

# Strategic Cooperation and Failure in Innovation Processes: Empirical Evidence from the Korean Manufacturing Industry

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## ABSTRACT

The aim of this paper is to analyse the impacts of R&D cooperation and obstacles to technological innovation on the innovation failure of the Korean manufacturing firms. Two hierarchical regression models including interaction variables are employed for the analysis. Some interesting findings are: first, almost all the obstacles have positive and significant effects on the failure. Second, R&D cooperation positively or negatively moderates the impact of obstacles to technological innovation on the innovation failure, although R&D cooperation itself is not directly related to the failure. Third, the interaction effects between the cooperation and the obstacles influence the failure in various manners. This study is expected to help manufacturing firms which are under unfavourable environments to formulate their cooperation strategies successfully based on what they learn from the failure.

Keywords: R&D Cooperation, Innovation Failure, Obstacle to Innovation, Technological Innovation, Manufacturing

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## 1. INTRODUCTION

As technological innovations become more important for firms and nations to acquire their competitive advantages, strategic decision on the direction of successful technological innovation has emerged as a critical issue in the area of technology management. Especially, the cooperation strategies play an important role in both technology development and commercialization.

Innovative firms attempt to cooperate with partners because cooperation strategy has a tentative possibility to boost the firm's innovative performance. Chesbrough (2003) stated that firms should enlarge open innovation

in response to the fast-changing knowledge landscape surrounding the firm. In advance of technological innovation, firms formulate a strategy on their own to cooperate with various partners.

Likewise, firms formulate a cooperation strategy to shorten the technological innovation period and react to the rapid market changes. Furthermore, the relationship between the cooperation and performances of technological innovation cannot be generally concluded, but rather would vary depending on the environments surrounding the firms. Although some environments might be favourable for technological innovation, there are various obstacles to technological innovation that ham-

per the successful completion of the technology development. In other words, the firms who are faced to negative situations or conditions in their industry field have a propensity to choose cooperation to overcome the situation. Those situations and conditions are different for each firm, however, it is extremely important for the firms to choose appropriate partners and formulate cooperation strategy.

Many studies have examined the effects of the obstacles on the success of technological innovation, but few studies regarding the cooperation considered the obstacles in technological innovation process (Becker and Dietz, 2004; Miotti and Sachwald, 2003; Tether, 2002). The analysis on the effects of cooperation activities of the firm experiencing the obstacles to innovation could provide more specific and practical implications for formulating technology strategies and policies.

Regarding the performances of the technological innovation, many studies focused on both success and failure or only the success of innovation.

The aim of this study is to empirically analyse the effects of R&D cooperation in a difficult circumstances by obstacles on the failure of the innovation. Based on the empirical analysis, this study provides a basis for formulating cooperation strategies that can lower the possibility of further failures. Moreover, this study expects to provide a valuable reference for formulating technology policies leading to better technological innovation performances.

This study focuses on the negative environments, i.e., the obstacles to technological innovation, and thus considering the failure as the performance indicator could be more appropriate. In addition, this study restricts the failure in various stages of technological innovation to the R&D stage before the commercial introduction in accordance with the case in cooperation, and this restriction would contribute to providing more practical implications. Furthermore, the studies on the failure of technological innovation (FTI) are rare despite its importance, and in turn, the analysis results on FTI could be the valuable reference different from those of the success.

The rest of the paper is organised as follows: Section 2 provides a brief overview of the related literature on factors that influence the failure of technological innovation, and based on the review, formulates research hypotheses. Section 3 shows the research framework and explains the data and variables. Section 4 proposes the empirical model used and discusses the results. Section 5 concludes and provides the direction of further studies.

## 2. LITERATURE REVIEW AND RESEARCH HYPOTHESES

Many innovators consider the cooperation as a breakthrough to solving the bottlenecks of technological

innovations; however, they rarely try finding the causes of their failures (Tinsley *et al.*, 2011). Accordingly, many efforts to identify the determinants of the failures have been made (Mansfield and Wagner, 1975; Ekvall and Ryhammar, 1998; Lhuillery and Pfister, 2009). The cooperation strategy for the firm is one of the key determinants of the failure of technological innovation, and the purpose of the cooperation varies according to the background situations of the firm. The diversity of the purpose of the cooperation has intimate connection with internal or external conditions which the firm is faced with. When uncertainty of the technology or excessive perceived economic risks make the firm hesitate to invest, when the regulations exist in the institution or technology market, or when the firm lacks finance or qualified personnel even if the possibility of success of the technology development and commercialization is highly evaluated, the firm will try to fill the gaps by means of effective strategy.

Likewise, the firms which are faced with internal or external problems will make an effort to overcome negative situations or conditions by taking the vaccine of cooperation strategy. However, every situation and condition of the firm is quite different in an actual business. If the diverse impact of cooperative activities depends on the types of negative situation or the types of cooperation partners of the firm, it is strongly needed to analyze its empirical data and study each pattern of the relation.

However, the studies related to the cooperation activities and performances of the firm hardly considered the firms' various environments, especially unfavourable ones, to analyse the effects of cooperation on the performances. This is a crucial omission because the practical cooperation activities contribute to the performances variously according to the firms' distinct circumstances.

This study attempts to bridge this gap by analysing the relationship between the cooperation and the performances of technological innovations, considering the distinct environmental obstacles to the innovations. This study closely observes if the firms' negative situations can be improved or solved on behalf of strategic cooperation. Moreover, in order to provide more practical guidelines, this study empirically analyses the interaction effects between the cooperation activities and the obstacles. Prior to the empirical analysis, this section reviews the related literature, and formulates explicit hypotheses.

### 2.1 Failure of Technological Innovation

Technological innovations, in general, include uncertainties because of its nature related to creativity, and thus the success and failure have been traditionally a major point on the innovations (Freeman *et al.*, 1972; Johne and Snelson, 1988; Maidique and Zirger, 1984; Rubenstein *et al.*, 1976).

The success and failure of technological innovations could be simply considered as mutually opposite concepts. Nevertheless, the studies on the success and the failure could provide different implications to innovators, respectively. More specifically, the studies on the failure contribute to advancing innovators' future potential performances by learning from their failures.

The FTI may be defined as a postponed or abandoned case during the survey period (OECD, 2005; Kim *et al.*, 2008). The postponement means halting during the period of technological innovation project for some reasons. This postponement can be interpreted in two ways, viz., the innovators 1) decide to quit the innovation project by themselves or 2) inevitably hold off the project owing to the inability to continue. This study regards FTI as an innovation project that is in a suspended state, either abandoned or with some innovation activities deferred.

Moreover, the suspension of an innovation may not constitute the failure because the halted technological innovation project can be restarted afterward. However, this study particularly narrows the scope of the failure to within the survey period, thereby developing a basis for defining the failure.

## 2.2 Obstacle to Technological Innovation

Firms essentially need to take strategic initiatives for overcoming or minimizing the obstacles to their technological innovation during the innovation process (March-Chorda *et al.*, 2002). The obstacles indicate the factors that have a detrimental effect on innovation, and are labelled as barriers or impediments to technological innovation in some studies (Baldwin and Lin, 2002; Galia and Legros, 2004; Mohnen and Lar-Hendrik, 2005; Moriyasu *et al.*, 2010; Veugelers and Cassiman, 2005). This study defines the obstacles to technological innovation (OTI) as various factors that would be reasons for not starting technological innovation activities at all, or factors that slow the innovation activities or have a negative effect on the expected results.

The previous studies related to obstacles to innovation broadly focus on 1) the elements to affect the concept of importance of obstacles such as R&D and innovation intensity (Mohnen and Rosa, 1999; Baldwin and Lin, 2002; Galia and Legros, 2004) or 2) the impact of obstacles to innovation intensity of the firm (Tourigny and Le, 2004; Mohnen and Lar-Hendrik, 2005). These studies explain the findings that more innovative firms experience more obstacles to innovation and they highly consider the importance of obstacles.

Furthermore, they mainly focus on the financial elements such as high costs, lack of internal or external resources as obstacles which affect innovation propensity or intensity of the firm (Galia and Legros, 2004). This study, however, highly considers and contributes to identify the effect of non-financial elements of the obstacles such as capacity, market, or institutional prob-

lems which are essential to the innovative strategy, rather than diversity or propensity of the obstacles to innovation. The empirical analysis of this study considers four types of obstacles to innovation such as cost, capacity, market, and institutional one to complement the limitations of previous studies.

Numerous studies on the obstacles have considered four types: cost, capacity, market, and institutional factors (Mohnen and Rosa, 1999; Galia and Legros, 2004; Mohnen and Lar-Hendrik, 2005; Veugelers and Cassiman, 2005). The obstacles represent the firms' negative environments for their technological innovations, and are likely to have crucial effects directly on the failure of the innovation. In turn, Hypothesis 1 is formulated as follows:

**Hypothesis 1.** The OTIs have positive effects on the failure of the innovation.

## 2.3 R&D Cooperation

Many previous studies viewed the cooperation as a key determinant of performance of the technological innovation, more specifically in terms of two major perspectives: how to cooperate and with whom to cooperate. While the former perspective deals with the cooperation method such as strategic alliances or licensing (Cassiman and Veugelers, 2002; Gautam, 2000), the latter perspective is related to the types of cooperation such as vertical and horizontal cooperation (Atallah, 2002; Tether, 2002; Belderbos *et al.*, 2004a; Fritsch and Lukas, 2001; Miotti and Sachwald, 2003). This study focuses on the latter perspective's cooperation.

Moreover, a viewpoint of R&D cooperation pertains to unilateral linkages such as consulting, technology transfer, or one-shot agreements (Hagedoorn, 1993; Howarth, 1994). The other viewpoint defines it as the cooperation wherein both parties participate mutually in any manner in R&D activities to produce technologies (Dodgson, 1993; Tyler and Steensma, 1995).

This study follows the second viewpoint by referencing the concept of R&D cooperation in the Korean Innovation Survey (KIS), and defines R&D cooperation as a cooperative relationship to achieve technological purposes in the process of technological innovation with agreed parties in a bilateral form, and share the outputs. Firms would cooperate with external organisations to share the expected risks and guard against the failure of innovation activities (Bayona *et al.*, 2001; Becker and Dietz, 2004; Fritsch and Lukas, 2001). In addition, firms could absorb technological knowledge and knowhow from external sources for securing and strengthening their own competitive edges.

Moreover, numerous studies have grouped the types of cooperation into vertical, horizontal, and other research-related types (Belderbos *et al.*, 2004a; Fritsch and Lukas, 2001). Though many studies classified the types of cooperation according to several cooperative

partners, the studies accepting the three-fold classification would focus on providing more intuitional implications rather than a variety of ones. This study classified the types of cooperation into three groups: vertical cooperation, horizontal cooperation, and cooperation with research organisations. First, vertical cooperation strategies would help reducing the uncertainties for entering a new market by acquiring vital information on technologies and customer's needs (Belderbos *et al.*, 2004b).

Second, horizontal cooperation is pursued in order to settle the de facto standard in the industry, or make the market active and innovative to release new technology or products. Moreover, firms would cooperate with competitors for the purpose of expanding the overall market size, while developing new products at first (Tether, 2002). Horizontal cooperation is potentially dangerous, however, because competitors sell on similar markets and may access the firm's own R&D resources through cooperation (Miotti and Sachwald, 2003).

Third, firms attempt to cooperate with external research organisations usually for collaborating or contracting out their technology project to external organisations (Tether, 2002). In addition, research organisations are valuable for the firm in order to acquire the necessary technology and knowledge when it develops an entirely brand new technology or expand its business field (Belderbos *et al.*, 2004b).

Many empirical studies have demonstrated that the cooperation has a positive impact on the performances of technological innovation, and some studies, however, found either negative or nonsignificant results, in respective cases of the vertical cooperation (Barge-Gil, 2010), horizontal cooperation (Kaufmann and Todtling, 2001; Freel, 2003), and cooperation with external research organisations (Dowling and Helm, 2006). Hence, though the R&D cooperation would be related to the FTI, there would be no direct relationship between the cooperation and the failure due to the dependency on various environments. Thus, to test it, Hypothesis 2 is formulated as follows:

**Hypothesis 2.** The R&D cooperation has no direct effects on the failure of technological innovation.

In this study, the obstacles and the cooperation are considered as major determinants of the FTIs, but would be correlated. Some studies found significant relationships between the obstacles and the cooperation (Arranz and Fernandez de Arroyabe, 2007; Bayona *et al.*, 2001; Becker and Dietz, 2004; Cassiman and Veugelers, 2002).

Although many types of barriers affect the firm's cooperation activities, proper cooperation strategies on the situation alleviate the firm's OTI (Bruneel *et al.*, 2010). Bruneel *et al.* (2010) studied the factors which diminish the obstacles to university-industry cooperation, and examined the effect of the prior experience of collaboration with universities on diminishing orientation-related barriers.

On the other hand, improper cooperation strategies of the firm on the situation could negatively affect the firm's OTI. For instance, research cooperation might generate substantial transaction costs. The adjusting costs of the firm caused by partners' different goal or management may exceed the benefit costs through the research cooperation with partners (Becker and Dietz, 2004). The lack of trust between cooperation partners also causes the free-rider problem, and makes them to leak vital information. As a result, the amount of leaking knowledge exceeds the amount of knowledge acquired from cooperation with partners (Belderbos *et al.*, 2004a; Busom and Fernandez-Ribas, 2008; Fritsch and Lukas, 2001).

This study considers the interaction effects between the obstacles and the cooperation, and investigates the interactions' effects on the FTIs. Based on the cited literature, Hypothesis 3 is considered as follows:

**Hypothesis 3.** The R&D cooperation has various effects on the failure according to the types of obstacles.

### 3. RESEARCH METHOD

#### 3.1 Conceptual Framework

The conceptual research framework in this study expects that FTI is affected by the types of R&D cooperation and OTI. It additionally indicates that these relationships would be influenced by the interaction between the cooperation and the obstacles. Moreover, several important controls, i.e., firm-specific environmental factors, are included in the framework for more precise analysis. The detailed measurements of the factors are discussed in the next subsection.

#### 3.2 Data

The data in this study are from the Korean Innovation Survey 2008: Manufacturing (KIS 2008; Kim *et al.* 2008) conducted by the Science Technology Policy Institute (STEPI). The survey is based on the third revision of the OECD Oslo Manual Guidelines, and STEPI has conducted the KIS several times; KIS 2008 has targeted both manufacturing and service firms, and this study has used the manufacturing data collected in 2008. A total of 3,081 firms responded to the survey. Using the data, this study analyses a total of 1,251 observations, excluding missing values and non-innovative firms. Moreover, this study narrows the scope of measurement to products and process innovation, excluding management innovation.

#### 3.3 Variables

This study considers FTI as the dependent variable. The respondents to KIS 2008 were asked to inform the

postponed or abandoned cases from their technological innovations over the survey period of 2005–2007. FTIs are divided into two types: the failures of product innovation and process innovation. These are dummy variables corresponding to abandonment and postponement, respectively.

Moreover, this study considers the R&D cooperation as the moderating variables and the OTIs as independent variables. First, the R&D cooperation is divided into three types: vertical cooperation, horizontal cooperation, and cooperation with external research organisations. The variable is measured as dummy variables.

Second, OTIs are divided into four factors: cost, capacity, market, and institution. First, the cost factor (OTI1) includes excessive perceived risks, high cost, lack of funds within the firm, lack of finance from sources outside the firm, and lack of supporting finance. Second, the capacity factor (OTI2) includes lack of qualified personnel, lack of information on technologies and markets, difficulty in finding cooperative partners, and organisational rigidities within the firm. Third, the market factor (OTI3) indicates uncertain demand for innovative products or processes and oligopoly of dominant firms. Fourth, the institutional factor (OTI4) represents lack of infrastructure—regulations, standards, and taxation. Each variable is measured by a five-point Likert scale.

Furthermore, to analyse the precise effect of cooperation activities of the firm having OTI on innovation failure, this study considers several important control variables: firm size (SIZE), venture firm (VENT), government support (GOV), R&D intensity (RDI), and researcher intensity (RSI).

First, the firm size, a dummy variable, is classified into large-, middle-, and small-sized firms. The impact of a firm's size on its technological innovation capacity still remains controversial (Hsu and Hsueh, 2009). Larger firms relatively have advantages in monitoring and collecting information, benefiting from internal economies of scale (Steinherr and Huvencers, 1994). On the contrary, smaller firms are relatively flexible in their operation and are less bureaucratic, thereby achieving sometimes higher innovation performance (Santarelli and Piergiovanni, 1996). Whether the firm size has a positive or negative influence on the abandonment of innovation is hardly confirmed, but the variable deserves to be considered as a control variable.

Second, venture firms are regarded as firms focusing on conducting technological innovations or utilizing new technological knowledge (Cooper, 1981). This study sets up VENT as a binary variable, whether the firm is classified as a venture firm or not. Korea's venture firms manifest a relatively high rate of technological ability and growth, and thereby are supported preferentially by the government as a major target for investment. This study expects venture firms are different from other firms due to their own nature of intensive R&D activities.

Third, GOV of this study includes reduction of taxation, financial support, participation in a government R&D project, support and instruction of government-owned technology, provision of technology information, support of experts and training opportunities, purchase in public sector, and support of marketing. GOV was modified as a dummy variable whose value depends on whether or not the firm experienced any of these eight factors. According to Audretsch *et al.* (2002), the government supports stimulate the R&D investment of firms, and thus boost their commercialization. However, David *et al.* (2000) reported both advantages and disadvantages of government supports for industrial firms.

Fourth, a firm's RDI is measured by the ratio of its R&D investment to its sales, and represents the relative importance of technological innovation in the firm (Lin *et al.*, 2006). The intensity also reflects a firm's capability to develop technologies, and various studies have found a positive relationship between a firm's R&D intensity and performances (Zahra, 1996).

Fifth, RSI indicates the intensity of technological innovation in terms of researchers, and moreover represents an absorptive capacity to find or utilize technological knowledge from external sources (Cohen and Levinthal, 1989). In this study, a firm's RSI is measured by the ratio of the number of its R&D personnel to that of its total number of employees. Table 1 is a summary of the descriptive statistics of the variables above.

### 3.4 Regression Models

The equation of logistic regression for empirical analysis is as follows: Eq. (1) refers to the ratio of innovation failure,  $\pi_i$ , through the mean of the dependent variable,  $Z_i$ :

$$E(Z_i) = \pi_i = \frac{e^{\beta_0}}{1 + e^{\beta_0}} \quad (1)$$

In order to find an estimate that most suitably explains the odds ratio, Eq. (1) applies the maximum likelihood estimation; its logarithm is substituted in Eq. (2):

$$\log \left[ \frac{E(Z_i)}{1 - E(Z_i)} \right] = \log \left[ \frac{\pi_i}{1 - \pi_i} \right] = \beta_0 + \beta_{1a} \sum COOP + \beta_{2b} \sum OTI + \beta_{3c} \sum CTR \quad (2)$$

The modified left-logarithmic equation can be explained linearly, showing the odds ratio of to-fail innovation divided by the ratio of not-to-fail innovation. Eq. (3) describes it as:

$$P_i(Z_i) = \beta_0 + \beta_{1a} \sum COOP + \beta_{2b} \sum OTI + \beta_{3c} \sum CTR, \quad (3)$$

where  $Z_i$  refers to the failure of product and process innovations for  $i$ th firm,  $COOP$  is the R&D cooperation,

OTI is the obstacles to innovation, and CTR refers to the control variables. However, Eq. (3) does not include a variable that considers interaction between COOP and OTI; thereby, another equation, Eq. (4), is formulated:

$$P_i(Z_i) = \beta_0 + \beta_{1a} \sum COOP + \beta_{2b} \sum OTI + \beta_{3c} \sum (COOP \times OTI) + \beta_{4d} \sum CTR. \quad (4)$$

Eq. (4) includes an interaction term of the R&D cooperation and OTI for analysing the effect of the interaction on the FTI.

**Table 1.** Descriptive statistics

	Mean	SD
Product innovation	0.880	0.325
Failure of technological innovation	0.589	0.492
Vertical cooperation	0.157	0.364
Horizontal cooperation	0.121	0.326
Cooperation with research institute	0.255	0.436
Cost (OTI1)	1.362	1.221
Capacity (OTI2)	1.663	1.360
Market (OTI3)	1.616	1.441
Institution (OTI4)	1.327	1.421
Process innovation	0.698	0.459
Failure of technological innovation	0.354	0.478
Vertical cooperation	0.199	0.399
Horizontal cooperation	0.102	0.302
Cooperation with research institute	0.198	0.399
Cost (OTI1)	1.260	1.213
Capacity (OTI2)	1.412	1.340
Market (OTI3) <sup>a)</sup>	-	-
Institution (OTI4)	1.196	1.328
Large-sized firm	0.232	0.422
Medium-sized firm	0.382	0.486
Small-sized firm	0.386	0.487
Venture firm	0.540	0.499
Government support	0.344	0.475
R&D intensity	0.112 <sup>b)</sup>	0.481 <sup>b)</sup>
Researcher intensity	0.097 <sup>b)</sup>	0.099 <sup>b)</sup>

OTI: obstacles to technological innovation, SD: standard deviation.

<sup>a)</sup> Not included in the survey. <sup>b)</sup> Unit: %.

## 4. ECONOMETRIC RESULTS AND DISCUSSION

### 4.1 Basic Econometric Specification

This study conducts logistic regression based on the technological innovation-active firms that carried out technological innovation projects during the period. The logistic regression model could predict the ratio of incidence as a discontinuous variable. This study analyses the effects of interactions between the three types of R&D cooperation and the four types of OTI on the failure in terms of product and process innovations, respec-

tively.

Two models in the analysis of the failure of product and process innovations are considered in this study. Model 1 employs Eq. (3), and Model 2 employs Eq. (4) which contains interaction effects between the cooperation and the obstacles.

The results of the empirical analysis based on the two models are shown in Table 2. First, almost all the variables of R&D cooperation do not have significant effects on the failure. In addition, the cooperation with external research organizations has a significant and positive effect on the failure of process innovation in Model 1, however, is not related to the failure in Model 2.

Second, most of the OTIs have positive and significant impacts on the failure of the innovation. More specifically, in Model 1, while the cost and market factors have significantly positive effects on the failure of product innovation, the capacity factor has significant and positive effects on that of process innovation. Moreover, in Model 2, the capacity factor has positive and significant impacts on the failures of both product and process innovations. The market and institution factors have partially positive and significant effects on the failures.

Third, the interaction effects between the cooperation and the obstacles are various according to the types of cooperation and obstacles; however, one-third of the interaction variables have significant impacts on the failures of both product and process innovations. In addition, while a half of the significant variables represent positive effects, the other half negative effects.

Fourth, the coefficient of the firm size has significantly positive impacts on the failures, indicating that large firms are more likely to experience the innovation failure. However, this result requires careful understanding, i.e., it would be hardly concluded that larger firms are more likely to end in failure. The larger firms have more accumulated capacity, which can drive the success of their innovation (Bayona *et al.*, 2001; Frisch and Lukas, 2001). For the smaller firms, however, a single failure can trigger their bankruptcy, and they rarely decide to cooperate, preventing from the loss of their core competence (Narula, 2004). The result about SIZE indicates that more attempts at technological innovations lead to increased rates of both success and failure. In addition, the coefficients of VENT, GOV, RDI, and RSI are not significantly different from zero.

### 4.2 Discussion

The primary goal of this study is to investigate the interaction effects between the R&D cooperation and OTI on the failure of the innovation. In brief, the empirical analyses in this study suggest that the types of R&D cooperation affect the impacts of OTIs on the failure of the innovation. Table 3 sums up the results of the logistic regression analyses, especially focusing on the interaction effects on the failures.

**Table 2.** Regression results

	Product innovation		Process innovation	
	Model 1	Model 2	Model 1	Model 2
Constant	-0.537***	-0.497***	-1.857***	-1.874***
Cost (OTI1)	0.174**	0.056	0.126*	0.076
Capacity (OTI2)	0.135*	0.228***	0.316***	0.346***
Market (OTI3)	0.248***	0.202***		
Institution (OTI4)	-0.109	-0.052	0.131*	0.187**
Vertical cooperation (VC)	-0.143	-0.077	-0.160	-0.070
Horizontal cooperation (HC)	-0.050	-0.360	-0.014	0.288
Cooperation with research institute (RC)	0.097	0.193	0.523***	0.346
OTI1×VC		-0.279		-0.503**
OTI1×HC		0.296		0.054
OTI1×RC		0.528**		0.621***
OTI2×VC		-0.124		-0.126
OTI2×HC		-0.295		0.032
OTI2×RC		-0.018		0.050
OTI3×VC		0.262		
OTI3×HC		0.673***		
OTI3×RC		-0.509**		
OTI4×VC		-0.010		0.602***
OTI4×HC		-0.459**		-0.306
OTI4×RC		0.097		-0.556***
Large-sized firm	0.433**	0.398**	0.579***	0.567***
Medium-sized firm	0.219	0.184	0.100	0.085
Small-sized firm				
Venture firm	0.058	0.027	-0.087	-0.122
Government support	0.058	0.081	0.228	0.220
R&D intensity	-0.534	-0.545	0.578	0.584
Researcher intensity	0.255	0.172	0.253	0.110
-2 Log likelihood	1600.0	1570.7	1442.6	1425.7
Chi-square	94.3	123.6	183.6	200.5

OTI: obstacles to technological innovation.

\*\*\*, \*\*, and \* denote significance at the 0.01, 0.05, and 0.1 levels, respectively.

**Table 3.** Summary of the interacting effects

	Cost (OTI1)	Capacity (OTI2)	Market (OTI3)	Institution (OTI4)
Product innovation				
Vertical cooperation				
Horizontal cooperation			(+)	(-)
Cooperation with research institute	(+)		(-)	
Process innovation				
Vertical cooperation	(-)			(+)
Horizontal cooperation				
Cooperation with research institute	(+)			(-)

OTI: obstacles to technological innovation, (+): positive effects on the failure, (-): negative effects on the failure.

In the perspective of the OTI, the statistical analyses found that the obstacles have various but direct impacts on the failure of the innovation (Hypothesis 1).

More specifically, the lack of firm capacity has significant impact on the FTI, and the obstacle regarding the market turned out to have a detrimental effect on the

technological innovation. Furthermore, it is interesting to note that while the possibility of failure of product innovation changes mainly according to the market factor, the probability of failure of process innovation fluctuates mostly according to the institution factor.

The empirical analyses indicate that the R&D cooperation has no significant relationship with the FTI (Hypothesis 2). In Model 1 for the process innovation, the cooperation with research organisations is found to raise the possibility of the failure, and the result implies that such cooperation is more likely to hamper successful performances in process innovations. Nevertheless, in Model 2, the same coefficient is not significant. Moreover, all other coefficients regarding the cooperation are not significant. This result implies that there are no remarkable relationships between the R&D cooperation and the failure, and it strongly supports Hypothesis 2 that cooperation would have no direct effects on the FTI.

These effects of the cooperation and the obstacles on the failure provide an important base to formulate technological innovation strategies. Nevertheless, the effects of individual factors hardly provide practically required implications for the strategies. It is due to the distinct environments which the firms face and moreover multiple factors' interaction in a simultaneous manner in reality. Therefore, the focus of this study is on the impacts of the interaction on the FTI.

It is found that the interaction effects of the cooperation and the obstacles on FTI are various depending on the combinations of the two sets of factors (Hypothesis 3). More specifically, first, it could be favourable that the firm encountering cost-related problems reconsiders to continue its cooperation with research organizations, and the focuses especially on vertical cooperation in process innovation can boost the possibility of innovation success. In turn, avoiding cooperation with research organizations and enhancing vertical cooperation for the process innovation in the event of cost escalation is advantageous for the firm.

The research organizations relatively pursue the development of basic and core technologies. Such activities of the research organizations have a propensity to entail high risk, a long period of commercialization, and high investment costs resulting from serial trial-and-errors. Hence, when a firm suffers financial problems, the follower strategy rather than the first-mover strategy by entering the market relatively late in terms of the product life-cycle and catching up with the first-mover could be effective for success of technological innovation and its commercialization. Moreover, in the case of process innovation, a firm suffering financial problems is advised to pursue vertical cooperation in order to reduce production costs and share technology-related information.

Second, in the case of a lack of firm capacity, the result represents that the selection of the types of cooperation itself does not impact on the FTI. An effective

way for a firm to succeed under such circumstances is to make an effort to generate core competencies before searching for and selecting cooperative partners. Regarding the capacity factor includes the difficulty in finding cooperative partners and organizational rigidities within the firm. One possible implication is that searching for cooperation partners is hard for firms that do not have considerable capacity. Another possibility is that a rigid organization struggles even to find cooperative partners; this impedes the technological innovation in the course of R&D cooperation due to some problems such as communication.

Third, market-related obstacles exist only in the product innovation. Under this kind of environment, it is favourable to avoid horizontal cooperation and to cooperate with research organizations. If a firm encounters market-related obstacles, its competitors could severely restrict the firm's activities in the market, by dominating the market share. The solution for overcoming the market-related OTI can be acquired from external research organizations beyond the concerned market or industry. The research organizations such as government-funded institutes could have relatively low commercialization capabilities; however, they are more likely to access to core technologies, which could be the key sources of firms' competence. In turn, a firm can make practical use of cooperation with R&D organizations as a means to develop a core competence through the transfer of valuable technologies as a result of such cooperation.

Fourth, the product innovation-active firms facing institutional obstacles are recommended to cooperate with horizontal partners; however, the process innovation-active firms need to cooperate with external research institutes, avoiding the vertical cooperation. Firms facing institution-related obstacles endure a lack of infrastructure or unfavourable institutions such as legislation, regulation, standards, and taxation. The product innovation-active firms under these environments could cooperate with their competitors in the same industry to share technological innovation-related infrastructure the competitors have already installed and to search for measures to cope with unsupportive institutions. Meanwhile, the process innovation-active firms facing the institution-related obstacle are advised to cooperate with external R&D organizations to acquire technological knowledge or knowhow in lieu of cooperating with business partners within the supply chain.

## 5. CONCLUSION

This study has reported the results of empirical analyses on multi-dimensional determinants of the FTI of Korea's manufacturing firms in 2005–2007. These findings should be understood in view of the limited samples analysed and the reliance on documentary sources. Nevertheless, this study contributes to the following three areas of technological innovation research:



failure of the innovation, environments of R&D cooperation, and impacts of the cooperation and environments on the failure.

First, this study focused on FTI among numerous performance indicators of the innovation. The analyses on the determinants of the failures provided distinct implications to firms' strategies, and contributed to advancing the firms' future potential performance through what they learn from the failures.

Second, this study considered the unfavourable environments, i.e., OTI. Although numerous studies investigated the cooperation and performances of firms, most of them did not consider the negative environments regarding technological innovation. Moreover, unfavourable environments rather than favourable ones would bring about failures. The findings related to the obstacles would be a valuable reference for formulation of cooperative strategies.

Third, this study also found that the interaction between the obstacles and the cooperation has an influence on failures in various manners. This finding strongly supports the importance of considering the environmental factors as well as the internally controllable factors, for formulating more precise and practical cooperation strategies. Furthermore, this study is expected to help the firms operating in distinct environments to successfully position their strategies in their industry based on what they learn from their failures.

The limitations of this study provide some directions for further studies. First, the advantageous environments as well as the unfavourable ones would be significant determinants of innovation failure. Second, although this study considered the discrete performance indicators, continuous indicators may provide different implications. Third, the future research needs to analyse more subdivided factors with a bigger sample size. Fourth, the results of determinants of innovation failure in this study may differ with time. Dynamic analyses on the issue can provide more fruitful implications for innovation strategies.

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