assets [43]. Moreover, we use the square of R&D intensity to identify the possibility of a non-linear relationship between R&D investments and firm value. Specifically, if the sign of the coefficient on the square of R&D intensity is positive (negative), then its relationship with firm value is expected to be U-shaped (inverted U-shaped).

Based on prior studies [3,5,18,27,44,45], we choose the following control variables. Specifically, we control for State ownership, Leverage, Assetgr, Lnasset, and Profitability. State ownership is the percentage of equity shares held by the state and its agencies. Leverage is calculated as total debt divided by total assets. Prior studies provide mixed results as to the relationship between

leverage and firm value. Ferreira and Matos [46] show that leverage is positively related to firm value, while Ruiqi et al. [18] suggest that leverage is negatively related to firm value. We control for Assetgr as a proxy for investment opportunities, measured as the percentage of annual growth in total assets. We control for Lnasset as a proxy for firm size, calculated as the natural logarithm of total assets. The association between size and firm value is mixed. For example, while several studies [46,47] show that firm size is positively associated with firm value, Lang and Stulz [48] provide evidence of a negative association. We control for Profitability as a proxy for firms' profitability, measured as net income divided by total assets. Aggarwal et al. [44] find a positive relationship between profitability and firm value. In Equation (1), we also control for firm and year fixed effects and use White's [49] robust-standard errors. Table 2 presents the definitions of variables used in our empirical analysis.

Variables	Definition
Tobin's Q	Book value of total assets minus the book value of equity, plus the market value of equity, divided by the book value of total assets.
IndAdjTobin's Q	Difference between a firm's Tobin's Q and the average Tobin's Q in the firm's industry in the observation year.
R&D intensity	R&D expenditures divided by total assets.
R&D intensity ²	Square of R&D intensity.
State ownership	Percentage of equity shares owned by the state and its agencies.
Leverage	Total debt divided by total assets.
Assetgr	Percentage of annual growth in total assets.
Lnasset	Natural logarithm of total assets.
Profitability	Net income divided by total assets.

Table 2. Vallable definitions.

4. Results and Discussion

4.1. Descriptive Statistics and Correlations

Table 3 presents the descriptive statistics for the sample firms. Panel A of Table 3 shows a mean value of 2.155 for Tobin's Q. The mean value of the industry-adjusted Tobin's Q (IndAdjTobin's Q) is 0.497. The mean value of R&D intensity is 0.2 percent of their total assets. The mean value of State ownership is 25.601 percent, indicating that Chinese firms hold high state ownership. The mean values of Leverage, Assetgr, Lnasset, and Profitability are 0.533, 0.186, 3.490, and 0.024, respectively. Panel B of Table 3 shows descriptive statistics for firms with high state ownership. The mean values of Tobin's Q and IndAdjTobin's Q are 2.044 and 0.455, respectively. The mean value of R&D intensity is 0.002. The mean values of Leverage, Assetgr, Lnasset, and Profitability are 0.549, 0.240, 3.652, and 0.028, respectively. Panel C of Table 3 shows descriptive statistics for firms with low state ownership. The mean value of Tobin's Q is 2.206. The mean value of R&D intensity is 0.002. Finally, the mean values of Leverage, Assetgr, Lnasset, and Profitability are 0.525, 0.161, 3.415, and 0.023, respectively.

Panel A. All firms.									
Variables	Ν	Mean	Std. Dev.	Min.	25%	Median	75%	Max.	
Tobin's Q	5067	2.155	1.676	0.448	1.226	1.623	2.460	25.112	
IndAdjTobin's Q	5067	0.497	1.646	-1.581	-0.372	0.007	0.774	23.662	
R&D intensity	5067	0.002	0.008	0.000	0.000	0.000	0.000	0.143	
State ownership	5067	25.601	36.250	0.000	0.000	2.505	56.941	99.420	
Leverage	5067	0.533	0.235	0.002	0.393	0.533	0.662	4.358	
Assetgr	5067	0.186	1.079	-0.778	-0.009	0.082	0.206	44.513	
Lnasset	5067	3.490	0.528	1.616	3.127	3.436	3.769	5.572	
Profitability	5067	0.024	0.114	-3.677	0.007	0.024	0.049	1.754	
Panel B. Firms with High State Ownership.									
Variables	Ν	Mean	Std. Dev.	Min.	25%	Median	75%	Max.	
Tobin's Q	1611	2.044	1.481	0.668	1.194	1.566	2.366	20.912	
IndAdjTobin's Q	1611	0.455	1.439	-1.335	-0.330	0.014	0.727	18.671	
R&D intensity	1611	0.002	0.009	0.000	0.000	0.000	0.000	0.143	
State ownership	1611	75.370	21.381	25.813	61.911	83.410	92.419	99.420	
Leverage	1611	0.549	0.232	0.012	0.408	0.560	0.677	2.627	
Assetgr	1611	0.240	1.263	-0.751	-0.001	0.090	0.219	36.136	
Lnasset	1611	3.652	0.577	1.977	3.277	3.568	4.007	5.572	
Profitability	1611	0.028	0.080	-0.731	0.007	0.026	0.053	1.012	
		Panel	C. Firms with	Low State	Ownership.				
Variables	Ν	Mean	Std. Dev.	Min.	25%	Median	75%	Max.	
Tobin's Q	3456	2.206	1.757	0.448	1.241	1.654	2.488	25.112	
IndAdjTobin's Q	3456	0.516	1.734	-1.581	-0.395	0.003	0.788	23.662	
R&D intensity	3456	0.002	0.008	0.000	0.000	0.000	0.000	0.122	
State ownership	3456	2.402	4.522	0.000	0.000	0.000	2.759	24.537	
Leverage	3456	0.525	0.237	0.002	0.384	0.521	0.653	4.358	
Assetgr	3456	0.161	0.981	-0.778	-0.013	0.079	0.199	44.513	
Lnasset	3456	3.415	0.485	1.616	3.081	3.373	3.676	5.222	
Profitability	3456	0.023	0.127	-3.677	0.007	0.023	0.047	1.754	

Table 3. Descriptive statistics of sample firms by high versus low state ownership.

Table 4 presents the correlations among the variables used in this study. Regarding the Pearson correlations, Tobin's Q is positively and significantly correlated with IndAdjTobin's Q (0.986) and Profitability (0.068), respectively, while it is negatively and significantly correlated with State ownership (-0.061), Leverage (-0.134), Assetgr (-0.040), and Lnasset (-0.359), respectively. IndAdjTobin's Q is positively and significantly correlated with Profitability (0.057), while it is negatively and significantly correlated with State ownership (-0.032), Leverage (-0.105), Assetgr (-0.034), and Lnasset (-0.331), respectively. With respect to the Spearman rank correlations, Tobin's Q is positively and significantly correlated with R&D intensity (-0.087), State ownership (-0.044), Leverage (-0.247), and Lnasset (-0.414), respectively. IndAdjTobin's Q is positively and significantly correlated with Assetgr (0.028) and Profitability (0.239), respectively, while it is negatively and significantly correlated with R&D intensity (-0.073), Leverage (-0.175), and Lnasset (-0.331), respectively.

Taken together, even though we find an insignificant Pearson correlation between Tobin's Q and R&D intensity, and between IndAdjTobin's Q and R&D intensity, we interpret that the result is due to problems with omitted variables. Thus, we perform a multivariate analysis, after controlling for variables that affect firm value.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) Tobin's Q	1.000	0.919 **	-0.087 **	-0.044 **	-0.247 **	0.009	-0.414 **	0.258 **
(2) IndAdjTobin's Q	0.986 **	1.000	-0.073 **	0.009	-0.175 **	0.028 *	-0.331 **	0.239 **
(3) R&D intensity	-0.018	-0.011	1.000	-0.004	0.012	-0.006	0.113 **	-0.056 **
(4) State ownership	-0.061 **	-0.032 *	0.010	1.000	0.084 **	0.071 **	0.234 **	0.067 **
(5) Leverage	-0.134 **	-0.105 **	-0.014	0.053 **	1.000	0.060 **	0.250 **	-0.350 **
(6) Assetgr	-0.040 **	-0.034 *	-0.012	0.025	0.018	1.000	0.337 **	0.345 **
(7) Lnasset	-0.359 **	-0.331 **	0.058 **	0.255 **	0.130 **	0.100 **	1.000	0.172 **
(8) Profitability	0.068 **	0.057 **	-0.003	0.027	-0.352 **	0.071 **	0.120 **	1.000

Table 4. Correlations among variables.

Note: This table shows the Spearman (Pearson) correlation above (below) the diagonal for our sample. ***, **, and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

4.2. Comparison of Descriptive Statistics between High and Low R&D Firms

Table 5 compares descriptive statistics of variables between high and low R&D firms. We classify high R&D firms as those with a value of R&D intensity above the mean. Firms with a value of R&D intensity below the mean are defined as low R&D firms.

The mean value of Tobin's Q for the high (low) R&D firms is 2.014 (2.451). The mean difference in Tobin's Q in the two groups is negative and statistically significant (p < 0.01). However, we find that the mean difference in IndAdjTobin's Q is negative, but insignificant. The mean differences in State ownership, Leverage, and Lnasset between high and low R&D firms are positive and statistically significant (p < 0.01). In addition, the mean difference in Profitability is negative and statistically significant (p < 0.01).

Variables	Firms with High R&D Intensity		Firms with Inte	Firms with Low R&D Intensity		t-Value
	Ν	Mean	Ν	Mean	2	
Tobin's Q	3438	2.014	1629	2.451	-0.437 ***	-8.735
IndAdjTobin's Q	3438	0.488	1629	0.516	-0.028	0.565
State ownership	3438	29.010	1629	18.405	10.605 ***	9.817
Leverage	3438	0.555	1629	0.487	0.068 ***	9.633
Assetgr	3438	0.201	1629	0.155	0.046	1.414
Lnasset	3438	3.543	1629	3.379	0.164 ***	10.430
Profitability	3438	0.018	1629	0.038	-0.020 ***	-5.719

Table 5. Descriptive statistics by high versus low R&D firms.

Note: *** denotes statistical significance at the 1% level.

4.3. The Non-Linear Relationship between R&D Investments and Firm Value

Table 6 presents the results of the regression with three estimation specifications. For the regression of Tobin's Q, column (1) presents the pooled OLS regression, in which we do not control for year and firm fixed effects. The coefficient on R&D intensity is positive and significant (p < 0.1). Likewise, the coefficient on the square of R&D intensity is negative and significant (p < 0.05), showing an inverted U-shaped pattern. The optimal value of R&D intensity is 0.042, indicating 4.2 percent of their total assets. Column (2) presents the firm fixed-effects panel regression, in which we control for year and firm fixed effects. The coefficient on R&D intensity is positive and significant (p < 0.01), showing that firm value is increasing as R&D intensity increases. In contrast, the coefficient on the square of R&D intensity is negative and significant (p < 0.01), indicating that the relationship between R&D investments and firm value has an inverted U-shaped pattern. The results show that the optimal value of R&D intensity is 0.053. Column (3) presents the dynamic-panel GMM estimation, in which we control for year and firm fixed effects. Moreover, we include Tobin's Q in the previous year (Tobin's Qt-1). The coefficient on R&D intensity is positive and significant (p < 0.05). The optimal value of R&D intensity is positive and significant (p < 0.05). The coefficient on the square of R&D intensity is negative and significant (p < 0.05). The optimal value of R&D intensity is positive and significant (p < 0.05). The optimal value of R&D intensity is negative and significant (p < 0.05). The coefficient on the square of R&D intensity is negative and significant (p < 0.05), confirming the presence of an inverted U-shaped relationship between R&D investments and firm

value. For the regression of the IndAdjTobin's Q, we find consistent results with those reported in columns (1) through (3). Overall, our main finding of the inverted U-shaped relationship between R&D investments and firm value is robust across all the different estimation specifications.

Turning to control variables, the coefficient on State ownership is positive and significant in columns (1), (3), (4), and (6). These results indicate that firm value is increasing as state ownership increases. The coefficient on Leverage is negative and significant in columns (1) and (4), which is consistent with Ruiqi et al. [18]. The coefficient on Assetgr is negative and significant in columns (3) and (6). The coefficient on Lnasset is negative and significant, showing that larger firms tend to have lower firm value, which is consistent with Lang and Stulz [48]. We find a positive and significant coefficient in Profitability in columns (1) and (4), indicating that profitable firms have high firm value. This finding is consistent with Aggarwal et al. [44]. The coefficient on the lagged (IndAdj)Tobin's Q_{t-1} is positive and significant.

Taken together, our results show that as R&D investments increase, firm value increases to a certain point and then decreases. These results provide consistent evidence of the inverted U-shaped relationship between R&D investments and firm value, supporting our central hypothesis.

	Dependent Variables:					
		Tobin's Q	IndAdjTobin's Q			
	Pooled OLS	Fixed Effects Model	GMM	Pooled OLS	Fixed Effects Model	GMM
Independent Variables	(1)	(2)	(3)	(4)	(5)	(6)
Intercept	6.417 *** (42.465)	-5.057 (-0.181)		4.358 *** (28.991)	-6.712 (-0.240)	
R&D intensity	10.822 *	16.749 ***	11.056 **	12.125 **	16.750 ***	10.165 **
	(1.939)	(3.616)	(2.488)	(2.184)	(3.616)	(2.312)
R&D intensity ²	-128.762 **	-157.136 ***	-97.003 **	-130.877 **	-157.148 ***	-92.352 **
	(-2.084)	(-2.807)	(-2.332)	(-2.130)	(-2.807)	(-2.230)
State ownership	0.002 ***	0.616	19.201 ***	0.003 **	0.616	20.156 ***
	(2.638)	(0.564)	(2.750)	(4.276)	(0.564)	(2.786)
Leverage	-0.383 ***	-0.091	-0.063	-0.209 **	-0.091	-0.083
	(-3.804)	(-0.773)	(-0.370)	(-2.090)	(-0.774)	(-0.507)
Assetgr	-0.014	-0.022	-0.056 ***	-0.008	-0.022	-0.063 ***
	(-0.667)	(-1.526)	(-2.967)	(-0.390)	(-1.526)	(-3.276)
Lnasset	-1.186 ***	-2.441 ***	-1.886 ***	-1.105 ***	-2.441^{***}	-1.906 ***
	(-26.972)	(-27.399)	(-8.856)	(-25.264)	(-27.399)	(-9.076)
Profitability	1.383 ***	0.174	-0.106	1.283 ***	0.174	-0.282
	(6.640)	(1.155)	(-0.399)	(6.194)	(1.154)	(-1.083)
(IndAdj)Tobin's Q _{t-1}			0.105 *** (4.873)			0.124 *** (5.709)
year fixed effects firm fixed effects Adj. R ²	No No 0.144 5067	Yes Yes 0.634 5067	Yes Yes	No No 0.123 5067	Yes Yes 0.621 5067	Yes Yes

Table 6. The non-linear relationship between R&D investments and firm value.

Note: ***, **, and * denote statistical significance at the 1%, 5% and 10% levels, respectively; The t-statistics are in parentheses.

5. Additional Analysis

5.1. The Non-Linear Relationship between R&D Investments and Firm Value in High and Low State Ownership Firms

Ownership structure has an important implication in understanding the relationship between R&D investments and firm value. This is important because ownership structure is one of the determinants of corporate resource allocation [18,50]. In the context of Chinese firms, Zhang et al. [51] document that the state sector has lower R&D and productive efficiency than the non-state sector, suggesting that a high level of state ownership can decrease the overall productivity of firms in

transition economies. Financial performance in state-owned enterprises (SOEs) may be given low profit incentives since SOEs contribute to promoting social stability and continuing social welfare due to public nature [52].

We test whether there is a non-linear relationship between R&D investments and firm value by splitting our sample into two subsamples, i.e., high and low state ownership firms. High (low) state ownership firms are defined as those with above (below) the average values of state ownership.

Table 7 presents the regressions of Tobin's Q on R&D intensity, its square, and control variables. Regarding firms with high state ownership, we find no relationship between R&D intensity and Tobin's Q in columns (1) through (3). Similarly, the coefficients on the square of R&D intensity are insignificant in the columns. In contrast, with respect to firms with low state ownership, we find a positive and significant coefficient R&D intensity in columns (4) through (6). These findings indicate that R&D investments are positively related to firm value. Moreover, the coefficients on the square of R&D intensity are negative and significant in the columns, indicating the inverted U-shaped relationship between R&D investments and firm value.

Furthermore, we repeat the analysis using the industry-adjusted Tobin's Q (IndAdjTobin's Q) as an additional dependent variable. The results, not reported for the sake of brevity, are qualitatively similar to our findings based on Tobin's Q.

Taken together, we find no evidence of a non-linear relationship between R&D investments and firm value in the subsample of high state ownership firms. In contrast, we find that R&D investments have an inverted U-shaped relationship with firm value in the subsample of low state ownership firms. These findings suggest that the inverted U-shaped relationship is more pronounced for firms with low state ownership than for firms with high state ownership.

	Dependent Variable: Tobin's Q						
	H	High State Ownership Firms			Low State Ownership Firms		
	Pooled OLS	Fixed Effects Model	GMM	Pooled OLS	Fixed Effects Model	GMM	
Independent Variables	(1)	(2)	(3)	(4)	(5)	(6)	
Intercept	5.126 *** (22.007)	3.338 (0.041)		7.337 *** (37.127)	6.848 (1.062)		
R&D intensity	-13.325 (-1.531)	10.087 (1.382)	7.748 (1.625)	24.742 *** (3.323)	21.339 *** (3.308)	8.001 * (1.928)	
R&D intensity ²	65.842	-80.977	-21.667	-267.877 ***	-270.443 **	-152.200 ***	
, 	(0.825)	(-1.155)	(-0.574)	(-2.747)	(-2.392)	(-3.557)	
State ownership	-0.004 ** (-2.202)	0.066 (0.062)	24.309 (1.275)	0.014 ** (2.340)	2.056 (0.766)	170.037 *** (12.290)	
Leverage	-0.199 (-1.243)	-0.288 (-1.492)	0.413 ** (1.993)	-0.290 ** (-2.313)	0.051 (0.348)	0.485 * (1.853)	
Assetgr	-0.052 (-1.939)	-0.070 *** (-3.569)	-0.114 *** (-7.432)	0.007 (0.253)	0.001 (0.064)	0.004 (0.132)	
Lnasset	-0.773 *** (-12.371)	-1.690 *** (-12.564)	-1.985 *** (-6.341)	-1.480 *** (-25.426)	-2.819 *** (-24.437)	-2.792 *** (-8.003)	
Profitability	5.414 *** (11.470)	1.155 *** (3.048)	0.230 (0.490)	0.777 *** (3.320)	0.095 (0.561)	-0.289 (-1.044)	
Tobin's Q _{t-1}			0.091 *** (4.689)			0.021 (0.846)	
year fixed effects firm fixed effects Adj. R ²	No No 0.171	Yes Yes 0.626	Yes Yes	No No 0.170	Yes Yes 0.626	Yes Yes	
Observations	1611	1611	1253	3456	3456	2688	

Table 7. The non-linear relationship between R&D investments and firm value in high and low state ownership firms.

Note: ***, **, and * denote statistical significance at the 1%, 5% and 10% levels, respectively; The t-statistics are in parentheses.

5.2. The Non-Linear Relationship between R&D Investments and Firm Value in High and Low Growth-Opportunities Firms

We further test the non-linear relationship between R&D intensity and firm value in the context of firms with high and low growth opportunities. To do this, we divide sample firms into two subsamples, high and low growth-opportunities firms. We define firms with high (low) growth opportunities as those with above (below) the mean value of Tobin's Q.

Table 8 presents the results of the regression with several estimation specifications. Regarding the regression of Tobin's Q using high growth-opportunities firms, we find a positive and significant coefficient on R&D intensity is positive and significant in columns (1) through (3). We further find a negative and significant coefficient on the square of R&D intensity in the columns. These findings suggest an inverted U-shaped relationship between R&D investments and firm value in firms with high growth opportunities. In contrast, for firms with low growth opportunities, the coefficients on R&D intensity are negative and significant in columns (4) and (6). We also find a positive and significant coefficient on the square of R&D intensity in the columns, likely indicating the existence of a U-shaped pattern.

In addition, we repeat the analysis using the industry-adjusted Tobin's Q (IndAdjTobin's Q) as the dependent variable. The untabulated results are qualitatively similar to our findings using Tobin's Q.

Taken together, our results imply that the R&D investments-firm value nexus in firms with high growth opportunities is affected by the degree of information asymmetry, which is consistent with Cui and Mak [33].

	Dependent Variable: Tobin's Q						
	High	Growth-Opportunities	Firms	Low C	Low Growth-Opportunities Firms		
	Pooled OLS	Fixed Effects Model	GMM	Pooled OLS	Fixed Effects Model	GMM	
Independent Variables	(1)	(2)	(3)	(4)	(5)	(6)	
Intercept	7.42 9 *** (24.632)	-17.214 (-0.227)		2.326 *** (29.467)	-6.213 (-0.579)		
R&D intensity	29.732 *** (2.668)	33.977 *** (3.536)	14.852 * (1.933)	-9.040 *** (-3.685)	-0.125 (-0.065)	-4.167 *** (-3.387)	
R&D intensity ²	-359.581 *** (-2.641)	-363.711 ** (-2.214)	-147.551 ** (-2.087)	52.589 ** (2.097)	-3.681 (-0.177)	40.246 *** (3.662)	
State ownership	0.001 (1.116)	1.380 (0.410)	66.843 *** (4.555)	0.001 ** (2.564)	0.367 (0.981)	16.548 *** (7.599)	
Leverage	-0.421 *** (-2.687)	-0.383 ** (-2.136)	0.509 ** (2.040)	0.076 (1.227)	0.304 *** (4.217)	0.358 *** (3.191)	
Assetgr	-0.036 (-1.265)	-0.010 (-0.504)	-0.044 ** (-1.995)	0.010 (0.573)	-0.011 (-1.006)	-0.008 (-0.430)	
Lnasset	-1.361 *** (-15.203)	-3.314 *** (-22.408)	-3.683 *** (-9.237)	-0.255 *** (-11.295)	-0.822 *** (-17.877)	-1.305 *** (-9.591)	
Profitability	1.397 *** (4.756)	-0.004 (-0.018)	-0.693 ** (-2.085)	0.625 *** (3.734)	0.303 *** (2.604)	-0.207 (-1.520)	
$\text{Tobin's } Q_{t-1}$			0.198 *** (6.824)			0.136 *** (5.705)	
year fixed effects firm fixed effects Adi. R ²	No No 0.09	Yes Yes 0.630	Yes Yes	No No 0.06	Yes Yes 0.635	Yes Yes	
Observations	2538	2538	1974	2529	2529	1967	

Table 8. The non-linear relationship between R&D investments and firm value in high and low growth-opportunities firms.

Note: ***, **, and * denote statistical significance at the 1%, 5% and 10% levels, respectively; The t-statistics are in parentheses.

6. Robustness Checks

6.1. Testing for the Validity of a Non-Linear Relationship between R&D Investments and Firm Value

We check the validity of the existence of an inverted U-shaped relationship between R&D investments and firm value. To do this, we use the techniques proposed by Lind and Mehlum [53] in order to test the inverted U-shaped relationship. The procedure jointly tests whether the relationship is increasing at the low level and decreasing at the high level of R&D intensity within our sample firms. The null hypothesis (H₀) is that there is a monotone or U-shaped pattern. The alternative hypothesis (H₁) is that there is an inverted U-shaped pattern. The untabulated result shows that the null hypothesis is rejected (t-value = 2.42; p = 0.008). Thus, we confirm that there is the existence of the inverted U-shaped relationship between R&D investments and firm value, validating our regression Equation (1) and supporting the results shown in Table 6.

6.2. Alternative Robust Standard Errors

In our previous analyses, we use White's [49] robust standard errors in assessing statistical significance. As a robustness check, we repeat our analysis using robust standard errors clustered at the firm level. The untabulated findings indicate that the results reported in Tables 6–8 remain robust to the alternative robust standard errors.

6.3. The Possibility of Time-Invariant Industry Fixed Effects in the R&D Investments-Firm Value Relationship

In our regression model presented in equation (1), we control for year and firm fixed effects. We repeat our analysis after controlling for year and time-invariant industry fixed effects, except for the fixed-effect model in Tables 6–8. The untabulated results suggest that those reported in previous Tables 6–8 are robust when we consider industry fixed effects.

6.4. The Possibility of Omitted Variable Problems in the R&D Investments-Firm Value Relationship

We consider the possibility of omitted variable problems. Prior studies control for the following variables that affect firm value: Profit margin, Export intensity, and Firm age [10,18]. Profit margin is defined as the ratio of net income to net sales. Export intensity is measured as the ratio of total exports to net sales. Firm age is the number of years since the firms' establishment. We repeat the analysis by including these additional control variables in equation (1). In columns (1) through (3), we find the inverted U-shaped relationship between R&D investments and firm value, indicating that our results are robust to omitted variable biases. Furthermore, the untabulated results using the industry-adjusted Tobin's Q (IndAdjTobin's Q) are qualitatively similar to those in Table 9.

Dependent Variable: Tobin's O					
	Pooled OLS	Fixed Effects Model	GMM		
Independent Variables	(1)	(2)	(3)		
Intercept	6.253 *** (41.216)	-7.071 -(0.133)			
R&D intensity	10.092 *	17.526 ***	9.829 **		
	(1.821)	(3.802)	(2.205)		
R&D intensity ² -122.069 *		-163.165 ***	-88.241 **		
(-1.991)		(-2.931)	(-2.134)		
State ownership	0.002 ***	0.693	14.645 **		
	(3.058)	(0.539)	(2.101)		
Leverage -0.722 ***		-0.138	-0.103		
(-7.624)		(-1.272)	(-0.584)		

Table 9. The possibility of omitted variable problems.

Dependent Variable: Tobin's Q					
	Pooled OLS	Fixed Effects Model	GMM		
Assetgr	0.001 (0.064)	-0.019 -(1.331)	-0.061 *** -(3.321)		
Lnasset	-1.100 *** (-25.244)	-2.340 *** (-26.185)	-1.585 *** (-8.077)		
Profit margin	Profit margin -0.163 *** (-6.780)		-0.405 * (-1.852)		
Export intensity 0.609 *** (5.623)		0.379 *** (4.428)	0.042 (0.219)		
Firm age	Firm age 0.002 ** (2.111)		9.526 (1.467)		
Tobin's Q _{t-1}			0.107 *** (6.217)		
year fixed effects firm fixed effects Adj. R ² Observations	No No 0.149 5056	Yes Yes 0.635 5056	Yes Yes 3933		

Tab	le	9.	Cont.
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Note: ***, **, and * denote statistical significance at the 1%, 5% and 10% levels, respectively; The t-statistics are in parentheses.

6.5. Semi-Parametric Approach in the R&D Investments-Firm Value Relationship

Table 10 present the estimation results through a semiparametric quantile model. We find that the effect of R&D investments on firm value is not stable across all quantiles of the conditional distribution. Except for the quantiles 30, 40, and 90, the effect is significantly positive and negative. These results imply that R&D investments are likely to have non-linear relationship with firm value. We further repeat the analysis using the industry-adjusted Tobin's Q (IndAdjTobin's Q). The untabulated results show similar results to those presented in Table 10.

	Dependent Variable: Tobin's Q								
Independent Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Q10	Q20	Q30	Q40	Q50	Q60	Q70	Q80	Q90
Intercept	1.540 ***	1.847 ***	2.082 ***	2.263 ***	2.552 ***	3.006 ***	3.542 ***	3.929 ***	4.426 ***
	(22.648)	(23.032)	(20.047)	(18.823)	(20.173)	(20.910)	(25.841)	(24.298)	(16.417)
R&D intensity	3.111 **	3.046 **	1.366	-0.747	-4.184 ***	-8.229 ***	-11.647 ***	-15.194 ***	-8.731
	(2.471)	(2.125)	(1.010)	(-0.521)	(-2.622)	(-2.799)	(-4.334)	(-4.424)	(-1.224)
State ownership	0.00004 *	0.00004 *	0.000	0.000	0.001 **	0.001 ***	0.001 ***	0.002 ***	0.002 ***
	(1.857)	(1.985)	(1.533)	(1.369)	(2.397)	(3.037)	(3.135)	(2.764)	(2.885)
Leverage	0.258 **	0.109 *	0.010	-0.077	-0.137 *	-0.292 ***	-0.470 ***	-0.651 ***	-0.790 ***
	(3.441)	(1.728)	(0.177)	(-1.084)	(-1.679)	(-3.924)	(-6.316)	(-4.763)	(-8.789)
Assetgr	-0.069 ***	-0.058	-0.071 ***	-0.088 ***	-0.096	-0.061 ***	-0.058 ***	-0.075 ***	-0.072
	(-3.184)	(-1.432)	(-8.997)	(-7.913)	(-1.454)	(-2.683)	(-12.479)	(-15.974)	(-1.440)
Lnasset	-0.221 ***	-0.272 ***	-0.318 ***	-0.352 ***	-0.412 *	-0.505 ***	-0.604 ***	-0.662 ***	-0.779 ***
	(-9.972)	(-13.692)	(-14.127)	(-13.351)	(-13.320)	(-17.915)	(-20.464)	(-14.389)	(-15.823)
Profit margin	-0.161	-0.188 ***	-0.179 ***	-0.235	-0.274	-0.266 ***	-0.191 ***	-0.314	-0.397 *
	(-0.553)	(-20.626)	(-17.510)	(-1.314)	(-1.065)	(-11.840)	(-11.027)	(-1.065)	(-1.783)
Export intensity	0.186 ***	0.131 ***	0.220	0.197	0.350	0.388	0.352 ***	0.138	-0.062
	(6.884)	(3.793)	(1.235)	(0.721)	(2.729)	(1.187)	(12.282)	(0.417)	(-0.443)
Firm age	0.000	0.001	0.000	-0.000	-0.000	-0.000	-0.001	-0.000	-0.002
	(0.042)	(1.423)	(1.069)	(-0.027)	(-0.363)	(-0.781)	(-1.497)	(-0.384)	(-1.369)
Adj. R ²	0.094	0.114	0.136	0.161	0.185	0.211	0.245	0.287	0.354
Observations	4496	4496	4496	4496	4496	4496	4496	4496	4496

 Table 10. The semiparametric quantile model.

Note: ***, **, and * denote statistical significance at the 1%, 5% and 10% levels, respectively; The t-statistics are in parentheses.

7. Conclusions

In this paper, we examine whether there is a non-linear relationship between R&D investments and firm value. Using a sample of Chinese listed firms between 2005 and 2013, we provide empirical evidence that the R&D investments–firm value relationship has an inverted U-shaped pattern, which is consistent with our central hypothesis. We also find an inverted U-shaped relationship between R&D investments and firm value in firms with low state ownership. However, we find no evidence that there is a non-linear pattern of the relationship in firms with high state ownership. These findings suggest that the existence of a non-linear relationship between R&D investments and firm value can be determined by the degree of state ownership. In addition, we find the presence of an inverted U-shaped relationship between R&D investments and firm value in firms with high growth opportunities. We further find a U-shaped pattern of the relationship in firms with low growth opportunities. These findings imply that there is a different non-linear pattern between R&D investments and firm value with respect to the extent of firms' growth opportunities.

This study extends and complements the R&D investments–firm value literature in two ways. First, we provide new evidence on the presence of a non-linearity in the relationship between R&D investments and firm value in the context of China. Second, this study sheds light on the role of state ownership in the relationship between R&D investments and firm value. This study provides meaningful implications for academics and practitioners. In particular, our findings can be useful to policy makers who implement R&D investment policies.

This study also provides theoretical and managerial implications by providing evidence of a non-linearity in the R&D investments-firm value relationship. First, our findings confirm the theoretical prediction. According to the real option theory, the future volatility of the return on R&D investments affects market value. The real option theory suggests that a higher risk leads to a higher return. Our evidence from Chinese firms suggest that increased market uncertainty augments the market value of R&D investments until a certain level; then, beyond a certain level, it reduces the market value. Second, our findings confirm the prediction of information asymmetry hypothesis. Firms with more R&D investments may face higher information asymmetry and thus greater adverse selection costs, which negatively affects firm value. Third, our findings confirm the prediction of the S-curve theory by showing the diminishing marginal return to R&D investments. Our evidence based on Chinese firms suggests that an increase in R&D investments augments the marginal rate of return until a certain point; then, it appears to diminish the marginal rate of return beyond a certain point. From a managerial perspective, as Oriani and Sobrero [31] point out, R&D investments are closely linked to uncertainty. Thus, managers need to recognize market and technological uncertainty when they decide to invest in R&D. From the perspective of stakeholders (e.g., investors and creditors), Chinese capital markets are less efficient compared to developed countries, such as the U.S. Thus, for their easy access to financing for R&D investments, firms need to mitigate information asymmetry between firms and stakeholders. This implies that Chinses firms should enhance market transparency and manage risk efficiently.

This study has the following limitations. First, we empirically test the non-linear relationship between R&D investments and firm value based on Chinese firms. In our analysis, we consider the possibility of omitted variable problems. We repeat the analysis by controlling for firm age, export intensity, and profit margin that can affect firm value. However, we are not able to control for potential variables such as advertising intensity and technological intensity of imports due to the difficulty of obtaining data from Chinese firms. Thus, further research should consider these variables in examining the R&D investments–firm value relationship. Second, based on the leapfrogging theory, which is constructed around Schumpeter's concept of creative destruction [54–56], it is crucial to discuss the type of innovations firms pursue, e.g., incremental or radical innovations. Thus, further research should explore the relationship between R&D investments and firm value in the framework of types of innovations. Furthermore, regarding state ownership, it is more interesting to consider competition and knowledge spillovers in this framework. Third, even though we investigate the role of state

ownership in the R&D investments–firm value relationship, we do not pay attention to state-initiated channels associated with the generation of knowledge and the support of technological innovations in more detail. Thus further research should consider these channels in the relationship. Fourth, several studies provide policy implications for China, one of the efficiency-driven economies [27,57,58]. In particular, Xu and Sim [27] focus on the comparative study between China and Korea in the framework of competitive market conditions. Thus, further research should consider the link between R&D investments and firm value in the context of competitive advantages from the cross-country comparative perspective. Sixth, our sample period is restricted from 2005 to 2013; thus, further research should extend the sample period in examining the R&D investments–firm value relationship.

Author Contributions: W.S.K. designed the research, collected the data, developed the hypotheses, and performed the empirical analysis. K.P. contributed to the hypothesis development, conducted the empirical analysis, and finalized the manuscript. S.H.L. contributed to the development of the hypotheses and provided valuable comments with respect to the manuscript. H.K. summarized the literature review and provided valuable suggestions regarding the manuscript. All authors discussed the implications and wrote the paper.

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