

## Article

# The Impact of Innovative Technology Exploration on Firm Value Sustainability: The Case of Part Supplier Management

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**Abstract:** With rapid changes driven by technical advances, innovative technology capacity is a strategic asset unique to a company allocating various tangible and intangible resources, and it promotes technological innovation. This study analyzed the technology applied to iPhone series by Apple from 2007 to 2017 and measured the information effect of innovative technology exploration on the firm value for managing global supply chain (USA, Taiwan, Japan, Korea, and Europe). Adopting the pooled OLS (Ordinary least square) and panel analysis, this study revealed that exploration technology exploring new technologies shows a positive market response in the information effect of sustaining innovation. Results identified that exploitation and exploration can give different results depending on a construct (exploration and exploitation technologies) or congruence (combination and balance). In addition, the results indicate the importance of the balance between exploitation and exploration technologies and rational part supplies management in Apple's new product development strategy. Analyzing the impact of innovative technology exploration on the firm value for global supply chain management, this study suggests significant implications for strategic decision making for the company to build continuous innovation path through technology search and to secure sustainability of organizations facing rapid changes in technical advances.

**Keywords:** disruptive innovation; information effect; exploration technology; exploitation technology

## 1. Introduction

With rapid technical advances in IT industry, technological innovation capacity has brought an important impact on firms' value sustainability. In particular, sustaining innovation to improve existing technologies in the knowledge-intensive industry is effective for external knowledge exploitation. Disruptive innovation that develops new technology completely different from existing technology is an effective strategy for external knowledge exploration [1]. Companies tend to explore technology within their existing technology area [2]. However, pursuing the internal technology search may cause organizational tension and conflicts between the two activities, which can accordingly have a negative impact on corporate performance [3]. Therefore, as they develop external technology search activities in various technology areas, they can utilize many technical resources, enhancing the possibility of innovation [4]. This can be explained in various aspects: increasing opportunities for new technology discovery [5], expanding existing technology basis through complementary technology acquisition [6], and creating new technology by combining existing knowledge with new knowledge.

A study on Exploitation and exploration conducted by March [7] shows different findings in different fields [3]. Gupta et al. [8], in the research review on exploration and exploitation,

presented definition between two concepts (trade-off or complementary), relationship (continuum or orthogonal), balance (ambidexterity or punctuated equilibrium), and long-term performance (sustainable equilibrium or specialization on one side). Raisch and Birkinshaw [9] also argued that it is necessary to consider the need for longitudinal research, the temporal balance of two domains, and the contingency specific to the firm.

The technology that a company possesses is the result of innovation, and the result of a knowledge activity that demonstrates its technological innovation capabilities. The process of technology development shows what technology search the company has done for new knowledge [10]. Therefore, technical data are a suitable study target that shows how companies use exploitation and exploration technologies. As the importance of innovation through securing external technologies is emphasized, studies on external search behavior of companies are actively carried out [11]. External search behavior for innovation is divided into exploration search for acquiring new technology and exploitation search for strengthening existing technology [12]. However, there are few empirical studies on the impact of external search depth and external search breadth on corporate performance from the viewpoint of technology search. Therefore, this paper aims to analyze the impact of exploitation and exploration technologies on firm's performance by applying congruence among the constructs presented by Bareto [13]. Specifically, this study examined the impact of exploitation and exploration technologies on firm performance, which are derived from new product release rather than input of new product development process. In the congruence of the two technologies, we verified whether combinations that generate synergies or balance of simple compatibility have a different impact on corporate performance. Originality and implications of this study are as follows: First, we examined the information effect of disruptive innovation and continuous innovation through the analysis of the excess earning rate. Second, this study derived implications to improve the understanding of technology innovation capability, which is innovative technology exploration through empirical verification of the impact on the firm value in balance exploitation and exploration technologies pursue with a mutually contradictory combination at the same time. In addition, results revealed the impact of innovative technology exploration on the firm value for managing global supply chains, providing important implications for securing sustainable competitive advantages of companies with building continuous innovation path through technology search.

## 2. Literature Review and Hypothesis Development

### 2.1. Disruptive Innovation

Disruptive innovation means innovations that change the competition criteria between companies through technology, products and business models to create new markets and values [1]. Technology innovation capacity means innovation ability such as product innovation and process innovation. Disruptive innovation begins with the technological innovation capacity of these companies and changes in internal and external values. As time passes and technology develops, values change, and disruptive innovation is achieved through a cascading process that creates new values combining technology and value. From a technical point of view, the practical answer to "how to make a new market" can be explained by the concept of disruptive innovation. Analyzing at the technology level, we can examine the changes caused by technology innovation capacity in the company. Therefore, disruptive innovation is reasonable to explain the impact of technological innovation capabilities that provide new value on existing firms and markets.

To supplement existing research on disruptive innovation from a market perspective, it is necessary to closely examine products which are the subject of destruction. The new product market created by the disruptive innovation is divided into the product category as the upper concept, and the product type as the lower concept. By dividing the market into two concepts, disruptive innovation can be viewed as a new market type disruptive innovation that creates new product categories or creates new product types within existing product categories [14]. This divides the hierarchical structure of the

product market into categories and types according to the result of disruptive innovation, broadening practical understanding.

Apple's iPhone (Apple, Cupertino, CA, USA) could create a new market because it pursued a disruptive innovation that overturned the existing market rather than the progressive Nokia-type innovation. This "innovation paradox" explains that the sincere and steady improvement work deemed to be a virtue in the past is being destroyed by disruptive innovation. This means that innovation is not improvement but breakthrough, and it should be the change itself, rather than reacting to change. iPhone released by Apple is a disruptive innovation because it pioneered a new market for its customers and created new value. Selling apps through an open market called the App Store is a business model innovation that has fundamentally changed the way businesses work, and its performance is higher and longer than product innovation.

As shown above, Apple created a smartphone market through disruptive innovation. Then, Apple has maintained sustainable competitive advantages by eliminating technical uncertainties and strategic uncertainties through sustaining innovation, making a better way rather than competing with other companies by giving an edge that gradually improves rather than by seeking for big changes. Based on the research of Son and Kim [15], the following hypotheses are used to examine the impact of Apple's disruptive innovation that created the smartphone market called "iPhone 2G" and sustaining innovation of iPhone 3G–iPhone X which have been released since then.

**Hypothesis 1.** Disruptive innovation has a positive information effect on part suppliers' firm value.

**Hypothesis 2.** In continuous innovation, exploration technology has a more positive information effect on part supplier' firm value than exploitation technology.

## 2.2. Technology Search

Technology innovation capacity is a strategic asset unique to a company that allocates various tangible and intangible resources including technology, and it promotes technological innovation of the company and has more importance for IT companies [16]. These include corporate processes [17], specific assets [18], and functional capabilities [19].

Companies conduct technology search to develop new products in uncertain situations. This allows the companies to adapt to changes in the environment by improving current technologies or developing new technologies [20]. There are various studies on the impact of this technology search on performance. First, Rosenkopf and Nerkar [21] identified the impact of local search and radical search on technological evolution according to the degree of technical similarity inside and outside the company. To analyze the impact of technology search on innovation, Katila and Ahuja [12] divided it into the search depth, which means how deeply the existing technology is utilized and search scope, which means how broad a new technology is explored. The company explores technology to secure exploitation technology with technical alliance with various partners for technological innovation and then gains exploration technology, which is a source of competitive advantages with R&D (Research and Development) alliance that requires constant interaction between partners [22]. The technology search is divided into exploitation technology and exploration technology. One is about the degree of exploitation of internal technology, and the other is about how well external technology is explored [23]. These exploitation and exploration technologies are systematic indicators that can explain the company's knowledge base and evaluate the output of technology innovation capacity [24]. As shown above, if exploitation technology increases, companies can continue to use similar knowledge to increase efficiency. If exploration technology increases, companies can expand the base of knowledge and increase the flexibility to create new products [12].

Exploitation technology requires a specific technology within the company and a depth in its field [25]. Exploration technology, including wide range of technologies, enables companies to easily

identify opportunities for innovation. If exploitation technology increases, companies can continue to use similar knowledge to increase efficiency. If exploration technology increases, on the other hand, they expand their knowledge base and increase the flexibility to create new products, leading to positive performance [12]. Companies do not pursue a balance between exploration and exploitation technologies within the domain. They pursue balance through congruence across domain such as combination between the domain with superior exploration technology and domain with superior exploitation technology [26].

As such, companies are more likely to rely on one of exploration and exploitation technologies. Hence, they maintain the balance through the method of maintaining the exploitation technology internally and securing scarce elements externally [27]. In particular, as the importance of pre-emptive investment in innovative new technologies is increasing in companies, efforts to find a balance between exploration and exploitation technologies are being carried out in various fields. In particular, Rothaermel and Alexandre [28] argued that the balance between external exploration technology which seeks new technologies in the process of new technology development and complementary internal exploitation technology has a positive impact on performance. In a study on the balance and performance of exploration and exploitation, Barreto [13] suggested congruence between constructs and variables. First, construction, exploitation, and exploration may have different impacts on performance depending on input or output. Thus, this study divided the results of technology search into exploitation and exploration technologies. Next, we could derive other research results by assuming the independent balance of exploitation and exploration technologies and the combination emphasizing synergy by performing both exploitation and exploration technologies well in congruence between variables. In other words, different implications can be given depending on whether to emphasize synergy-oriented combination or emphasize independent activities such as complementary materials. Therefore, this study was carried out by dividing the impact of exploitation and exploration technologies on performance and the relationship between them into combination and balance. As such, when the technology search process is divided into exploitation and exploration technologies, the impact on the company performance is derived differently. In other words, in the technology development process, exploitation activity affects performance more positively than exploration activity. In the results of technology development, however, exploration technology has a more positive impact on performance than exploitation technology. Therefore, based on the research of Son and Kim [15], this study set the following hypotheses to examine the impact of exploitation and exploration technologies on the performance of the part supplier of the technology applied to the iPhone.

**Hypothesis 3.** Exploration technology has a more positive effect on part suppliers' firm value than exploitation technology in the technology search.

**Hypothesis 4.** The combination of exploitation and exploration technologies has a positive impact on part suppliers' firm value in the technology search.

**Hypothesis 5.** The balance of exploitation and exploration technologies has a positive impact on part suppliers' firm value in the technology search.

### 3. Methodology

#### 3.1. Sample Design

##### 3.1.1. Data Collection of Part Suppliers

This study used global part suppliers participating in the iPhone's new product release as research samples under the theme of the impact of exploitation and exploration technologies on company

performance. Exploitation and exploration technologies are the results of technology search and have been studied as tools to measure technological competence in the company [29]. In the existing research, new technology reflects both the process and the results of the technology search [30]. Based on the research of Son and Kim [15], technical data applied to Apple iPhone was used as data, and the specific method of collection was as follows: First, we collected part supplier data based on the supplier list provided by Apple's annual report. Second, we obtained data based on the part supplier list disclosed by Apple. With a one-year difference, during which the independent variable is reflected in the dependent variable, we collected company performance data using OSIRIS DB. A total of 1089 part suppliers of Apple were selected as the final samples based on these criteria. Table 1 summarizes the results of the country-by-country classification of all part suppliers participating in the new product release of iPhone for the 11 years from 2007 to 2017. The average number of part suppliers of Apple iPhone is 91. With the exceptions of eight part suppliers in Korea and six in Europe supplying core parts, 30 companies, 26 companies, and 27 companies are evenly distributed in the USA, Taiwan and Japan, respectively.

**Table 1.** Apple iPhone part supplier classification.

Year	Model	USA	Taiwan	Japan	Korea	Europe
2007	iPhone 2G	23	22	25	6	5
2008	iPhone 3G	25	23	24	6	6
2009	iPhone 3GS	30	23	27	5	5
2010	iPhone 4	29	23	22	7	7
2011	iPhone 4S	35	27	29	8	6
2012	iPhone 5	24	23	25	11	7
2013	iPhone 5S	33	36	27	9	6
2014	iPhone 6	32	27	28	9	5
2015	iPhone 6S	36	30	30	10	6
2016	iPhone 7	33	30	31	9	7
2017	iPhone X	35	31	33	11	7
Avg.	iPhone Series	30	26	27	8	6

### 3.1.2. Technology Classification

Technology reflects the process of knowledge search in the company's knowledge creation activities and is suitable as an index of innovation results. The technology announced in the release of the new product of iPhone includes exploitation technology used to develop the technology and exploration to find new technologies. Therefore, exploitation technology and exploration technology are suitable as the proxies of existing technology and new technology, respectively, and were classified based on the following criteria.

First, to identify the part suppliers only for iPhone among Apple's products, we disassembled the iPhone and checked the part suppliers on the site that provides the technical information applied to each part. Second, we collected data using information provided by Phone Arena ([www.phonearena.com](http://www.phonearena.com)) for detailed classification of the technology applied to the iPhone. Apple is taking a strategy of classifying it into product domain, operating system, service domain, content domain, etc. to apply new technology to iPhone and acquiring a company with the technology rather than internal development. Specifically, multi-touch technology is a new core technology applied to iPhone. On 11 April 2005, they acquired FingerWorks to obtain the original technology and utilized it to acquire various user interface technologies. On 24 April 2008, Apple implemented a highly integrated, low-power Apple A series of CPUs based on the ARM core used in the existing iPhone through Semi acquisition and mounted it on iPhone 4 and consigned it to Samsung Electronics and TSMC for production. Through the acquisition of AuthenTec on 27 July 2012, Apple's fingerprint authentication technology was implemented for the first time in Apple's iPhone 6 and was being used to pioneer a new market called mobile payments



service (Apple Pay). As shown above, acquisition for Apple is a means of securing technology and Apple is making efforts to improve iPhone through companies with competitiveness in specialized areas such as software and semiconductor.

On the other hand, Apple is using new technologies to enhance the various user experiences of iPhone users. For example, they have implemented various technologies in the platform they have already built through the acquisition of AuthenTec (Touch ID), PrimeSense, Perceptio (Face ID) for authentication technology, the acquisition of Siri, Catch.com, Novauris, VocallQ, Tuplejump, init.ai, Shazam for voice recognition technology, the acquisition of Polar Rose, Emotient for face recognition technology, the acquisition of Placebase, Poly9, C3 Technologies AB, HopStop.com, Locationary, BroadMap for map service and the acquisition of Lala.com, Swell, Beats Electronics, Semetric Ltd, Camel Audio for music service. In recent years, Apple has acquired Perceptio (5 October 2015), Emotient (7 January 2016) and Turi (7 August 2016), which are famous for their image recognition technology for smartphones and AI to apply artificial intelligence technology to iPhone.

As shown above, Apple has obtained technologies through its own technology development, strategic alliances, and M&A (Merger and Acquisition) to maintain the competitiveness of the iPhone. The technology that Apple has put in the most effort is the user interface and technology of user experience, including location recognition technology, human information processing technology, emotional information processing technology, etc. Next, hardware-related technologies include low-power system development technology for battery problem improvement and 3D implementation technology. Finally, mobile related technologies include recognition technology, mobile payment technology, etc.

Generally, the technology application direction of smartphone industry is developing from hardware-based standard technology to software-based application technology, as shown in Figure 1. It can be sub-classified into PC technology, mobile technology, and personal mobile technology. First, the PC technology areas includes standardized technology areas such as AP (Associated Press) functioning as a brain, memory (RAM) which is a temporary storage space, and storage capacity (NAND) and differentiated areas such as user interface (UI). This includes faster system chips (Apple A series) and system memory, more intuitive and convenient interfaces, and precise input technology. For example, AP and semiconductors for communication are equipped with high-performance processors of hexa-core in dual-core to handle various functions, and semiconductors are used to implement various communication environments such as LTE (Long Term Evolution), Wi-Fi, etc. These companies include Samsung, Qualcomm, Intel, etc.

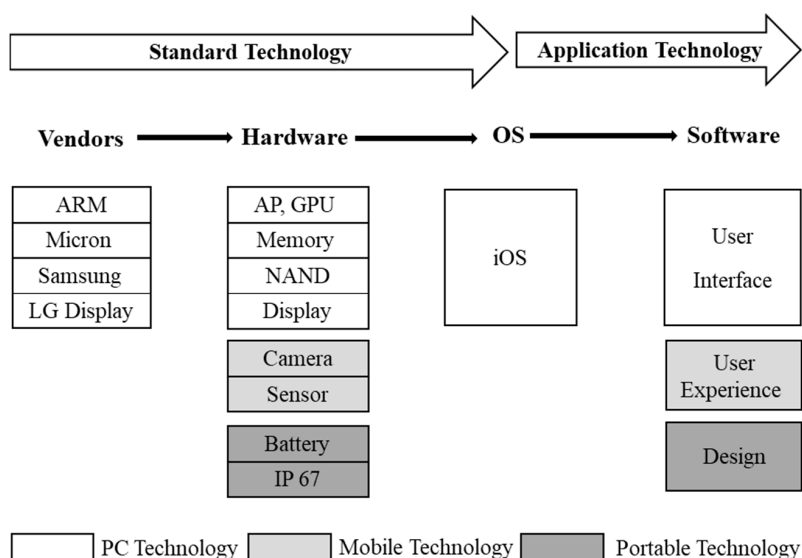


Figure 1. Technology area classification of iPhone.

Second, mobile technology areas include the generalization area of sensor related technologies such as acceleration sensor, compass, fingerprint recognition, mic, GPS (global positioning system), camera imitating human sensory organs and differentiation area of user experience using them. That is, vision (camera and illuminated sensor), hearing (mic), sense of direction (compass and accelerometer sensors), and sense of position (gyroscope) among human senses are implemented through new sensing technology. For example, the performance of the camera module used in smartphones is increasing to the performance of high-end digital camera (HDR, high dynamic range) by merging several devices into one.

Third, the personal portable technology area is to improve hardware performance such as waterproof/dustproof, battery, display, etc. while enhancing portability. The integrated battery technology led by Apple solved robustness and radiation with metal materials such as duralumin or magnesium based on integrated design. The waterproof and dustproof technology enhances users' convenience and extends the usability of smartphones. For example, the power consumption of batteries has increased as processors and semiconductors for communication, etc. have become more sophisticated, so higher capacity batteries and power semiconductors have been attracting attention. Table 2 shows the results of classifying existing technologies and new technologies into exploitation technology and exploration technology, respectively, depending on the three technical areas applied by Apple from iPhone 3G to iPhone X. Table 3 presents iPhone Series' new product preannouncement and launching day.

**Table 2.** Classification according to technology search results of iPhone 3G–iPhone X.

Year	Model	Exploration Technology	Exploitation Technology
2008	iPhone 3G	32	48
2009	iPhone 3GS	35	53
2010	iPhone 4	33	42
2011	iPhone 4S	37	62
2012	iPhone 5	42	61
2013	iPhone 5S	38	60
2014	iPhone 6	39	60
2015	iPhone 6S	37	63
2016	iPhone 7	35	59
2017	iPhone X	37	57
Avg.	91.2	36.5	56.5
Sum	912	365	565

**Table 3.** iPhone Series' new product preannouncement and launching day.

Year	Model	Preannouncement Day	Launching Day
2007	iPhone 2G	9 January 2007	29 June 2007-
2008	iPhone 3G	9 June 2008	11 July 2008
2009	iPhone 3GS	8 June 2009	19 June 2009
2010	iPhone 4	7 June 2010	24 June 2010
2011	iPhone 4S	4 October 2011	14 October 2011
2012	iPhone 5	12 September 2012	21 September 2012
2013	iPhone 5S	10 September 2013	20 September 2013
2014	iPhone 6	9 September 2014	19 September 2014
2015	iPhone 6S	9 September 2015	18 September 2015
2016	iPhone 7	7 September 2016	16 September 2016
2017	iPhone X	12 September 2017	22 September 2017

### 3.2. Measures and Data Analysis

#### 3.2.1. Event Study

This study employed an event study to analyze the information impact of new product preannouncement on the stock market. Then, we divided the stock price of the part supplier and the event day by the following criteria. First, we used the adjusted stock price to maintain the continuity of the stock price. Second, Apple's iPhone adjusted the event day by applying time difference to each country (US, Taiwan, Japan, Korea, and Europe) based on the launching day of new products of WWDC (2007–2010) and separate Apple Keynote Events (2011–2017). Event days were classified, as shown in Table 3, based on the pre-announcement day of new product of Apple iPhone.

An event study is a methodology of analyzing how companies with the same specific events respond on average around the point of announcement. The degree of an individual firm's response to stock price is called an abnormal return, which is measured as the difference between the expected return before a particular event is announced, normal return and return realized by the announcement of a particular case [31]. The event window of this study was set to 11 days for five days before and after the announcement date by selecting a new product launching day, and the estimation window was set from −170 days to −6 days. The daily stock price return of the individual sample firm is calculated based on the market model.

$$R_{i,t} = P_t / P_{t-1} - 1 \quad (1)$$

In Equation (1),  $R_{i,t}$  is the daily return of an individual firm, and  $P_t$  and  $P_{t-1}$  are the closing prices of  $t$  day and  $t - 1$  day of the individual firm, respectively. In addition, we estimated the intercept of stock ( $\hat{\alpha}_i$ ) and the gradient, Beta ( $\hat{\beta}_i$ ) of the market model of Equation (2) using the data of the estimation window in which the information effect of a specific event was not reflected and using daily returns and market indices of individual stocks through OLS (ordinary least squares) regression analysis.

$$AR_{i,t} = R_{i,t} - \hat{\alpha}_i - \hat{\beta}_i R_{m,t} \quad (2)$$

After estimating the abnormal return ( $AR_{i,t}$ ) of individual firms from −5 to 170 days based on the estimated alpha and beta, we estimated the abnormal average return ( $AAR_{i,t}$ ) by dividing the abnormal return of individual firms by the number of sample firms at the time ( $n$ ) as in Equation (3).

$$AAR_{i,t} = \frac{1}{n} \sum_{i=1}^n AR_{i,t} \quad (t; -170 \sim 5) \quad (3)$$

As shown in Equation (4), the cumulative mean abnormal return ( $CAR_{(t_1,t_2)}$ ) is estimated by summing all the  $AAR_{i,t}$  during the period between specific two points.

$$CAR_{(t_1,t_2)} = \sum_{t_1}^{t_2} AAR_t \quad (4)$$

We used the method of Brown and Warner [31], which assumes independence of the statistical significance of  $AAR_t$  and  $CAR_{(t_1,t_2)}$  during the derived event window to obtain the test statistic and calculate it as Equation (5).

$$t_{AAR_t} = \frac{AAR_t}{\sigma(AAR_t)}, \quad t_{CAR_{(t_1,t_2)}} = \frac{CAR_{(t_1,t_2)}}{\sigma(CAR_{(t_1,t_2)})} \quad (5)$$

The difference test to analyze the difference between cumulative average excess return between innovative technologies and non-innovative technologies was analyzed using Equation (6).



$$\text{CAR}(t_1, t_2)'s \text{ difference analysis : } t = \frac{\text{CAR}(t_1, t_1)^{\text{INNO}} - \text{CAR}(t_1, t_1)^{\text{NON-INNO}}}{\sqrt{\text{var}(\text{CAR}(t_1, t_1))^{\text{INNO}} + \text{var}(\text{CAR}(t_1, t_1))^{\text{NON-INNO}}}} \quad (6)$$

Here,  $\text{CAR}(t_1, t_2)^{\text{INNO}}$  is cumulative average excess return from the event period  $t_1$  to  $t_2$  between innovative technologies and  $\text{CAR}(t_1, t_2)^{\text{NON-INNO}}$  is cumulative average excess return from the event period  $t_1$  to  $t_2$  between non-innovative technologies.

### 3.2.2. Effect of Exploitation and Exploration Technology on the Firm Value

To test hypotheses, this study analyzed data using pooled OLS and panel analysis. To test the fitness of pooled OLS and panel analysis model, we conducted Lagrange Multiplier Test and, as a result (g-statistic), when the null hypothesis ( $H_0: \sigma_{\eta}^2 = \sigma_{\lambda}^2 = 0$ ) is rejected, the panel analysis model is selected because the company effect ( $\eta_i$ ) and time effect ( $\lambda_t$ ) exist [32]. In the panel analysis model, the fixed effect model (FEM) makes an estimate with least squares dummy variable (LSDV) assuming that the company effect ( $\eta_i$ ) and time effect ( $\lambda_t$ ) are fixed. Assuming these two as random variables, the random effect model (REM) makes an estimate with generalized least squares (GLS). To determine the suitability of these two research models, the Hausman test was carried out and, as a result (m-statistic), when the null hypothesis ( $H_0: E(\eta_i/X_{it}) = 0$ ) is rejected, FEM is selected [33]. F-test was conducted to confirm the fitness of FEM. As a result, if the null hypothesis is rejected, this model is considered appropriate. In addition, to identify the impact of the company's technology search for new product release on firm value, this study analyzed Tobin's q value of firm, as shown below.

$$\text{Tobin's } Q_{it} = \alpha + \beta_1 \text{EXPR}_{it} + \beta_2 \text{RD}_{it} + \beta_3 \text{SIZE}_{it} + \beta_4 \text{COM}_{it} + \beta_5 \text{BAL}_{it} + \eta_i + \lambda_t + \varepsilon_{it} \quad (7)$$

$$\text{Tobin's } Q_{it} = \alpha + \beta_1 \text{EXPI}_{it} + \beta_2 \text{RD}_{it} + \beta_3 \text{SIZE}_{it} + \beta_4 \text{COM}_{it} + \beta_5 \text{BAL}_{it} + \eta_i + \lambda_t + \varepsilon_{it} \quad (8)$$

where Tobin's  $Q_{it}$  is Tobin's q value of firm  $i$  at time  $t$ ,  $\text{EXPR}_{it}$  is the exploration technology of firm  $i$  at time  $t$ ,  $\text{EXPI}_{it}$  is the exploitation technology of firm  $i$  at time  $t$ ,  $\text{RD}_{it}$  is the research and development intensity of firm  $i$  at time  $t$ ,  $\text{SIZE}_{it}$  is the firm size of firm  $i$  at time  $t$ ,  $\text{COM}_{it} = \text{EXPR}_{it} \times \text{EXPI}_{it}$ ,  $\text{BAL}_{it} = [1 - (\text{EXPR}_{it} - \text{EXPI}_{it})]$ ,  $\eta_i$  is the company effect, and  $\lambda$  is the time effect.

There is no common criterion that suggests how to measure the impact of exploitation and exploration technologies on the firm value [9]. However, the firm's competitive advantage can be measured using Tobin's Q, a financial indicator, as a dependent variable that indicates the long-term growth potential [34].

A firm's Q is the ratio of its market value to the current replacement cost of its assets as follows:  $\text{Tobin's } Q = (\text{market value of equity} + \text{book value of debt}) / \text{total assets} = (\text{share price} \times \text{number of shares outstanding} + \text{total value of preferred stock} + \text{long-term debt} + \text{short-term debt}) / \text{total assets}$ .

Exploitation and exploration technologies, the main independent variables, are the result of innovative activities of the company, each of which becomes judgment criterion for new technology and existing technology, respectively [35].

Therefore, exploitation technology and exploration technology can be understood as narrow technology area based on the company's existing technology and various and broad technology areas in addition to the existing technology. The exploitation technology is measured by a technology with a reuse proportion of more than 0.6 and originality of less than 0.4. Exploration technology uses technology with reuse proportion of 0 and originality of 0.6 or more [29]. To control the technology base within the company, R&D concentration obtained by dividing R&D expenses by total assets is used as a control variable [26]. A natural log value of total assets is used as company size. A large company size indicates that the accumulation of internal capabilities would be high. The expansion of company size is expected to have a positive impact on the firm value due to economies of scale.

The combined effect of exploitation and exploration technologies to test Hypothesis 4 uses the product of these two ( $EXPR_{it} \times EXPI_{it}$ ). This is to see if a company performs both exploration and exploitation technologies smoothly to create a synergy effect, and if both values are large, it shows high combination effect [36]. The balance between exploitation and exploration technologies to test Hypothesis 5 uses the difference between the two. To find what the balance between exploitation and exploration technologies is in the company, the difference between the two values is subtracted from 1 ( $[1 - (EXPR_{it} - EXPI_{it})]$ ). This difference value reflects an independent balance because it represents a simple existence for both activities. Thus, the larger is the difference between the two, the better is the balance achieved [36].

## 4. Results and Discussion

### 4.1. Information Effect of Disruptive Innovation

Apple's iPhone is disruptive innovation that pioneered a new market that did not exist for customers and created new value. Table 4 shows the results of testing the information effect of this disruptive innovation. Specifically, the AAR of the part supplier is 2.79% on the event day (Day 0), which is statistically significant at 1% level and has a positive impact on the stock price of the company. In addition, these significances are continually detected in the following days. It means that there is no information leakage effect which allows investors in the stock market to expect an innovative product called "iPhone" to some extent while there is an information effect. This is consistent with Apple's mystic marketing strategy of not providing information about the technology applied to the new product before the official announcement of the new product as an innovator, and an end-to-end strategy of building the ecosystem from software to hardware. That is, the technology applied from the development of new products to the moment of disclosure is strictly confidential, which stimulates consumers' curiosity and maximizes the promotion and investment effect of the part supplier.

Table 4. Information effect of disruptive innovation.

Day	AAR (%)	t-Value	CAR (%)	t-Value	iPhone 2G (N = 81)
−5	0.27	0.37	0.27	0.37	
−4	0.07	0.09	0.34	0.33	
−3	0.14	0.20	0.49	0.38	
−2	0.40	0.55	0.89	0.60	
−1	0.10	0.13	0.98	0.60	
0	2.79	3.78 ***	3.77	2.09 **	
1	0.79	1.07	4.56	2.34 **	
2	0.89	1.20	5.45	2.62 ***	
3	0.79	1.07	6.24	2.82 ***	
4	0.38	0.52	6.62	2.84 ***	
5	0.90	1.22	7.52	3.08 ***	

Significance levels: \*\*  $p < 0.01$ ; \*\*\*  $p < 0.001$ .

### 4.2. Information Effect of Sustaining Innovation

Since launching an innovative product called iPhone, Apple has been launching new versions of iPhone every year through sustaining innovation over the past decade. Thus, Tables 5 and 6 show the result of examining the information effects of the new product release time by dividing iPhone 3G–iPhone X into exploitation and exploration technologies from a technology search perspective.

**Table 5.** Information effect of exploration technology.

Day	AAR (%)	t-Value	CAR (%)	t-Value	iPhone 3G–iPhone X (N = 365)
−5	0.19	−0.34	−0.19	−0.34	
−4	0.31	0.56	0.12	0.15	
−3	0.58	1.04	0.70	0.73	
−2	0.67	1.20	1.37	1.23	
−1	0.63	1.13	2.00	1.60	
0	1.82	3.27 ***	3.82	2.80 ***	
1	0.76	1.36	4.58	3.11 ***	
2	0.41	0.74	4.98	3.17 ***	
3	0.71	1.27	5.70	3.41 ***	
4	−0.21	−0.38	5.49	3.11 ***	
5	0.35	0.63	5.84	3.16 ***	

Significance levels: \*\*\*  $p < 0.001$ .**Table 6.** Information effect of exploitation technology.

Day	AAR (%)	t-Value	CAR (%)	t-Value	iPhone 3G–iPhone X (N = 565)
−5	0.52	1.07	0.52	1.07	
−4	−0.13	−0.27	0.39	0.57	
−3	0.58	1.19	0.97	1.15	
−2	0.16	0.33	1.13	1.16	
−1	0.51	1.05	1.64	1.50	
0	0.78	1.60	2.42	2.03 **	
1	0.32	0.66	2.74	2.12 **	
2	0.63	1.29	3.37	2.44 **	
3	−0.18	−0.37	3.19	2.18 **	
4	0.61	1.25	3.80	2.47 **	
5	0.14	0.29	3.94	2.44 **	

Significance levels: \*\*  $p < 0.01$ .

In Table 5, the part supplier's AAR is 1.82%, which is statistically significant at 0.1% level on the event day (Day 0), positively affecting the stock price of the company. It means that there is no information leakage effect which allows investors in the stock market to expect a technology newly applied to "iPhone" to some extent while there is the information effect. These significances are continually detected in the following days. In Table 6, the part supplier's AAR is 0.78 on the event day (Day 0), which is statistically significant, and investors in the stock market have no information effect for existing technologies applied to iPhone. Therefore, the excess return of exploration technology is higher than that of exploitation technology in the information effect of sustaining innovation, supporting Hypothesis 2. This means that, for the technology applied to iPhone released every year, investors are more interested in the part suppliers which offered new technology than existing technology. This is also consistent with Apple's mystic marketing and end-to-end strategy of not providing any information prior to the official announcement of the technology applied to the new product.

#### 4.3. Difference Analysis of the CAR between Innovative Technologies and Non-Innovative Technologies

Table 7 presents the results of dividing group variables into innovative technologies and non-innovative technologies and analyzing difference for independent sample with the test variable as CAR to identify how the average cumulative excess return change depending on the collective nature of the companies involved in the pre-announcement of the Apple's iPhone series. Results of difference analysis identified that innovative technologies recorded higher average cumulative excess return at 1% significance level than non-innovative technologies. The results indicate consistently positive evaluation of innovative technologies applied for iPhone series in the market.

**Table 7.** Innovative technologies and non-innovative technologies: CAR difference analysis.

Model	Period	Innovative Companies	Non-Innovative Companies	Difference	t-Value
iPhone series	CAR (−5, 5)	3.53	1.91	1.62	6.37 ***

Significance levels: \*\*\*  $p < 0.001$ .

#### 4.4. Effect of Exploration and Exploitation Technology on Firm Value

This study analyzed the effect of exploration technology and exploitation technology on firm value from the perspective of the technology search result. In Tables 8 and 9, Model 1 is a Pooled OLS model that does not take into account the company effect and time effect; Model 2 considers all of control variable, combination effect, company effect and time effect; and Model 3 is a fixed effect model that takes into account all of control variable, control variable, company effect and time effect. The Hausman test was carried out based on Equations (7) and (8) and the results of the test are  $m = 76.08$  and  $m = 98.56$ , respectively, rejecting the null hypothesis at the 99.9% confidence level. The F-test results are  $F = 3.89$  and  $F = 3.95$ , respectively, and the null hypothesis is rejected at the 99% confidence level and the fixed effect model is used.

In Table 8, the exploration technology shows a significant positive coefficient of 0.1% for all three models in the firm value. It is noteworthy that the Balance Effect (BAL) variable shows a significant positive coefficient at the 1% level in Model 3. This supports Hypothesis 4 that balanced exploration emphasizing independent activities positively affects performance (0.657, 8.51). In other words, independent activities of exploration technology and exploitation technology that do not take synergy into account have a positive effect on performance. In Table 9, exploitation technology shows a significant positive coefficient of 5% for all three models in the firm value. It should be noted that the combination of exploration and exploitation technologies (COM) in Model 2 has a positive effect on performance (1.472, 9.58). This supports Hypothesis 5 that maintaining a relatively low level of exploitation and exploration technologies in the company has a positive effect on performance. In other words, exploitation technology means that activities considering synergy have a positive effect on performance.

**Table 8.** Results of panel analysis: The effect of exploration technology on firm value.

Variables	Dependent Variable: Tobin's Q		
	Model 1	Model 2	Model 3
EXPR	0.472 *** (7.12)	0.583 *** (8.12)	0.571 *** (8.37)
RD		0.938 *** (7.79)	0.932 *** (7.83)
SIZE		−0.127 *** (−5.25)	−0.121 *** (−5.21)
COM		1.323 * (1.82)	
BAL			0.657 *** (8.51)
Company effect	no	Yes	Yes
Time effect	no	Yes	Yes
F	15.53	17.37	21.89
N	1315	1315	1315
Adjusted_R <sup>2</sup>	0.028	0.29	0.31

Significance levels: \*  $p < 0.05$ ; \*\*\*  $p < 0.001$ .

**Table 9.** Results of panel analysis: The effect of exploitation technology on firm value.

Variables	Dependent Variable: Tobin's Q		
	Model 1	Model 2	Model 3
EXPI	0.377 ** (2.98)	0.493 ** (2.45)	0.486 ** (2.51)
RD		0.538 ** (2.32)	0.529 ** (2.46)
SIZE		−0.113 *** (−3.59)	−0.109 *** (−3.87)
COM		1.472 *** (9.58)	
BAL			0.539 * (1.73)
Company effect	no	Yes	Yes
Time effect	no	Yes	Yes
F	16.01	19.56	19.31
N	1785	1565	1565
Adjusted_R <sup>2</sup>	0.032	0.35	0.38

Significance levels: \*  $p < 0.05$ ; \*\*  $p < 0.01$ ; \*\*\*  $p < 0.001$ .

#### 4.5. The Impacts of Innovation Capacity on Firm's Value: Comparison among Countries

Son and Kim [15] analyzed market responses to partner volatility of the part suppliers. Research results identified that the newly selected companies have the stronger innovative capacity and higher excess earning rate than that of re-selected companies. Therefore, this study compared the impacts of innovation capacity on firms' value. Based on Son and Kim [15], we classified part suppliers of iPhone into three largest groups: USA, Taiwan and Japan. Table 10 presents results of comparison among the groups.

**Table 10.** The impacts of innovation capacity: Comparison by countries.

Variables	Dependent Variable: Tobin's Q		
	USA	Taiwan	Japan
IC	0.039 *** (3.71)	0.016 * (1.83)	0.023 * (1.89)
SLACK	0.027 (1.51)	0.021 (1.43)	0.017 (1.37)
SIZE	0.019 * (1.69)	0.025 *** (2.98)	0.028 *** (2.85)
PPE	0.016 (1.12)	0.022 (1.32)	0.021 (1.36)
F	7.23 ***	8.52 ***	8.63 ***
N	335	295	301
Adjusted_R <sup>2</sup>	0.26	0.28	0.28

Significance levels: \*  $p < 0.05$ ; \*\*  $p < 0.01$ ; \*\*\*  $p < 0.001$ .

In a model to compare the countries, results identified that part suppliers in USA show positive values (0.039, 3.71) at 1% significance level. Taiwan and Japan recorded (0.016, 1.83) and (0.023, 1.89). Results identified suppliers in USA show higher innovation capacity than Taiwan and Japan. This indicates that suppliers in USA such as Intel, NVIDIA, Qualcomm and Micron Technology are in charge of innovative technologies of iPhone. On the other hand, suppliers in Taiwan including Lite-On Technology, Largan Precision, AU Optronics, TPK, etc. and suppliers in Japan such Furukawa, Nissha Printing, Panasonic, Sharp and Sony provide relatively less innovative technologies.

## 5. Conclusions

This study examined the information effect of the result of disruptive innovation called iPhone for Apple's global supply chain (Apple, USA, Taiwan, Japan, Korea, and Europe). Although there is no clear guideline even if the combination and balance of exploitation and exploration technologies are emphasized as the driving force of technological innovation of companies, this study empirically analyzed the relationship between exploitation and exploration technologies by dividing it into the combination and balance effect. The main results of the study are summarized as follows: First, this study confirmed positive market reaction of technology applied to disruptive innovation. Disruptive innovation requires a lot of time and cost, but its influence is significant in that it can change the "world" rather than the industry or market. This means that disruptive innovation overturns the existing market and creates a new market. For example, Apple is creating new markets while continuously succeeding in new market type disruptive innovation through convergence with the next generation technologies such as Healthcare, FinTech, and Artificial Intelligence (AI) in the smartphone market where technology changes rapidly.

Second, it was found that exploration technology exploring new technologies showed a positive market response in the information effect of sustaining innovation. This means that exploration technology is not in a breakthrough, but is improving and searching new changes on its own rather than reacting to them. For example, Apple is discovering the optimal elements of its products and services through the simultaneous achievement of cost advantage and differentiation advantage to find new changes.

Third, exploration technology has a more positive effect on firm value than exploitation technology in the outcome of constructs for exploitation and exploitation. This can be understood as an independent orthogonal concept rather than trade-off, i.e., the concept of two end-continuum in which companies have limited access to resources such as new technology in the technology search, so exploitation technology constrains exploration technology [8]. For example, Apple approaches innovative technologies they want and applies them to new products with superior buyer bargaining power in the already established ecosystem.

Fourth, we examined the effect on performance by dividing the relationship between exploitation and exploration technologies into combination and balance congruence for exploitation and exploitation. In the balance effect, which emphasizes the independent balance of the two technologies, exploration technology was found to have a positive impact on firm value. In the combination effect that emphasizes the synergy of the two technologies, exploitation technology was found to have a positive impact on firm value. This can be interpreted as a result that Apple has built a continuous innovation path through technology search to remain as an innovative company over the past decade. For example, Apple is seeking innovation by balancing exploitation technology with exploration technology such as "True Depth Camera" and "Super Retina Display" equipped with "Face ID", OLED (Organic Light Emitting Diodes) using 3D scanning in the release of iPhone X.

Based on above results, the implications of this study are as follows: First, the information effect of the disruptive innovation has a huge impact on the market. The innovation method of a company needs to be in the order of "prior-disruptive innovation" and "after-sustaining innovation", and limited resources should be put more into disruptive innovation than sustaining innovation. Second, the high exploration technology in the information effect of sustaining innovation means that the market recognizes exploitation and exploration technologies as different technology domains. This means that the company should build a wide, long-lasting and deep relationship with external partners with a wide range of technologies in external search behavior. Third, exploitation and exploration can give different results depending on a construct (exploration and exploitation technologies) or congruence (combination and balance). In particular, it was found that the balance due to external performance of exploration technology plays a complementary role with time difference while minimizing tension and conflict caused by simultaneous pursuit of two activities. Thus, there is a virtuous circle relationship in



which exploration technology strengthens future technology capability and exploitation technology helps future technology search through profit creation in the existing market.

On the other hand, among part suppliers of Apple, Sandisk Corp, Broadcom Corp, TriQuint Semiconductor Inc., Sharp Corp, Elpida Memory Inc., Intersill Inc., RF Micro Devices Inc and so on are merged or acquired by other companies. This originates from squeezing part supplier and/or self-development of Apple. At first, to reduce a unit cost of the part, Apple employs at least two companies per each part. Making a Non-Disclosure Agreement and an exclusive agreement, the contract can be terminated or part supplier has to pay a penalty for breach of contract when the suppliers violate the agreements. Through these unconscionable supply structures, Apple takes the profit rate over 70% excluding the costs for selling and administrative expenses, labor and marketing, whereas the most relevant company, Foxconn, take less than 2% operating profit to sales ratio. In addition, with increasing dependence to Apple, not only competitive small and medium companies in Japan but also major companies such as Sharp, Sony, Toshiba, Panasonic, etc. are practically dominated. Apple has grown with exploitation of subcontractors by undercutting prices and snatching up the latter's hard-developed technology and manpower. Apple manages part suppliers as subcontracting enterprise (called as iFactory). In response, Avent Electronics discontinued parts supply due to undercutting the unit cost. TSMC also refused one billion investment of Apple. This paper provides the following practical value to companies that continue to perform exploitation and exploration activities for innovative technology exploration. It should be understood that companies are creating synergies through the combination and proper balance among part suppliers to achieve innovative new product performance in practical technology search. The results of empirical analysis are of significance in that it is an opportunity to recognize the importance of innovative external technology exploration and rational part supplies management in Apple's new product development strategy.

Lastly, this study provides useful insight for a better understanding of the relationship between technology search and firm value based on various exploration paths such as technical similarity. As a future research, it is required to examine the relationship among various technology searches inside and outside the company by expanding external technology exploration (exploration technology–exploitation technology) activities to ambidexterity strategy (External exploration–internal exploitation).

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