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How Does Corporate Innovation Affect Sustainable Business Investment?

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Abstract: This study examines the impact of corporate innovation on sustainable business investments of companies listed on the Korea exchange from 2011 to 2019. To this end, our study applies Hennessy's investment model, which presents the relationship between corporate investment and Tobin's mean Q in a probabilistic space. We find evidence of a positive relationship between corporate investment and Tobin's average Q. Greater corporate growth opportunities lead to greater business investments, whereas the expected recovery ratio of debt capital has a negative relationship with corporate investments. The innovation performance variable is positively associated with the investments. Our results are suggestive of business investments being determined by investment outcomes, rather than the financial resource inputs for corporate innovation. Our study holds significance not only in the academic dimension, but also in policymaking. Since corporate growth is the outcome of corporate investments, the government may establish and implement economic policies that induce such investments.

Keywords: innovation; investment; Tobin's average Q; innovation performance; R&D activities

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1. Introduction

This study aims to examine the impacts of innovation on the sustainable investments of Korean companies, listed on the Korean exchange. Corporate innovation induces investments, which are the managers' allocation of corporate resources, leading to qualitatively positive changes in the industry. In addition, corporate innovation creates new industries by producing new products, and contributes to the country's overall and sustainable economic development. Therefore, it is important to explore the relationship between corporate innovation and investment.

Despite this importance, studies on the relationship between corporate innovation and (business) investment are sparse. In reality, studies on innovation are heavily concentrated on the relation between innovation, performance, growth, and value at the company, industry, or country (e.g., [1–6] among others). Specifically, at a company level, the two studies of [1,2] show evidence that innovation is positively associated with company performance variables (ROA, ROE, Tobin's Q, corporate market value, etc.). Ref. [6] reports empirical evidence that via adjusting the input mix and capital structure, companies with innovation capacity enhance their corporate equity value and financial performance. Showing that high-tech industry has a positive moderating effect, Ref. [7] finds that innovative efficiency obviously enhances a Chinese-listed firm's valuation on the securities market. They additionally suggest that portfolio returns with different innovative efficiencies can be appropriately determined by the market. At a country level, the recent study of [4] confirms that an innovation capacity increases a country's GDP for economic growth. However, these studies do not suggest any process or channel where innovation has a positive relationship with a country's economic growth and corporate performances.

Very exceptionally, using Australian industry sector data, Ref. [8] sets up a relation between innovation and investment in historical time without reference to any static equilibrium. The two recent studies of [9,10] argue that from the perspective of foreign direct investment (FDI) rather than corporate innovation, corporate investment causes corporate innovation. That is, the corporate investment of FDI can trigger corporate innovation, leading to corporate temporary developments. In the perspective of the effect of corporate innovation performance on the cost of financing in private investments in public equity, Ref. [11] reports that innovative US companies issue securities in private equity placements at a lower cost than the cost of non-innovative firms. However, it is still questionable whether the corporate investment heads corporate sustainable development. To overcome this problem, corporate innovation should substantially lead to their business investments, and the profits from the investments should be sustainably reinvested for greater innovation. Eventually, this virtuous cycle structure enables companies to achieve their sustainable developments. However, for the economic effect of corporate innovation on corporate business investment, there is a lack of extant studies, to the best of our knowledge.

There are two reasons to explain this. First, an appropriate theoretical model for an effect of innovation on tangible asset investment is not available at a corporate level. That is, there are a variety of theoretical models between corporate investment, growth (Tobin's Q), value, and so on. On the other hand, there is no direct theoretical model for the relationship between innovation variables and investment. Second, the results of the empirical analysis on innovation and investment at an enterprise level might be unsatisfactory. Corporate R&D costs are widely used as the proxy for innovation (e.g., [12–14] among others). However, the R&D expense variable has no significant influence on corporate investments on tangible assets. This result agrees with our empirics.

To fill up the lacuna to the literature, our study rarely attempts to examine that at the company level, innovation induces investment on tangible assets. Thus, this study sheds light on how innovation induces corporate growth. To this end, our study systematically examines the economic effect of corporate innovation on business investment, targeting the companies listed in Korea, one of leading countries in innovation and investment. To examine the impact of innovation on Korean companies' investment, this study applies Hennessy's [15] investment model, which presents the relationship between corporate investment and Tobin's mean Q in a probabilistic space. Unlike [15,16], we specifically assume a firm's complete dependence on both internal and external (i.e., debt) capital for corporate investment, whereas the former assumes a firm's sole dependence on internal capital.

Under these assumptions, Ref. [15] suggests a theoretical model of the relationship between Tobin's average Q of corporate investments and corporate debt's expected recovery ratio. He also demonstrated the negative relationship between corporate investments with Tobin's average Q and the debt capital's expected recovery ratio. However, Ref. [17] leaves an additional task of testing for the research model, by substituting the debt capital's expected recovery ratio with the leverage ratio's debt capital ratio (i.e., total liabilities/total assets), and empirically testing it. The expected recovery of debt capital refers to the shares attributable to creditors, in the event of a company's bankruptcy. Accordingly, it is somewhat difficult to conduct an empirical analysis by only replacing the debt capital's expected recovery ratio with debt capital. To solve this problem, we derive debt capital's expected recovery amount using the put option pricing model devised by [18], and use it for our empirical analysis. The main empirical work of our study is to check for the following research questions (RQs):

RQ 1. How do corporate investments affect corporate growth?
RQ 2. What kind of relationship does the expected recovery ratios of debt capital have with corporate investments.

The main findings obtained by this study are as follows: First, corporate investments are positively associated with Tobin's average Q proxied for corporate growth. This result suggests that greater growth opportunities for companies promote greater investments.

The expected recovery ratio of debt capital has a negative relationship with corporate investments. This finding confirms that the debt capital's expected recovery ratio decreases corporate investments.

Second, the innovation outcomes have a significant positive effect on companies' investments, regardless of the types of industries (i.e., manufacturing or non-manufacturing industries). However, we find no relationship between the R&D expense ratio and corporate investment. These results imply that corporate investments are determined by outcomes by innovation, rather than corporate input activities of the financial resources for it. This suggests that the performance of innovation could improve corporate investments for corporate growth rather than innovation input itself. Therefore, this study sheds valuable light on how innovation induces corporate investments for corporate growth.

Our study holds significance not only in the academic dimension, but also in policy-making. Since corporate growth is the outcome of corporate investments, the government may establish and implement economic policies that induce such investments. These investments are determined by many corporate management factors, including corporate innovation. Hence, policymakers are concerned about the probability of corporate innovations stimulating corporate investments.

The remainder of this paper is organized as follows. Followed by the introduction in Section 1, Section 2 discusses the analytical and empirical methods to examine the relationship between innovation and investments. Section 3 describes the data used in our empirical analysis. Section 4 presents the empirical results on the relationship between corporate innovation and investment. Section 5 discusses the main results of our study and Section 6 briefly concludes our study.

2. Research Method

2.1. Establishing the Relationship between Tobin's Marginal q and Average Q

A firm's investment FI can be implemented in the amount of new investment I at the point of coincidence of the marginal cost and marginal profit, expressed as Tobin's marginal q. This relationship can be expressed as Equation (1). For more detail, refer to [15,16].

$$\boldsymbol{FI}(\boldsymbol{I},\boldsymbol{K}) = \boldsymbol{q}(\boldsymbol{K},\boldsymbol{\varepsilon})_t \tag{1}$$

where I and K denote a new investment and capital stock, respectively. ε is a state variable.

Given that Tobin's average Q is defined as corporate value V on corporate capital stock K, the relationship between Tobin's marginal q and average Q is expressed by Equation (2). This equation shows that corporate marginal profit is the value obtained by deducting the value obtained and by dividing the present value of the expected recovery of debt capital, for corporate bankruptcy by capital stock, defined as the corporate value.

$$\boldsymbol{q}(\boldsymbol{K}_0,\boldsymbol{\varepsilon}_0) = \boldsymbol{Q}(\boldsymbol{K}_0,\boldsymbol{\varepsilon}_0) - \frac{\boldsymbol{R}(\boldsymbol{K}_0,\boldsymbol{\varepsilon}_0)}{\boldsymbol{K}_0} \tag{2}$$

where $R(K_0, \varepsilon_0)$ presents the value of debt capital's expected recovery.

2.2. Present Value of Expected Recovery on Debt Capital

We note that Tobin 's marginal q is expressed as the relationship between Tobin's average Q and the present value of debt capital's expected recovery, following bankruptcy $R(K_0, \varepsilon_0)$. However, there exists the challenge of an unknown present value of the debt capital's expected recovery amount, of debt capital at the current time period (t_0). Therefore, we assume the following to derive the expected recovery of debt capital $R(K_0, \varepsilon_0)$, based on Merton's study [19].

① There are no transaction costs and taxes. ② There are numerous investors in the capital market who may buy and sell assets at given prices. ③ It is possible to borrow and lend at the same interest rate. ④ Short-selling of all assets is available. ⑤ Assets are continuously tradable. ⑥ The term structure of the interest rate is flat and deterministic. ⑦ The corporate value V follows a stochastic process, as shown in Equation (3). (Equation (3) assumes that corporate value follows a probabilistic process different from [16] and Hennessy [15]. It is assumed that the value is the sum of the present value of the balance of deducting total investment costs from the expected future operating profits. However, this is to derive the present value of the corporate value and expected recovery amount.)

$$\boldsymbol{dV_Z = \mu_v d_t + \sigma_v V_t dz} \tag{3}$$

where V, μ_v, and σ_v denote the corporate value, its expected return, and its volatility, respectively. z is the winner process.

It is also assumed that the entity raises debt capital by issuing one pure discount bond, with par value D_T and maturity T. Given that the corporate value at maturity is greater than D_T, shareholders will pay debt capital and continue operating their company. On the contrary, if the corporate value is less than D_T, the company might be confronted with bankruptcy. There is no cost involved in this event, and an absolute priority rule is guaranteed. This means that, in the case of bankruptcy, assets are allocated according to the priority of debt capital repayment, and shareholders are only responsible for their equity.

Given the risk-neutral probability distribution of the corporate value at maturity $\hat{f}$, the expected recovery amount of debt capital is measured using Equation (4):

$$\boldsymbol{R(K_T, \varepsilon_T) = \int [D_T - \max(D_T - V_T, 0)]\hat{f}(V_T)dV_T} \tag{4}$$

where $R(K_T, \varepsilon_T)$, D, and $\hat{f}$ denote the expected recovery of debt capital at maturity, the par value of net discount bonds, and the risk-neutral probability distribution, respectively.

According to the risk-neutral valuation argument, Equation (4), which expresses the present value, is the same as Equation (5) [20].

$$\boldsymbol{R(K_0, \varepsilon_0) = e^{-r_f T} D_T \int \max(D_T - V_T, 0)\hat{f}(V_T)dV_T} \tag{5}$$

where r_f is the risk-free rate.

In Equation (5), $e^{-r_f T} D_T \int \max(D_T - V_T, 0)\hat{f}(V_T)dV_T$ represents the present value of a European put option, with an underlying asset V_T and strike price D_T. This can be derived using Black and Scholes's [18] put option pricing model, as shown in Equation (6). In that equation, $N(.)$ is the cumulative probability distribution function of the normal distribution.

$$\boldsymbol{R(K_0, \varepsilon_0) = e^{-r_f T} D_T - D_T e^{-r_f T} N(-d_2) + V_0 N(-d_1)} \tag{6}$$

where $d_1 = \frac{\ln\left(\frac{V_0}{D_T}\right) + \left(r_f + \frac{\sigma_v^2}{2}\right)T}{\sigma\sqrt{T}}$ and $d_2 = d_2 - \sigma\sqrt{T}$ The computation of Equation (6) requires the whole value of the parameters r_f, T, D_T, V_0, and σ_v, but V_0 and σ_v are unknown. To solve this problem, the present value E_0 of equity capital is considered as a European call option, with the underlying asset V_T and strike price $D_{T,}$ as shown in Equation (7) [19].

$$\boldsymbol{E_0 = V_0 N(d_1) – D^{-r_f T} N(d_2)} \tag{7}$$

Applying Ito's Lemma, Equation (8) is obtained:

$$\boldsymbol{\sigma_E E_0 = \frac{\partial E}{\partial V}\sigma_v V_0} \text{ or } \boldsymbol{\sigma_E E_0 = N(d_1)\sigma_v V_0} \tag{8}$$

Since it is possible to estimate the parameters σ_E and E_0 using companies' stock price data, we can obtain the parameters V_0 and σ by simultaneously solving Equations (7) and (8). In addition, by substituting the estimated values V_0 and σ_v in Equation (6), we can derive the present value of debt capital's expected recovery $R(K_0, \varepsilon_0)$.

2.3. Investment and Innovation

Assume that for changing a corporate capital stock, the total investment cost TIC is expressed in the form of Equation (9) (see [15,16,21–23]).

$$\boldsymbol{TIC(I_t, K_t) = I_t + \frac{1}{2}\eta K_t \left\{ \frac{I}{K} - \delta \right\}^2} \tag{9}$$

where η and δ denote the unknown parameter and average investment rate, respectively.

In Equation (9), η is an unknown parameter to be estimated and δ denotes the average rate of corporate investment [23]. This equation shows that a higher (or lower) investment rate than the current average rate of investment entails adjustment costs $\frac{1}{2}\eta K_t \left\{ \frac{I}{K} - \delta \right\}^2$ according to the changes in outcomes. For the adjustment cost to have a greater value than zero, η should be a positive constant. If Equation (9) is partially differentiated with respect to I_t, Equation (10) can be obtained as follows:

$$\boldsymbol{TIC(I_t, K_t) = 1 - \eta\delta + \eta \left(\frac{I}{K} \right)_t} \tag{10}$$

Equation (10) is changeable to Equation (11), by plugging Equation (10) into Equation (11).

$$\boldsymbol{\left(\frac{I}{K} \right)_t = \left(\delta - \frac{1}{\eta} \right) + \frac{1}{\eta} q_t} \tag{11}$$

Substituting Equation (2) for Tobin's marginal q and average Q into Equation (11), we obtain Equation (12).

$$\boldsymbol{\left(\frac{I}{K} \right)_t = \left(\delta - \frac{1}{\eta} \right) + \frac{1}{\eta} Q_t - \frac{1}{\eta} \left(\frac{R}{K} \right)_t} \tag{12}$$

This equation presents the relationship between corporate investments, Tobin's average Q, the expected recovery of debt capital (i.e., expected return on debt divided by total assets), and $\frac{R}{K}$. The absolute values of the constant terms for Tobin's average, Q, and $\frac{R}{K}$ are identical. This may lower the logic of the model but simplifies the basic assumptions for effectively deriving the model. As Tobin's average Q is defined as the corporate market value with respect to the replacement cost of capital stock, some studies use Tobin's average Q as a proxy for growth opportunities [24].

Equation (13) is the regression equation for Equation (12), adding the industry dummy I_d and year dummy Y_d to control for the effects of industry and year.

$$\boldsymbol{\left(\frac{I}{K} \right)_t = \alpha + \beta_1 Q_t + \beta_2 \left(\frac{R}{K} \right)_t + \beta_3 I_d + \beta_4 Y_d + \varepsilon_t} \tag{13}$$

where $\frac{I}{K}$ and $\frac{R}{K}$ denote the investment rate and ratio of the expected recovery of debt capital, respectively. I_d and Y_d are the industry and year dummy, respectively.

The investment rate of the dependent variable $\frac{I}{K}$ aggregates the acquisition of land in the cash outflow account from investment activities in the statement of cash flow; the acquisition of buildings, structures, and equipment; machinery tools and equipment, vehicle carriers, and the increment and acquisition of assets under construction and mergers (i.e., transfer of business) in cash outflows. Next, for the investment rate, we sum the following cash inflow items: the disposal of land in the cash inflow account from investment activities in the statement of cash flow; the disposal of building structures and equipment; the disposal of machinery; the disposal of tools and equipment; the disposal of vehicle carriers; and the decrement and merger of assets (i.e., business transfer) under construction. The sum of the cash inflows is deducted. The deducted value is then divided by the total assets [12].

Another measurement can be calculated by subtracting the cash inflow from the cash outflow from investment activities, on the cash flow statement, and dividing it by the total assets [25]. When the investment ratio is measured by the amount of cash flows (i.e., inflows and outflows), there is a detrimental problem in its accuracy, because this measurement includes investment activities that are not associated with the intrinsic business of the company. Since cash outflows and inflows through investment activities particularly include R&D costs, the flows have the problem of endogeneity with the R&D expense ratio R&D, a proxy for innovation [3] measured by the cash inflow and outflow from investment activities, by dividing the increment and decrement of tangible assets, excluding lands and the depreciation in total assets, or by dividing the increment in total assets and fixed assets by total assets. However, the aforementioned method of measuring corporate investments with the actual amount of cash spent is more desirable [25].

2.4. Innovation Indicator

To analyze the effect of innovation on corporate investments, this study sets up Equations (14) and (19) below, which are extensions of the regression equation (Equation (13)). Equation (14) adds an innovation input indicator, R&D expense ratio R&D, and the square of R&D expense ratio R&D^2 to Equation (13). A variety of indicators, such as the R&D cost ratio (or R&D costs), the purchase cost of machinery and tools relevant to new products and processes, and costs of technology introduction, are used as proxies for innovation inputs. Of these indicators, the R&D expense ratio, calculated as R&D expenditures divided by total sales, is more commonly accepted as the most representative innovation input indicator in studying innovation.

Studies that use the R&D ratio emphasize the importance of technological innovation in launching new products and improving processes. Technological innovation is, above all, the outcome of companies' ceaseless R&D activities. Then, it is appropriate to measure innovation in terms of the costs invested in technological innovation. In addition, the R&D expense ratio has the advantages of easy measurement and collection of associated data, compared to the availability of data on new products, processes, sources, markets, and reorganization. In the case of new products, there is a problem of how they embrace many new characteristics to be recognized as new ones. It is also difficult to quantify and secure such data for numerous companies. For these reasons, many studies by [16,26–30] use the R&D ratio or R&D expenses as the innovation input variable. To control for corporate financial characteristics, we define the company size variable (*Size*), and the rate of sales growth variable (*Growth*), in Equation (14).

Despite the above-mentioned advantages, the R&D expense ratio for innovation inputs has a limit in that the indicator does not effectively account for aspects of innovation that are not associated with corporate R&D activities, such as new sources of supply, new market development, and business reorganization. In addition, the R&D expense ratio includes not only the cost spent in a knowledge utilization process (e.g., a process improvement), but also the cost input in the knowledge creation process (e.g., the discovery of new substances). Ref. [31] points out that the R&D ratio might be an inappropriate proxy for innovation.

$$\left(\frac{I}{K}\right)_t = \alpha + \beta_1 Q_t + \beta_2 \left(\frac{R}{K}\right)_t + \beta_3 R\&D_t + \beta_4 R\&D_t^2 + \beta_5 Size_t + \beta_6 Growth_t + \beta_7 I_d + \beta_8 Y_d + \varepsilon_t \quad (14)$$

where *R&D*, *Size*, and *Growth* denote the R&D expense ratio, company size, and rate of sales growth, respectively.

To supplement the limitation of the R&D expense ratio of the innovation input, we measure a corporate innovation performance indicator of the innovation output. The innovation output indicator in this study is driven from the Cobb–Douglas production function. This indicator represents the portion of corporate gross profits not explained by capital stock and labor quantity. Corporate innovation (*CI*) contributes to the gross profits. If so, it would be more reasonable to view the term as an outcome of *CI* rather than *CI* itself.

$$\boldsymbol{lnGP_t = lnCI_t + a_1 lnK_t + a_2 lnL_t} \quad (15)$$

where GP, CI, K, and L denote the gross profits, corporate innovation, capital stock, and amount of labor, respectively.

Basically, Equation (15) is the modified form of the Cobb–Douglas production function, which indicates that a firm's gross profit is a function of innovation, capital, and labor. $lnGP$,lnK, and lnL can be measured by taking the natural logarithm of gross profits in the income statement, total liabilities and equity on the balance sheet, and number of employees, respectively. Given that a_1 and a_2 are known, the corporate innovation outcome (CIO) at time (t) can be derived using Equation (15). When one assumes that companies a_1 and a_2 are constant, Equation (15) can be transformed into Equation (16) of a first-order differential type.

$$\mathbf{\Delta lnGP_t = \Delta lnCIO_t + a_1 \Delta lnK_t + a_2 \Delta lnL_t} \tag{16}$$

We can consider the following regression model of Equation (17), where the first difference of the natural log of gross profits is the dependent variable, and the first differences of the natural log of capital stock and labor quantity are the explanatory variables. In Equation (18), α and ϵ denote the intercept and random error, respectively.

$$\boldsymbol{\Delta lnGP_t = \alpha + a_1 \Delta lnK_t + a_2 \Delta lnL_t + \varepsilon_t} \tag{17}$$

The estimates $\hat{a_1}$ and $\hat{a_2}$ for a_1 and a_2 are obtained by running the regression model of Equation (17), respectively. Substituting the estimated values $\hat{a_1}$ and $\hat{a_2}$ of innovation performance into the right-hand side of Equation (18) with the natural logarithm e as the base, we can obtain the estimated value $C\hat{I}O$ for CIO, the corporate innovation outcome.

$$CI\hat{O}_t = e^{lnGP_t} - (\hat{a_1} lnK_t + \hat{a_2} lnL_t) \tag{18}$$

Finally, our regression model of Equation (19) includes innovation performance variables, such as the innovation outcome indicator CIO in the regression model of Equation (14) above.

$$\left(\frac{I}{K}\right)_t = \alpha + \beta_1 Q_t + \beta_2 \left(\frac{R}{K}\right)_t + \beta_3 CIO_t + \beta_4 Size_t + \beta_5 Growth_t + \beta_6 I_d + \beta_7 Y_d + \varepsilon_t \tag{19}$$

where CIO indicates the corporate innovation outcome.

Tobin's average Q is measured by dividing the corporate value by total assets, and the corporate value is calculated using Equation (6). The expected recovery ratio of debt capital $\frac{R}{K}$ is calculated by dividing the expected recovery of debt capital, calculated in Equation (6), by the total assets. The explanatory variable of the R&D expense ratio $R\&D$ is calculated by dividing R&D expenses by sales. R&D expenses are calculated as the sum of assets and expenses accounting for R&D expenses. Asset-accounted R&D expenses are calculated by subtracting the R&D expenses of the previous year from that of the current period on the financial statement and adding the amortization amount for R&D expenses on the income statement. The innovation performance variable was measured in CIO [13]. For the regression analysis, we take the natural logarithm of this value.

Corporate temporary profits can be determined by non-innovative factors, such as market conditions, but long-term sustainable profit creation is the outcome of innovation [4]. Profits provide companies with substantial incentives to stimulate new investments. Therefore, corporate innovation is positively associated with corporate investment.

Ref. [1] argues that each company has an optimal level of R&D activities. To examine whether companies' R&D activities beyond their optimal level are an impediment to their investments, we add the square of the R&D expense ratio $R\&D^2$ in Equation (14). If R&D activities beyond the optimal level hinder corporate investments, $R\&D^2$ is expected to have a negative coefficient. The control variable, company size (*Size*), is calculated by taking the natural logarithm of total assets. The larger the size of the company, the more diversified and lower the default risk; thus, large companies have more flexibility and cost advantage in raising capital than small companies [32]. By contrast, larger companies have a more complex decision-making structure. This nature of larger companies does not allow them to respond promptly and flexibly to changes in the business environment. Thus, company size has a negative relationship with investments. The rate of sales *growth* (=$\sqrt{\frac{Sales_t}{Sales_{t-2}}}$ -1) is measured as the geometric average growth rate of annual sales for the previous two years. An increase in market demand is an important factor that induces corporate investment, and the rate of sales growth is used as a proxy for the increase in market demand. Accordingly, we expect that the sales growth rate has a positive (+) relationship with a company's investments.

For a simpler understanding on our methods, the complexity of the numerous equations can be visualized in the three following steps:

Step 1: Basic theoretical model in Equation (12):

$$\left(\frac{I}{K}\right)_t = \left(\delta - \frac{1}{\eta}\right) + \frac{1}{\eta}Q_t - \frac{1}{\eta}\left(\frac{R}{K}\right)_t$$

Step 2: Augmented model 1 (innovation inputs model) for empirical analysis in Equation (14):

$$\left(\frac{I}{K}\right)_t = \alpha + \beta_1 Q_t + \beta_2\left(\frac{R}{K}\right)_t + \beta_3 R\&D_t + \beta_4 R\&D_t^2 + \beta_5 Size_t + \beta_6 Growth_t + \beta_7 I_d + \beta_8 Y_d + \varepsilon_t$$

Step 3: Augmented model 2 (innovation outcome model) for empirical analysis in Equation (19):

$$\left(\frac{I}{K}\right)_t = \alpha + \beta_1 Q_t + \beta_2\left(\frac{R}{K}\right)_t + \beta_3 CIo_t + \beta_4 Size_t + \beta_5 Growth_t + \beta_6 I_d + \beta_7 Y_d + \varepsilon_t$$

3. Data Issues

This study focuses on companies listed on the Korea exchange that do not issue preferred stocks and are not engaged in the financial and construction industries according to industry classification over the full sample period from 2011 to 2019. Companies in the financial industry were excluded from our sample because the standard booking of financial statements is different from those of other industries. Companies in the construction industry are also excluded because their total assets and employee contribution to gross profits are different from those of other industries due to the existence of subcontracting.

Targeting listed companies in this study enables us to efficiently obtain data on the market value of equity capital and its volatility to calculate the expected recovery of debt capital, corporate value, and default risk. Companies issuing preferred stocks are excluded because we assume companies with no preferred stocks for the derivation of the research model above. Outliers with a debt capital ratio of one or more than 1 are excluded from our sample because they may distort the estimates.

Finally, we exclude holding companies, real estate and leasing businesses, hotels, and resorts that are not matched with the nature of this study, and companies whose data on the variables used in this study are unavailable during the sample periods. Through the above-mentioned process, we finally collect 3349 observations for 492 companies over the full sample period. Table 1 reports the sample companies by industry for the entire sample period. Including companies in agriculture, forestry, and fisheries; electricity, gas, steam, and water businesses; and wholesale and retail industries in Table 1, non-manufacturing companies refer to companies categorized into the remaining industries that do not fall into the manufacturing industry. Out of our full sample of 3349 companies, 2484 are overwhelmingly in the manufacturing sector and 865 are in the non-manufacturing sector.

Table 1. Classification of sample companies by industry over the entire sample period.

Industry	Number of Samples	2011	2012	2013	2014	2015	2016	2017	2018	2019
Agriculture, Forestry, Fishing	32	4	4	3	3	3	3	4	4	4
Manufacturing	2484	262	274	240	243	242	287	302	314	320
Electricity, Gas, Steam, and Water Utilities	62	6	6	6	6	7	9	8	7	7
Wholesale and Retail	359	35	37	33	34	35	43	45	47	50
Transportation	118	12	13	12	12	12	15	14	14	14
Publishing, Video, Broadcasting communication, and Information services	186	19	22	19	18	17	23	26	20	22
Etc.	108	13	13	11	9	10	13	12	13	14
Sum	3349	351	369	324	325	326	393	411	419	431

All the data used in this study are collected from the KISVALUE (the KISVALUE is a paid database of Korean corporate financial statements and a variety of the data of the Korean stock markets operated by Korean NICE Ltd.). Table 2 presents the descriptive statistics for all the variables. Prior to our regression analysis, all the correlation coefficients for the pairs of the independent variables are overall low. The results suggest that there are no serious multicollinearities across the covariates. This enhances the reliance of the coefficients of the covariates estimated in the regressions (the specific results are not reported, to save space, but are available upon a request).

Table 2. Descriptive statistic of each variable.

Variables		Mean	Standard Deviation	Median	Minimum	Maximum
$\frac{I}{K}$	Investment ratio	0.015	0.027	0.002	−0.084	0.190
Q	Tobin's average Q	1.133	0.678	0.937	0.318	6.692
$\frac{R}{K}$	Expected recovery ratio on debt capital	0.385	0.184	0.383	0.001	0.956
$R\&D$	R&D expense ratio	0.014	0.035	0.001	0.000	0.676
CIO	Corporate innovation outcome	10.125	1.019	10.103	4.193	12.611
$Size$	Corporate size	26.596	1.294	26.384	23.024	32.300
$Growth$	Rate of sales growth	0.048	0.242	0.027	−0.958	6.242

4. Empirical Results

This section discusses the regression results to investigate the effects of innovation on corporate investments. Table 3 presents the regression results for Tobin's average Q on the corporate investment equation. The coefficient of Tobin's average Q shows highly significant positive values (0.004, 0.004, 0.003) at the 1% level for the entire industry, manufacturing industry, and non-manufacturing companies, respectively. On the other hand, the expected recovery of debt capital $\frac{R}{K}$ shows significant negative coefficients (-0.010, 0.010) at the 1% level for all the companies and manufacturing companies, although the variable shows no significant value for the non-manufacturing companies. The results suggest that the investment ratio is positively associated with Tobin's average Q and negatively associated with the expected recovery ratio of debt capital $\frac{R}{K}$.

Table 3. Regression results for Tobin's average *Q* on corporate investment.

Regression 1: $\left(\frac{I}{K}\right)_t = \alpha + \beta_1 Q_t + \beta_2 \left(\frac{R}{K}\right)_t + \beta_3 I_d + \beta_4 Y_d + \varepsilon_t$			
Variables	**All the Companies**	**Manufacturing Companies**	**Non-Manufacturing Companies**
Constant	0.010 (0.501)	0.010 *** (0.000)	0.003 (0.368)
Q	0.004 *** (0.000)	0.004 *** (0.000)	0.003 *** (0.014)
$\frac{R}{K}$	−0.010 *** (0.000)	−0.010 *** (0.000)	−0.003 (0.442)
I_d	Inclusive	Inclusive	Inclusive
Y_d	Inclusive	Inclusive	Inclusive
Adjusted R^2	0.066	0.050	0.025
F-value	12.240 ***	14.060 ***	7.370 ***
Observations	3349	2484	865

Notes: *** denotes significance at 1% level. Figures in brackets are *p*-values.

Table 4 presents the regression results for innovation on corporate investment. Regressions 2 and 3 estimate very significant positive coefficients (0.004, 0.003) at the 1% level for the Tobin's average Q. By contrast, the two models estimate very significant negative values (−0.011, −0.009) at the 1% level for the expected recovery ratio of debt capital, $\frac{R}{K}$. As for R&D expense ratio $R\&D$ and the square of R&D expense ratio $R\&D^2$, Regression 2 estimates no significant coefficient for either. However, in Regression 3, the innovation performance variable COI shows a significantly positive coefficient (0.002) at the 1% level. Based on the regression results, we suggest that corporate investments could be promoted by the outcomes resulting from innovation rather than their input activities. In a similar line with our finding, Ref. [33] reports empirical evidence that the R&D activity enhances corporate investment responsiveness to the news of the present value of growth opportunities. With regard to the control variables, company size *Size* shows an insignificant coefficient on Regression 2 but a significant negative one (−0.002) at the 1% level on Regression 3. For the sales growth rate, both regressions estimate insignificant coefficients.

Table 4. Regression results of innovation on investment.

Regression 2: $\left(\frac{I}{K}\right)_t = \alpha + \beta_1 Q_t + \beta_2 \left(\frac{R}{K}\right)_t + \beta_3 R\&D_t + \beta_4 R\&D^2{}_t + \beta_5 Size_t + \beta_6 Growth_t + \beta_7 I_d + \beta_8 Y_d + \varepsilon_t$ Regression 3: $\left(\frac{I}{K}\right)_t = \alpha + \beta_1 Q_t + \beta_2 \left(\frac{R}{K}\right)_t + \beta_3 CI_t + \beta_4 Size_t + \beta_5 Growth_t + \beta_6 I_d + \beta_7 Y_d + \varepsilon_t$		
Variables	**Regression 2**	**Regression 3**
Constant	0.024 (0.202)	0.029 (0.121)
Q	0.004 *** (0.000)	0.003 *** (0.000)
$\frac{R}{K}$	−0.011 *** (0.000)	−0.009 *** (0.000)
$R\&D$	−0.028 (0.220)	

Table 4. *Cont.*

$R\&D^2$	−0.065 (0.329)	
Size	−0.001 (0.158)	−0.002 *** (0.000)
CIO		0.002 *** (0.000)
Growth	0.002 (0.245)	0.002 (0.289)
I_d	Inclusive	Inclusive
Y_d	Inclusive	Inclusive
Adjusted R^2	0.069	0.071
F-value	10.960 ***	11.700 ***
Observations	3349	3349

Notes: *** denotes significance at the 1% level. Figures in brackets are *p*-values.

Table 5 shows the results of the regressions by classifying all the sample companies into manufacturing and non-manufacturing companies to check for whether there is a difference in the results by industry. In the case of manufacturing companies, Regressions 2-1 and 3-1 estimate the highly significant positive coefficients (0.004, 0.002) at the 1% level for Tobin's average Q. In the case of non-manufacturing industries, the two regressions estimate highly significant values (0.003, 0.002) at the 5% level for the Tobin's average Q, as well. For the manufacturing companies, the expected recovery ratio of debt capital $\frac{R}{K}$ shows the highly significant negative estimates (−0.011, −0.010) at the 1% level for Regressions 2-1 and 3-1. Meanwhile, for non-manufacturing companies, this variable has insignificant values in the regression models.

Table 5. Regression results of innovation on corporate investment by industry.

Regression 2-1:

$$\left(\frac{I}{K}\right)_t = \alpha + \beta_1 Q_t + \beta_2 \left(\frac{R}{K}\right)_t + \beta_3 R\&D_t + \beta_4 R\&D^2{}_t + \beta_5 Size_t + \beta_6 Growth_t + +\beta_7 Y_d + \varepsilon_t$$

Regression 3-1:

$$\left(\frac{I}{K}\right)_t = \alpha + \beta_1 Q_t + \beta_2 \left(\frac{R}{K}\right)_t + \beta_3 CIO_t + \beta_4 Size_t + \beta_5 Growth_t + \beta_7 Y_d + \varepsilon_t$$

Variables	**Manufacturing Companies**		**Non-Manufacturing Companies**	
	Regression 2-1	**Regression 3-1**	**Regression 2-1**	**Regression 3-1**
constant	0.034 *** (0.000)	0.039 *** (0.002)	−0.005 (0.735)	−0.002 (0.922)
Q	0.004 *** (0.000)	0.002 *** (0.009)	0.003 ** (0.024)	0.002 ** (0.048)
$\frac{R}{K}$	−0.011 *** (0.000)	−0.010 *** (0.001)	−0.004 (0.445)	−0.003 (0.498)
$R\&D$	−0.038 (0.135)		−0.022 (0.779)	
$R\&D^2$	−0.050 (0.477)		0.450 (0.472)	
CIO		0.002 *** (0.009)		0.002 ** (0.020)
Size	−0.001 (0.059)	−0.002 *** (0.001)	0.000 (0.587)	−0.001 (0.398)

Table 5. *Cont.*

Growth	0.012 *** (0.001)	0.011 *** (0.002)	−0.002 (0.458)	−0.001 (0.513)
Y_d	Inclusive	Inclusive	Inclusive	Inclusive
Adjusted R^2	0.060	0.058	0.066	0.072
F-value	12.320 ***	12.790 ***	5.380 ***	6.180 ***
Observations	2484	2484	865	865

Notes: *** and ** denote significance at 1% and 5% levels, respectively. Figures in brackets are *p*-values.

The coefficients of R&D ratio $R\&D$ and its square $R\&D^2$ are not significant at the standard level, regardless of the types of industries in which the companies fall. This result suggests that corporate investments are not associated with innovation input activities. Interestingly and importantly, for the innovation outcome variable CIO, Regressions 3-1s estimate the highly significant positive coefficients (0.002, 0.002) at 1% and 5% levels, respectively, in the two sample groups of manufacturing and non-manufacturing companies. Our findings for both manufacturing and non-manufacturing companies confirm that innovation outcomes are an important factor in corporate investment, rather than innovation input activity itself.

In addition, we attempt to examine the persistent nature of the impacts of innovation in the previous period ($t-1$) on the investments in the current period (t), replacing the current time lag (t) of the independent variables with their previous time lag ($t-1$). Our regressions estimate the very significant coefficients (0.004, 0.003) for the first lag of the Tobin's average Q_{t-1} at the 1% level. As for the first lag of the variable of the expected recovery ratio of debt capital $\left(\frac{R}{K}\right)_{t-1}$, the regressions estimate the significant negative coefficients. The first lagged R&D expense ratio $R\&D_{t-1}$ and its first lagged square $R\&D^2{}_{t-1}$ show insignificant values. These results indicate that both the input activities in the current period (t) for innovation and the input activities in the previous period ($t-1$) do not affect corporate investments. On the contrary, the first lag of the innovation outcome variable CIO_{t-1} shows a highly significant positive value. This result confirms that both the innovation performance of the current period (t) and the innovation performance of the previous period ($t-1$) are crucial factors in determining corporate investments (the specific results are untabulated to save space but are available upon request).

5. Discussion

This study aims to examine economic impacts of innovation on the sustainable investments of Korean companies, listed on the Korean exchange from 2011 to 2019. Extending the theories by [15,16], we establish a relationship between the investment ratio, Tobin's average Q, and the debt capital's expected recovery ratio. To empirically examine this relationship, we derive debt capital's expected recovery ratio, using Black and Scholes's [18] option pricing model. To test for Tobin's average investment equation Q suggested by [15], we use the ratio of the expected recovery of the corporate debt capital. Complementing Hennessy's model [15], this study is the first to explore the usefulness of Tobin's average Q investment equation for Korean-listed companies, one of the leading countries in innovation and investment.

Our principal findings are as follows: First, corporate investments are positively associated with Tobin's average Q proxied for corporate growth. This confirms that greater growth opportunities for companies promote greater investments. The expected recovery ratio of debt capital has a negative relationship with corporate investments, thus suggesting the debt capital's expected recovery ratio to decrease corporate investments. Separating the full sample into companies in the manufacturing and non-manufacturing industries, our findings remain confirmed still.

Next and principally, the innovation outcomes have a significant positive effect on Korean-listed companies' investments, regardless of the industries (i.e., manufacturing or non-manufacturing industries) of the sample companies. However, we find no relationship between the R&D expense ratio and corporate investment. These results of our main findings reflect that corporate investments are determined by the innovation outcomes rather than the input activities of the financial resources for innovation. To test for this, like Equations (14) and (19) above, we modified the investment model of Hennessy [15] on Equation (12). Specifically, Equation (14) estimates the relation between corporate input (*R&D*) and investment and Equation (19) estimates the relation between corporate innovation outcome (*CIO*) derived from the augmented Cobb–Douglas production function (Equation (15)) and corporate investment. Shortly, our main findings obtained by our investment model modified from the Hennessy investment model could shed invaluable light on the economic effect of corporate innovation (outcome) on the investment, given that there are few on the relationship between corporate innovation and investment. The flows of our analysis are in line with the three aforementioned steps of this study.

Importantly, as [8] addresses, both innovation and investment have been the source of capitalism and economic growth, following the beginning of the industrial revolution in the eighteenth century. In this respect, it should be meaningful to examine the relationship between innovation and investment at the levels of country, industry, and company, respectively. The empirical study on the relationship between innovation and investment is variously analyzed. As aforementioned, Ref. [8] using Austrian industry section data identifies the relationship between the instability of industry life cycles and growth trends. However, the study of [8] looks at the relationship between innovation and investment indirectly rather than directly. Along the similar vein, Ref. [34] demonstrates that innovation promoted in the public sector contributes to the increase in total factor productivity in the market. Unlike previous studies, our study directly empirically tested for whether corporate innovation promotes investment on tangible assets at the corporate level using the data of Korean-listed companies and found evidence of a significant positive relationship between both.

6. Conclusions

Our findings suggesting that corporate investments are predominately affected by the performances of corporate innovation provide policymakers with the necessity of seeking substantial policy instruments, to use the outcomes of innovation more effectively, rather than increasing the inputs of a variety of financial resources. To derive debt capital's expected recovery ratio, we assume corporate value to follow a probabilistic process expressed in terms of expected return, volatility, and the winner process. Different assumptions for corporate value may cause differences in the empirical results, due to the under-estimation (or over-estimation) of debt capital's expected recovery ratio, which could be a good venue for future studies on this topic.

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