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HANADA, Shoko
Chuo University

IKEDA, Yuya
NISTEP

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Determinants of staged project management and success in innovation: Empirical analysis based on the Japanese National Innovation Survey*

Shoko HANEDA†

Faculty of Commerce, Chuo University

Yuya IKEDA‡

First Theory-Oriented Research Group, National Institute of Science and Technology Policy, MEXT

Abstract

This empirical study examines the impact of a staged approach to management of innovation projects. This approach incorporates the threat of termination at each stage of the product development process. Under these conditions, the present study identifies firms that have abandoned and/or still have ongoing projects using a unique firm-level dataset constructed from the 2015 Japanese National Innovation Survey (J-NIS2015). Combining J-NIS with a firm-level accounting and credit information dataset, the study explores the determinants and the effects of staging of innovation processes. The study results show that R&D-intensive firms with broad collaboration and a lower debt ratio are more likely to adopt a staged approach in the product development process. Success in innovation is measured by the propensity of a firm to produce innovative products (or processes) and the ratio of innovative product sales to the total sales. Additionally, the study compared firms that did not implement staging of projects to those that employed staged project management and found that staging significantly improved innovation performance and increased the degree of radicalness.

Keywords: staged project management, real option, Innovation Survey, Japan

JEL classification: D22, L10, L40, O31, O32

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† Faculty of Commerce, Chuo University, 742-1 Higashinakano, Hachioji-shi, Tokyo 192-0393, Japan. Email: shaneda@tamacc.chuo-u.ac.jp

‡ First Theory-Oriented Research Group, National Institute of Science and Technology Policy (NISTEP), MEXT. Email: y-ikeda@nistep.go.jp

1. Introduction

Innovation has been recognized as key to economic development and growth of firms. Therefore, policy makers and enterprises constantly seek methods to promote innovation. Holmstrom (1989) states that innovation is characterized by high risk of failure, unpredictability, path dependency, and unforeseen contingencies. Given these characteristics of innovation, several studies focus on how to successfully organize and manage innovation (Souder et al., 1998; Story et al., 2001; Tidd and Bodley, 2002).

Manso (2011) presents a model of the innovation process and the trade-off between radical and incremental innovation. The study also shows that optimal compensation schemes for managers motivate them to not only innovate but also exhibit tolerance for early failures and reward for long-term success. The study by Manso (2011) has implications for human resource management as well as for managing the innovation process. The results suggest a need for early feedback on performance. However, the effects of the threat of termination on incentives for radical innovation are ambiguous. In the present study, the threat of termination refers as to “stopping investment” on the projects. This threat discourages researchers from exploring new actions, indicating a negative relationship between the threat of termination and radical innovation.

By contrast, studies on venture capital stage financing reveal how a threat of termination is positively associated with successful economic outcome (Gompers, 1995; Bergemann and Hege, 1998; Fluck et al, 2005). When projects are managed in stages, there is less uncertainty of technological and commercial feasibility if the project were to successfully progress to the subsequent stage. This implies that staging increases the value of the real option of the project. Dahiya and Ray (2012) show that staged investment filters good projects from the bad by giving managers the option of terminating projects with low early returns. Managers can invest more in the later stages of the development process where there is no uncertainty and the expected profits increase. In reality, the later stage of the process typically costs more than the initial stage because of several aspects, such as, constructing a pilot plant, conducting market research, and testing the market. Therefore, the retained projects are viable, suggesting that staged project management leads to higher innovation success.

Although theoretical and empirical studies explore the mechanisms of innovation underlying management decisions and the condition under which an organization can encourage radical innovation, there is scant research on organization management related to R&D. Therefore, the present study empirically examines the relationship between research project management and innovation success. For the analysis, we use firm-level data obtained from the Japanese National Innovation Survey conducted by the Ministry of Education, Culture, Sports, Science and Technology in 2015 (J-NIS2015). This survey is the Japanese equivalent of the Community

Innovation Surveys (CIS) conducted by the Europe Union. These survey data help in understanding staged project management of innovation using information on project abandonment or continuation.

Two types of innovation can be defined, namely, new-to-firm innovation, which is defined as the successful introduction of new goods or services within the firm (i.e., incremental innovation), and new-to-market innovation, which is defined as the successful introduction of new goods or services within the market or as the successful implementation of new development processes or delivery methods within the market (i.e., radical innovation). Moreover, when considering innovation output in terms of the sales volume generated by these two types of product innovations, the quantitative relevance of innovations can be generated. Combining firm-level accounting data with J-NIS2015, the factors that account for the difference in the implementation of staged management for innovation are considered.

The study results reveal the following. First, R&D-intensive firms with a low debt ratio and those using various external information sources are more likely to manage projects in stages. Firms adopting a staged development process use additional financial, physical, and external information resources. Firms with higher debt ratio may avoid project abandonment or reduce the total number of projects that potentially lead to new products; that is, financial constraints dissuade a firm from exploring new untested actions. In addition, the result suggests that firms collaborating with diverse partners from various regions may use external knowledge and information to filter the good projects from bad.

Second, compared to firms that do not manage development process in staging, firms engaging in staged management are likely to achieve higher propensity to innovate as well as larger sales volume of innovation products. The study result also confirms that firms that implement staging of innovation process increase their sales turnover of highly innovative goods or services similar to that of incremental innovation, suggesting that the threat of termination on product development process encourages more radical product innovation.

This paper is also related to several strands of literature, such as papers that examine the link between project abandonment and innovation success. There is some quantitative evidence for the association of the cost/benefit and collaboration for innovation, suggesting that more novel projects are mutually associated with a higher “failure,” that is, project abandonment or delay, in innovation activities (for example, Guzzini and Iacobucci, 2017; Kobarg et al., 2019). Following the theory of real options decision making on the staged project management, the present study extends further to the explanation on why firms with project failure can achieve higher sales generated by innovation.

Section 2 of this study provides a literature survey and presents the empirical hypotheses. Section 3 explains the data, key variables, and the empirical strategy. Section 4 presents the empirical results. Finally, Section 5 concludes.

2. Empirical Hypotheses and Literature Review

2.1 Staged project management and innovation radicalness

Staged innovation process is widely used to manage financial and physical resources for projects, including stages of ideation of new products or processes. The basic premise of staging is that projects only advance to the subsequent stages if there is justification for the risk involved in the next stage (Block and MacMillan, 1993). The justification, including the interim performance or action at each stage, is subsequently examined to decide whether to terminate or continue investing in the ongoing projects based on the milestones or metrics corresponding to the stage.

Manso (2011) theoretically examines the nature of contracts that promote radical innovation, based on the notion that the product development process involves several steps. In particular, the theory highlights the effects of feedback on performance, commitment to long-term contracts, and the threat of project termination. Manso (2011) shows the effectiveness of the combination of tolerance for early failure and reward for long-term success for motivating radical innovation. Feedback on interim performance should guide adjustments and improvement in the research performance. Meanwhile, threat of termination of finance discourages researchers from shirking or exploring new actions; thus, it can undermine the incentives for radical innovation but foster incremental innovation. In a laboratory experiment, Ederer and Manso (2013) provide new evidence that the threat of termination with the golden parachute, such as cash bonuses and generous severance pay, can alleviate effects that hinder innovation.

Literature on venture capital (VC) stage financing also discuss the staging of projects and innovation radicalness. The staging of capital infusion by VC refers to the stepwise disbursement of capital to entrepreneurial firms. Gompers (1995) finds that VC staging occurs more frequently in industries with greater intangible assets, a higher market-to-book ratio, and intensive R&D activities. The VC withholds investment in the early stages owing to the uncertainty. In particular, the VC sets a milestone at the first stage. If the project successfully clears this milestone, then the VC is convinced of the project's viability and, therefore, invests more in the subsequent stages.

Several studies opine that stage financing allows a VC investor to learn about the entrepreneurial firm over financing, referred to as the learning hypothesis (e.g., Bergemann and Hege, 1998; Fluck et al., 2005). Dahiya and Ray (2012) theoretically and statistically show that the threat of termination is effective in screening projects and encouraging radical innovation compared with cases of upfront financing. The results suggest that staging creates value by generating a real option for the VC investor to terminate financing the project at each stage, depending on the VC investor's learning between each stage about the venture or the entrepreneur.

Applying this theory to R&D and innovation projects, an R&D manager provides financial and physical resources to the projects that bind each resource to the point at which information is revealed about the quality of the project. This staged allocation builds real options by matching the amount of investment raised in each stage to the specific uncertainty that needs to be resolved with that stage of investment, for example, that of technological and commercial feasibilities (Kerr et al., 2014). Staging allows organizations to abandon projects with low early returns and, thus, filter good projects from bad. The ability to terminate projects when the intermediate information is negative prompts organizations to start projects that are more experimental in nature.

The production process that provides the option of abandoning or continuing ongoing projects based on the milestone has been adopted in both manufacturing and nonmanufacturing firms. A Product Development Management Association survey shows that 60% of the firms in practice adopt staged management in the product development process (Schilling, 2013). In a case study in Japan, Nishimura (2007) claims that over 90% of research institutes manage product development process and the funds by monitoring interim performance, not specified in staging, based on a series of criteria such as cost/benefit, fit with competencies, and technical feasibility.

With regard to the threat of termination in the staged development process, the issue of whether the staged approach encourages or discourages innovative outputs is ambiguous. Quantitative results underlying organizational studies indicate that trial-and-error learning aspects encourage radical innovation. For example, MacCormack et al. (2001) examine the characteristics of an effective production process in 29 development projects and find that a more flexible development process is associated with better-performing projects. In a study of 120 development projects in staged procedures, Sethi and Iqbal (2008) find a negative relationship between rigorous predetermined criteria and project flexibility. Although the sample size was small, the results may suggest that an explicit milestone possibly reduces the total number of radical innovation projects not only through screening in the earlier stages but also by discouraging incentives for innovation.

Few empirical studies of staged project management and innovation focus on large-scale firm-level databases, except the study by Andries and Hunemund (2014). They examine the relationship between staged project management and firm performance using the survey item on upfront financing for innovation projects at the beginning of a project or in stages based on Manheim Innovation Panel (MIP) for 2009 and 2011. These surveys indicate that 62% of the firms adopted staged management of innovation projects. The results show that implementing staged financing is positively associated with incremental innovation but not radical innovation.

Based on the arguments and findings on the staging of innovation projects earlier, the following hypotheses regarding the relationship between the project censoring and innovation success are drawn:

Hypothesis 1 Firms implementing in staged project management show better innovation performance than firms that do not.

Hypothesis 2 Firms implementing in staged project management have a larger amount of sales on radical innovations than on incremental innovations.

Hypothesis 3 Firms implementing in staged project management have a larger amount of sales on incremental innovations than on radical innovations.

2.2 Determinants of staged project management

Staging procedures act as screening tools for managers to terminate projects. Organizations that launch more than one project simultaneously are more likely to apply the staged approach in the development process. The decisions to invest further or terminate the project are often made by managers, whose actions are influenced by myriad problems of incentive, agency, and coordination. Therefore, the extent to which the best idea moves forward may depend on factors such as the organizational structure or the firm's incentive system where the investor is based, the available information set, and other such frictions (Kerr et al., 2014). In addition, the interim milestone at each stage of the development process is notably associated with not only the go/not-go decision but also the number of potentially promising projects. Cooper and Edgett (2007) contend that managers can be flexible in their control of research performance because the milestone or metrics, including both financial and nonfinancial information, are represented at every round. If the goal is to explore new methods, the research organization will appropriately adjust its milestone to perform better by utilizing what one learns from external organizations.

Given these characteristics of staging, the present study focuses on the factors that are likely to affect managing for innovation: (1) total number of projects at the start, (2) research-friendly organizational culture, and (3) sourcing of external knowledge for milestone. The remainder of this subsection reviews the findings of past empirical studies related to these factors. Studies showing the determinants of staged management projects are fairly scarce. Thus, there is much obscurity regarding the significant impact of those factors on implementing staging project management.

First, preferences for implementation in staged project management is dependent on firm size, reflecting the firm's access to finance, sales economies, and differences in the work organization. It is common that large firms may find it difficult to abandon projects before the termination even in case of infeasible projects, owing to the career concerns of the R&D managers in charge of the effort (Kerr et al., 2014). Conversely, large firms, including IBM, Procter & Gamble, 3M, General Motors, and Corning, run numerous concurrent projects using abundant resources

(Schilling, 2013), reducing the time to development and increasing the proportion of technically and commercially viable products. The study assumes a positive relationship between the staged approach for managing innovation project and firm size.

Higher debt ratio also impacts the total number of potentially viable projects. Owing to the intangible nature, uncertain outcome, and asymmetric information, R&D-driven firms find it difficult to use external finance (Brealey and Myers, 1996; Czanitzki and Kraft, 2009). Under tight budget constraints, research organizations might reduce the number of potentially viable projects at their earlier stages. Andries and Hunermund (2014), who use credit rating index for German firms as a proxy for availability of financial resources, found that initially constrained firms reduce the number of projects when adopting staged project management.

A topic that has received considerable attention is the role of organizational research culture represented by ownership structure and founders' social capital. Agency problems arising from information asymmetries between managers and owners negatively affect R&D investment decision (Ortega-Argil'es et al., 2005). Therefore, effective monitoring and in-depth understanding of the firm's business and its underlying process reduce the information asymmetries between the owners and managers. Resource allocation to innovation projects is also influenced by the firm's ownership structure (Miller and Le Breton-Miller, 2005). However, studies on ownership structure and innovation have produced mixed results. While some studies show that family firms commit more resources to investment activities than nonfamily firms, other studies on the underlying perspective of risk preference highlight that family firms commit fewer financial resources to long-term investment activities. Statistical studies (Anderson et al., 2012; Block, 2012) show that family-owned firms seek to reduce the risk levels by committing fewer resources to R&D projects.

Several studies empirically examine the link between top management team and innovation. With regard to innovation, Balsmeier and Buchwald (2015) argue that top management experience is critical to a firm's innovation strategy, because it enhances the understanding of the process involved. Kaiser et al. (2018) used a variable of the ratio of top management team experienced in scientific research and suggested that research-friendly organizations are able to apply patents of highly cited research by hiring individuals with university research experience. Chemmanur et al. (2018) find that managers with a postdoctoral degree are more likely to allocate resources to innovative projects. Results suggest that those managers accept uncertain product viability, which potentially increases the amount of sales generated by innovation, while they have more experience on the project termination. Although extant literature explains the importance of a research-friendly organization for innovation, few highlight the underlying theory. A positive relationship is assumed to exist between these variables and the staging approach. However, no research confirms the relationship.

Cooperation with other enterprises and institutions for innovation is another managerial dimension. Extensive literature shows that collaboration in innovation projects improves the innovation performance of firms (e.g., Kobarg et al., 2019; Du et al., 2014; Grimpe and Sofka, 2016; Aschhoff and Schmidt; 2008). Other organizations may have superior information on cutting-edge technology, consumer attitudes, and market potential of new products than the company's R&D personnel. Based on the dataset of concept and development phases in the innovation process, D'Este et al. (2016) argue that external knowledge is crucial for a firm across all stages in the innovation process. These findings suggest that collaboration with other organizations will be beneficial advantageous as innovation partners seek broader information when deciding to stop or hold projects. Additionally, it might produce alternative innovation projects.

3. Data, Variables, and Empirical Approach

3.1 Data and sample selection

The present study uses firm-level data obtained from J-NIS2015.[1] The survey is based on the Oslo Manual and provides extensive information on firms' innovation activities and their outcomes, such as the sale of innovative, novel products. In 2015, questionnaires were sent out to 24,825 firms (10 or more employees); of which, 12,526 (50%) firms responded. J-NIS2015 includes the up-to-date information on innovation activities for Japanese firms in addition to a largest realized sample size that is available for academic purposes.[2] Therefore, J-NIS2015 data is useful for constructing the present study data set to identify the relationship between staging approach on the product development process and characteristics of the firms.

Savignac (2008) and Hall et al. (2016) state that, although questionnaire (self-reported) data represents an important source of additional information, such data are biased from interpretation. The present study combines the J-NIS2015 with the company database compiled by a major credit investigation company in Japan, Tokyo Shoko Research (TSR). TSR database includes

[1] J-NIS was conducted in 2003, 2009, 2012, and 2015. Each survey is considerably different in terms of sample size and size distribution of responding firms. Moreover, the questions and the choices provided for answers were also quite different, although all the surveys are based on the Oslo Manual. We could try to construct a panel consisting of firms. However, unfortunately, there are very few such firms so that we do not have a sufficient number of observations. In the 2003 survey, 19% of the firms that answered were large firms (250 or more employees), while in the 2009 survey 48% were large firms. In a similar way, in 2013 survey, 20% were large firms, while in the 2015 survey 9% were large firms.

[2] In the 2003 survey, the questionnaire was sent out to 43,174 firms, and 9,257 firms answered (for a response rate of 21%). As for the 2009 survey, the questionnaire was sent out to 15,137 firms, and 4,579 firms answered (for a response rate of 30%). As for the 2012 survey, the questionnaire was sent out to 20,405 firms, and 7,034 firms answered (for a response rate of 35%).

accounting data, information of the top five shareholders, detailed information on CEOs, and supplier and seller networks within firms. TSR database provides the names of supplier and customer firms as well as their individual company codes. Therefore, it is easier to identify each firm and connect to his/her basic information.

Figure 1 shows the multilayer structure of the J-NIS questionnaire. Only firms reportedly engaged in innovation activities are categorized as *Innovation-active firms* (Savignac, 2008; D'Este et al., 2012), which were asked to complete the entire questionnaire. Innovation-active firms were those that answered they had developed new or changed the product or process, or that they have an experience with abandonment of innovation projects, or that they have incomplete or currently ongoing projects in the preceding three years. On including 3,524 innovation-active firms from the 2015 survey with the TRS data, 1,693 firms were included in the present study and excluded firms with a negative debt ratio to total assets. Consequently, the present empirical study included 1,468 observations obtained from firm-level fundamental information, accounting information, and information on business networks from the TSR database. Table 1 provides the number of firms by industry. From the detailed (3-digis level) industry information available, the study classifies firms into 11 manufacturing and 7 nonmanufacturing industries. The cross-section data include 727 manufacturing (49.5%) and 741 nonmanufacturing industries (50.5%).

INSERT Figure 1

INSERT Table 1

3.2 Key variables

The key variables in this research represent the staging of innovation project. The J-NIS2015 questionnaire included two items on activities that were abandoned before completion during the preceding three years and/or activities that were still ongoing at the end of 2014. In the study dataset, 686 firms (46.7%) out of 1,468 firms had successfully completed projects without experiencing abandonment or kept ongoing projects (*Successfully complete* in Fig.1). A total of 191 firms (13%) had experienced abandoned innovation activities prior to completion (*Abandoned* in Fig.1), 743 firms (50.6%) had still ongoing projects at the end of the targeted year (*Still ongoing* in Fig.1), and 152 firms (19.4%) out of 782 firms (=1,468–686) had activities abandoned as well as still ongoing activities, respectively.

In the J-NIS, there is no detailed information on each project, represented interim milestone, the number of innovation projects engaged by the firm, those abandoned, and the stage at which some of them were abandoned. However, there is available information on whether a firm abandons at least one innovation project before the completion, and whether a firm has still ongoing projects at the end of targeted year on questions 7(a) and (b) of the J-NIS2015. We infer that firms engaged in the staging of innovation projects have more opportunities to make a decision about whether to abandon or hold still ongoing projects, which might account for the positive relationship between innovation and project abandonment or continuity.

Firms dragging a project for a long term, without referring to interim milestone, might be more inclined to hold on to the ongoing projects. Furthermore, project abandonment or continuation could depend on the product development process that is unique to the industry or firm characteristics. For example, firms producing life science products such as pharmaceutical and biologicals are well known as applying the "screening funnel" process to mitigate investment risk on clinical testing or regulatory approval (Soenksen and Yazdi, 2017). Substantial additional resources required to complete product development and commercialization differ among industries and firms, therefore, not all firms would impose necessary metrics to confirm market potential.

However, there is a promising explanation for the link between project abandonment or continuation and staging of innovation projects. MIP for 2009 and 2011 contains survey items on the total number of innovation projects a firm has initiated in the last three years as well as on a lump-sum funding for innovation projects at the beginning of a project in stages, indicating that 63.4% of the full sample is implemented in the staged process. Andries and Hunermund (2017) use these survey items and find that a staged approach impacts the likelihood of abandoning projects with a marginal impact of 0.69. Moreover, the study by Andries and Hunermund (2014) confirms that staged project management has a positive and significant effect on the project abandonment or continuity, whereas such a management approach has a negative and significant effect on the project successfully completed by the end the sample periods.

Although a few studies have empirically examined the relationship between staged project management and project abandonment or continuity using CIS, the present study follows their results and employs a binary variable as a proxy for staging approach, which takes the value of 1 if a firm experienced project abandonment or held on to ongoing projects during the study periods.

3.3 Empirical approach

3.3.1 Determinants of implementing in staged project management

First, a probit model is estimated to observe the determinants on a new product development process. The probit model assumes that there exists an underlying relationship, $y_i^* = X_i\beta + u_i$, where $u_i \sim N(0,1)$. Here y_i^* is a latent variable for firm i measuring the likelihood of applying staged project management on new product development process, where X_i is a vector of firm characteristics including firm size, financial conditions, and the extent of external resources used for innovation. The corresponding observed variable y_i is a binary variable, which assume a value of 1 for firms that have adopted a staging approach in innovation and 0 otherwise:

$$y_i = (y_i^* > 0)$$

Table 2 presents a list of the variables, along their definition and sources, used in the following analysis. Appendix Table 1 reports correlation coefficients for all the variables.

INSERT Table 2

We include firm size as measured by the log of the number of employees in 2012. Furthermore, we include debt financing ratio, defined as debt finance divided by total finance, as a proxy for the firm's capital structure. Debt includes numerous separate accounting items, including bills payable, accounts payable, and loans payable, and not all of these fit the concept of debt finance from capital markets. Shareholders' equity includes retained earnings related to cash flow, and these accounting items do not fit the concept of equity financing from capital markets as well. Therefore, we extract information on debt and equity finance directly from the financial statements[3].

Two binary variables are taken as proxies for insider or outsider ownership structure, i.e., financial institutions or family members of founders. Financial institution is a binary variable that takes the value of 1 for a firm where trust and banking companies and insurance companies are listed in the top five shareholders. Similarly, another binary variable is constructed that takes the value of 1 for those firms with families of the founder. Moreover, as proxies for founder's social capital, two types of variables are used, indicating whether the firm's founder holds a university or postgraduate degree, taking the value of 1 for the firms with these types of founders, respectively.

As a proxy for sourcing of external knowledge, the study uses the logarithm of the number of geographical reasons for which a respective firm collaborated with a specific partner type, following studies measuring the diversity of external knowledge (Terjesen and Patel, 2017; Chapman et al., 2018; Kobarg et al., 2019; Tsinopoulos et al., 2019). The study uses the information on project collaboration activity indicated by the responding firms on a matrix with the dimensions on seven types and nine geographical areas of the partners. For each country,

[3] In this study, debt finance is defined as the sum of short- and long-term loans payable, corporate bonds, and commercial paper. Equity finance is defined as the sum of paid-in capital, deposits for subscriptions to shares, additional paid-in capital, share warrants, and convertible bonds. Additionally, total finance (capital) is defined as debt finance plus equity finance, and debt finance ratio as the debt finance divided by total finance.

firms indicated whether they had collaborated and the type of partner. Based on these data, a broad search was made as a measure of the overall number of partner types with which the firm collaborated in countries or regions, where the value could range between 0 and 63 (63 implies firms cooperating with all seven partner types in all nine regions/countries).

As another proxy for external knowledge sourcing, the study uses supplier/seller networks variables to indicate the possible spillover of industry-specific information and not through collaboration for innovation. Variables indicating the size and quality of the firm's business networks are considered. For each firm i in industry j, we identify its main suppliers s_k^0 and customers c_k^0 up to a maximum of 20 $(k = 1,2, \ldots, 20)$. We also identify supplier s_l^1 and customer c_l^1, where $(l = 1, 2, \ldots, 20)$. Then the following ratio is calculated:

$$Supplier\ info_{ik} = \frac{Number\ of\ s_l^1\ and\ c_l^1\ in\ industry\ j}{Number\ of\ total\ suppliers\ and\ customers\ for\ s_k^0}$$

Then, we consider the sum of all $supplier\ info_{ik} = \sum_k supplier\ info_{ik}$.

Additionally, various other variables presenting firm characteristics in the estimation are included. We include the logarithm of the number of markets supplied by the firm as a proxy for the range of their activities. Intensity of R&D, measured as the logarithm of the ratio of R&D expenditure to total sales, is a proxy for a firm's innovation inputs. ROA is defined as return on assets (i.e., net operating income before depreciation) divided by the book value of assets, indicating the profitability of a firm to control firm-level accounting profitability. Industry-specific factors such as industry-targeted technology policy, technological characteristics, and competitive pressures must be considered as well. These factors are controlled by including industry dummies.

Table 3 presents the overall means of the variables used in the present econometric analysis. Two categories of firms are compared: those that manage projects in staging and those that do not. Making univariate comparisons between the categories, it is found that firms adopting staging of innovation projects have a larger number of employees, a wider range of product market, higher R&D intensity, a large extent of innovation partners, and lower debt ratio to equity finance. Meanwhile, majority of the variables indicating the financial conditions and ownership structure do not exhibit a significant difference between the categories. As an outcome of innovation, firms adopting staged management are expected to be more likely to innovate products or processes and achieve larger sales volumes from innovative products.

INSERT Table 3

3.3.2 The effects of the staging approach: Treatment effect estimation

To test Hypotheses 1-3, the propensity-score matching (PSM) estimation [4] proposed by Rosenbaum and Rubin (1983) is used. By matching treatment firms (i.e., firms that apply the staging approach in innovation) with the appropriate control firms (i.e., firms that do not apply such an approach) having the "closest" propensity scores, which are estimated based on the probit estimation in the previous subsection, a sample that is assumed to be sufficiently similar to the one generated by randomization is created. Among the several matching algorithms used to find the "closest" control observations, the nearest-neighbor matching estimators are employed, and the nearest-neighbor matching within the specified propensity-score calipers of 0.03 deviations are specified. In other words, we match each firm implementing staged project management in innovation with the most similar firms in the control group that do not apply staged approach.

The present study considers two types of variables representing the technological superiority of products or processes, namely, new-to-market innovation and new-to-firm innovation. On the basis of the J-NIS2015, we identify whether a firm introduces new or significantly improved goods or services targeted for the market during the preceding three years. Similarly, we identify whether a firm implements new or significantly improved production processes or delivery methods targeted for the market during the preceding three years. Therefore, this study uses these two types of new-to-market innovation variables as proxies for radical innovation. We also identify whether a firm implements new or significantly improved goods or services but only those that are not new to the market during the preceding three years. The study also refers to new-to-firm products as incremental innovations[5].

Panel (c) in Table 2 shows the definition of measurements of innovation outcomes. New-to-firm products are binary variables that take the value of 1 for firms developing new-to-firm goods or services but only those that are not new to the market. New-to-market products (or processes) are also considered as binary variables that take the value of 1 for the respective firms similarly.

[4] Constructing a valid proxy for the counterfactual situation, difference-in-difference estimators, control function approaches (selection models), instrumental variable estimations, and matching techniques are used. For our cross-section dataset, we adopt a selection model but we do not obtain significant estimation results when we limit our sample to innovation-active firms only. We also tried to find appropriate, effective instrument variables that have an effect on innovation outcome but do not have an effect on a development procedure. However, the test of over-identifying restrictions indicated that our instrumental variables were likely to be correlated with the error terms.

[5] On the basis of the J-NIS2015 data, we identify whether a firm introduces new-to-firm products, but does not identify whether a firm implements new-to-firm processes. Due to the data limitation, we use new-to-firm product innovation only as a proxy for incremental innovation.

To display the robustness of the study results, we also employ alternative measurements that indicate the significance of new products in the market. As indicators of the magnitude or importance of highly innovative goods or services, we employ the share of new-to-market products in turnover introduced by the firm in the preceding three years. Additionally, we assume the sales ratio of new-to-firm products as another variable, explaining the magnitude of incremental innovation.

After matching the firms, we measure the average causal effect (average treatment effect of the treated group, ATT) of a binary variable (the treatment) on the outcome variable. ATT is defined as

$$\text{ATT} = \text{E}(Y_1 - Y_0 \mid staging = 1) = E(Y_1 \mid staging = 1) - E(Y_0 \mid staging = 0)$$

where $Y_1|staging = 1$ represents the realized innovation outcome for a firm managing development process in staging, and $Y_0|staging = 0$ represents the counterfactual outcome for the same firm if it had not applied staging approach of innovation projects.

4. Estimation Results

4.1 Probit estimation

The results of the probit estimation are presented. These examine the factors determining implementation of staged project management. Table 4 presents the marginal effects as the means of the explanatory variables based on the probit estimation results. Additionally, confirming the robustness of the likelihood on firms' applying the staged approach to their project management, we examine the determinants by using the three types of subsamples in a given sample. J-NIS does not contain survey items on the total number of projects that a firm had initiated during the sample periods nor staged funding that a firm adopted in the development process. Since there is no clear validation to judge which of the firms managed projects in staging, the robustness should be verified using the subsample of firms that are less likely to apply the staged approach.

Subsample 1 consisted of firms that have continuous projects but did not abandon any projects during the past three years or those that experienced project abandonment but do not hold on to the ongoing projects. This is done because we cannot identify whether those firms manage more than one project at the same time. Subsample 2 consisted of firms other than those in the pharmaceutical industry because pharmaceutical firms are promisingly managing the development process in staging. Subsample 3 consisted of small and medium sized firms that are not identified in relation to whether they are required to represent interim milestones to confirm market potential.

The study results reveal that firm size, breadth of collaboration, family ownership, and intensity of R&D have a positive influence on the implementation of staged project management in a given sample, although not all of the factors are strictly significant in the estimation results with Subsamples 1 and 3. R&D intensity has a much higher marginal effect than firm size does. Nearly 50% of the study sample consists of the firms in the service sector and majority did not appropriate R&D expenditure. Although for the manufacturing firms, 1% point increase in R&D intensity raises the probability of implementing in staged project management by 41.4%, even for the firms in the service sector, 1% point expansion in firm size increases the probability of employing staged management on their product development process by 2.3%.

In terms of factors affecting the total number of projects at the start, debt financing ratio is negatively associated with the firms' staged approach as our expectation. The study results suggest that a financially constrained firm is less likely to abandon the projects and keep ongoing projects, or more likely to reduce the total number of projects being potentially innovative. In other words, financial constraints dissuade a firm from searching for alternative innovative ideas; ultimately, the firm becomes more conservative in innovation, i.e., allocates smaller budget on fewer projects.

While most of research-friendly organizational culture is not associated with management in staging, ownership structure, that is, family members of the founders in this study, has a positive and significant impact on the staging of innovation projects in all samples except one. The study by Wang and Zhou (2004) explaining the monitoring hypotheses in VC staging shows that managers engage in staging financing only if monitoring on the research organization is not cost-effective. Staged financing involves several steps where a manager observes the interim performance and then decides on the go/not-go drawing upon the mid-term milestone at every stage. A possible interpretation of the results is that family-owned, rather than nonfamily-owned, firms might have a stronger advantage in committing more resources to research projects, for example, individuals monitoring the progress in product development process.

Regarding another proxy for research-friendly organization culture, the founder's educational background, the study results indicate that the founder's social capital has no significant impact on the implementation in staged project management. The study confirmed that the founder's social capital has a significantly positive effect on the decision to initiate R&D activities; however, it might have little effect on the resource allocation for each innovation project.[6]

Next, with regard to sourcing from external knowledge for milestone, variables representing the extent of collaboration for innovation are significantly and positively associated with implementation in staged project management; in fact, it has a relatively large marginal effect of 0.275 in given sample, indicating that the firm that uses various information sources over

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[6] We examine the determinants of firms' implementation in innovation with a sample of 3,637 "willing to innovate" firms. Regarding the definition of "willing to innovate" firms, see Savignac(2008). Appendix Table 2 shows estimation results.

countries increases the likelihood of adopting the staging of innovation projects by 27.5%. The study results suggest that broader information sources persuade such firms to reduce the uncertainty of technological and commercial viability on the innovation projects; consequently, it might be effectively used for milestone to screen good projects from bad. Finally, contrary to the study results, another proxy for external knowledge sourcing, i.e., spillover of industry-specific information through the firm's supplier and customer networks, does not have a significant impact on the screening process.

Insert Table 4

4.2 Treatment effect estimation

As described in subsection 3-2-2, a matching method is adopted to identify the effect of the staged project management on innovation success. In the following estimation, firms adopting staged innovation projects are considered as the treatment group. By estimating the propensity score, in the second step, we determine the "twin observations" of the firms that did not implement staging innovation project for each treated observation, i.e., untreated observations with the most similar characteristics to the treated observations. Table 5 shows the standardized difference and variance ratio (defined as variance to mean) for the treated and control observations before and after matching. The study confirms that there are no significant differences between the treated and the untreated observations regarding the control variables, indicating that the matching specification is valid, and confirms the standardized difference of 0.1 and variance ratio of 1.0.[7]

Table 6 shows the results when firms that managed projects in staging are taken as the treatment group. The overall ATT estimate for innovation outcomes in the table is positive and statistically significant for all firms as well as subsamples in the given sample, although the estimate for new-to-market processes is positive, but is not strictly significant in all samples. The results suggest that the firms adopting staged development processes experienced a greater innovation success than the firms that did not adopt the same.

Regarding the probability in product innovation for all firms in a given sample, the ATT estimate for new-to-market innovation, which is 7.2% point, is slightly higher than that for new-to-firm innovation, which is 7.0% point. We also find the ATT estimate for the ratio of new-to-market product sales to total sales (2.19% point), is slightly lower than that for new-to-firm product sales ratio (2.27% point). Given that the mean value of the new-to-market product sales

[7]Appendix Figure 1 presents box plot of the propensity score.

ratio in the total sample is 3.45% point, while that of the new-to-firm product sales to total sales is 5.61% point, this is a significant increase in the sales ratio of new-to-the-market products.

The study findings demonstrate that staged project management are positively associated with more innovative products, indicating that firms that employed staged approach to manage innovation projects are more productive than the other firms. Furthermore, comparing the probability (or magnitude) of radical and incremental innovation of the firms having implemented the staging of innovation projects, the study confirms that staged management is able to promote both incremental and radical product innovation. The estimation results, in a strict sense on product innovation, support Hypotheses 1 and 2 for all samples of our study. However, for the results of the estimation with subsamples, the effect on improving the amount of sales for radical product innovation in total sales is mitigated. For example, on comparing ATT estimate for the ratio of new-to-market product sales and that for new-to-firm product sales in small and medium sized firms (i.e., subsample 3), it was found that the effects of staging management on share of incremental innovation is much larger than that of radical innovation, indicating that the former sales ratio is around 1.8 times (=3.17/1.72) of the latter. The results imply that managing project in stage significantly increases the probability of innovative goods or services as well as the share of innovative sales in total sales; however, the magnitude on the degree of radicalness differs among industries and as per a firm's size.

Given the various data limitations, the study cannot accurately examine the reasons underlying the positive relationship between staged project management and innovation success. The study findings on higher probability of project abandonment or continuation could highlight the real options. Research organizations might implement staged management as a screening instrument because staging skews the efficient allocation of resources toward the later stages of the product development process at which the organization knows whether the project is sufficiently successful and invests more. Therefore, firms managing development process under the threat of termination are likely to achieve larger sales volume of innovative products as a whole.

INSERT Table 5

INSERT Table 6

5. Conclusion

The present study investigated the determinants and the effect of staging in innovation using the firm-level data underlying the J-NIS2015. The factors accounting for the differences in staged project management were quantitatively examined. Furthermore, to observe the advantage in staged approach, the study used a PSM estimation and identified the firms that did not implement in staged development process but has similar characteristics to those that implemented such process. Then, we estimated the average treatment effect of staging projects on innovation performance and the degree of radicalness.

The study found that the likelihood of managing projects in staging can be explained by a firm's abundant financial resources, R&D intensity, and various types of innovation partners they cooperate with. Given the estimate for the propensity score, the study found that, compared to the firms that did not implement staging projects, the firms that implemented significantly improved innovation performance and degree of radicalness in product innovation. Moreover, staged project management enhances the probability that firms produce radical products as well as the amount of sales associated with radical innovation.

It is often argued that, in the past few decades, it has been difficult to generate value from innovation, especially for many Japanese firms that have had to contend with long economic stagnation during the so-called "two lost decades." For example, the Cabinet Office of the Government of Japan (2011) reports that the effectiveness of R&D (i.e., the ratio of value added generated by the private sectors to R&D expenditure calculated using the country-level R&D data taken from OECD.stat) has declined in many developed economies, and particularly in Japan. The study findings provide a clue as to how the effectiveness of R&D could be improved by managing in innovation projects. Staging approach is more likely to be conducted by the firms that have abundant financial, physical, and information resources.

Considering the innovation policy, in particular, the cost of financing for smaller firms initiating in innovation activities must be reduced. Although R&D collaborations are frequently related to disappointing outcome (Lhuillery & Pfister, 2009), firm's engaging with a higher number of different types of knowledge sources for challenging innovation projects must be encouraged. The results also imply that upfront financing in research grant programs might not improve highly innovative products or processes because supported programs are expected to be at the forefront or knowledgeable and therefore entail risk. Under upfront financing, the recipients of the research grant program do not been required interim adjustments to actions based on performance.

The study findings have implications for managerial practice. Manso (2017) contends that managers must consider their organization culture to encourage experimentation and risk-taking by referring to the example of large bureaucratic organizations, which often struggle with termination projects due in part to career concerns of the managers in charge of the efforts. Corporate culture that allows failure is essential for researchers to select a range of radical innovation projects at the start point. The results of the present study are not consistent with the several empirical studies on the cost and benefit of collaboration, wherein project abandonment is associated with innovation failure. This study assumes that firms that adopt staging of innovation projects have more opportunities to abandon or hold on to ongoing projects on the product development processes. This, in turn, could explain the positive relationship between such failure and greater sales volume from radical innovation observed in previous empirical studies.

However, given the various data limitations, these results should be interpreted with caution. For example, the study data contain no detailed information about staged project management, the number of innovation projects that a firm is conducting, the projects abandoned, and in the stage at which some are abandoned. Moreover, we cannot rigorously examine the causal relationship between staged innovation project and innovation success. To examine the causal relationships and the mechanisms underlying such relationships, we would need to construct firm-level panel data and/or utilize various data sources for detailed firm-level information.

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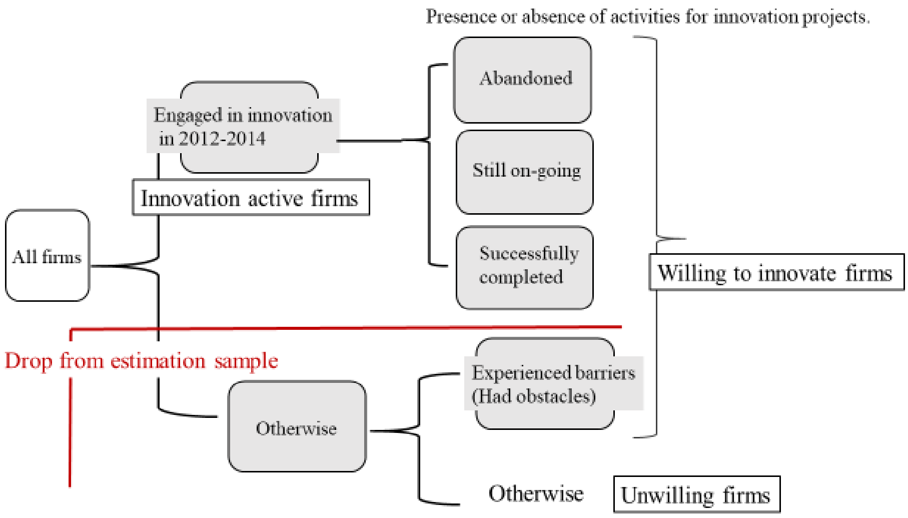

Figure 1. Sample of our study in J-NIS2015: innovation-active firms.

Table 1. Number of firms by industry.

Industry	ISIC Rev. 4	Total	(%)
Manufacturing		727	
(%)		49.5	
Food products and bevarages, tobacco products	10-12	47	3.2
Textiles; wearing apparel; dressing and dyeing of fur, tanning and dressing of leather, manufacture of luggage, handbags, saddlery, harness and footwear	13-15	36	2.5
Wood and products of wood and cork; articles of straw and plant materrials; paper and paper products; publishing, printing and reproduction of recorder media; furniture	16-18, 31	66	4.5
Coke, refined petroleum products and nuclear fuel; chemicals and chemical products; pharmaceutical products	19-21	180	12.3
Rubber and plastic products	22	27	1.8
Other non-material mineral products	23	18	1.2
Basic metals and recycling; fabricated metal products, except machinery and equipment	24-25	79	5.4
Machinery and equipment n.e.c.	28	77	5.2
Electronic parts, devices and electronic circuits; electrical machinery, equipment and supplies; information and comunication electronic equipment	26-27	129	8.8
Moter vehicles, trailers and semi-trailers, other transport equipment.	29-30	27	1.8
Miscellaneous manufacturing industries, n.e.c.	32-33	41	2.8
Non-manufacturing		741	
(%)		50.5	
Agriculture, hunting and forestry, fishing, mining and quarrying	1-3, 5-9	33	4.5
Construction	41-43	103	13.9
Electricity, gas, heat supply and water	35-39	24	3.2
Wholesale and retail trade; repair of motor vehicles	45-47	187	25.2
Transport and storage; postal services	49-53	69	9.3
Telecommunications	58-63	106	14.3
Financial intermediation	64-66	40	5.4
Real estate; rental and leasing activities; business services	55-56, 68-96	179	24.2

Table 2. Variables and their definitions.

Variable	Definition	Data source
Panel (a): Key variable		
Applying the staged project management	1 if a firm experienced project abandonment before completion or held still on-going projects during the period 2012-2014, 0 otherwise.	J-NIS2015
Panel (b): Determinant variables		
Firm size		
Log of employee (2012)	Log of number of regular persons employed in year 2014	J-NIS2015
Capital structure		
Amount of debt to new stock worth	Debt finance / debt finance plus equity finance as of 2013-2014.	TSR
Ownership structure		
Financial institutions	1 if trust and bankning companies, insurance companies are listed in the top five shareholders as of 2012-2014, 0 otherwise.	TSR
Family members of founders	1 if families of the founder are listed in the top five shareholders as of 2012-2014, 0 otherwise.	TSR
Frounder's social capital		
Educational background: Graduate school	1 if the founder has a post-graduate degree as of 2012-2014, 0 otherwise.	TSR
Educational background: University	1 if the founder has a university degree as of 2012-2014, 0 otherwise.	TSR
External knowledge sources		
Collaboration breadth	Log of numer of partner types with which the firm collaborated in countries or regions during the period 2012-2014.	J-NIS2015
Supplier network	Possible informational spillover of industry specific information through supplier's network, not through collaboration for innovation, as of 2013-2014.	TSR
Buyer network	Possible informational spillover of industry specific information through buyer's network, not through collaboration for innovation, as of 2013-2014.	TSR
Firm characteristics		
R&D/Sales (2014)	In-house R&D expenditure / total turnover in year 2014.	J-NIS2015
Log of number of market	Log of number of countries or regions in which the firm sold products or delivered services during the period 2012-2014.	J-NIS2015
ROA	Net income/ Total value of its assets as of 2013-2014.	TSR
Panel (c): Outcome variables		
Incremental innovation		
New-to-firm product innovation	1 if a firm introduced new-to-firm (not new ones for markets) goods or services during the period 2012-2014, 0 otherwise.	J-NIS2015
New-to-market product sales ratio	The appproximate proportion of new-to-market goods or services introduced during the period 2012-2014 in total turnover in 2014.	J-NIS2015
Radical innovation		
New-to-market processes	1 if a firm introduced new-to-market production process or delivery method etc. during the period 2012-2014, 0 otherwise.	J-NIS2015
New-to-market products	1 if a firm introduced new-to-market goods or services during the period 2012-2014, 0 otherwise.	J-NIS2015
New-to-firm product sales ratio	The appproximate proportion of new-to-firm goods or services introduced during the period 2012-2014 in total turnover in 2014.	J-NIS2015

We confirm the robustness of firm characteristics by the Basic Survey of Japanese Business Structure and Activities (METI).

Table 3. Descriptive statistics for the whole sample by the staged project management for innovation.

	(1) implementating in staged management		(2) Not implementing in staged management		t-Test
	Mean	s.d.	Mean	s.d	difference
Explanation variables					
Log of employees (2012)	4.448	1.583	4.170	1.379	***
R&D/sales(2014)	0.026	0.139	0.008	0.065	**
Log of number of market	0.979	0.520	0.881	0.438	***
Collaboration breadth	0.186	0.284	0.096	0.219	***
Amount of debt to new stock worth	0.806	0.283	0.830	-0.256	*
ROA	0.020	0.061	0.014	0.298	
Financial institutions	0.095	0.293	0.077	0.267	
Family members of founders	0.551	0.498	0.535	0.499	
Educational background: Gradate schools	0.017	0.128	0.009	0.093	
Educational background: Universities	0.639	0.480	0.615	0.487	
Supplier network	0.907	1.331	0.791	1.101	*
Buyer network	1.023	1.356	0.908	1.210	*
Outocome variables					
New-to-firm product innovator	0.648	0.478	0.534	0.499	***
New-to-market product innovator	0.294	0.456	0.184	0.388	***
New-to-market process innovator	0.109	0.311	0.061	0.240	***
New-to-firm product sales ratio	6.665	17.987	4.551	14.694	**
New-to-market product sales ratio	4.381	14.749	2.522	10.738	***
Osb.	782		686		

*Significant at 10%, ** at 5%, *** at 1%.

Table 4. Determinants of the applying staged project management (Probit model).

	All firms		Subsample 1		Subsample 2		Subsample 3	
	dy/dx	s.e.	dy/dx	s.e.	dy/dx	s.e.	dy/dx	s.e.
Log of employees(2012)	0.023 **	0.010	0.019 *	0.011	0.024 **	0.011	0.022	0.018
Log of number of market	0.045	0.030	0.003	0.033	0.036	0.031	0.030	0.035
R&D/Sales (2014)	0.414 **	0.183	0.337 *	0.179	0.354 *	0.181	0.339 *	0.187
Collaboration Breadth	0.275 ***	0.051	0.235 ***	0.057	0.282 ***	0.052	0.293 ***	0.062
Amount of debt to new stock worth	-0.095 *	0.054	-0.093 *	0.054	-0.092 *	0.055	-0.099 *	0.059
ROA	0.059	0.070	0.049	0.069	0.059	0.070	0.051	0.071
Financial institutions	-0.041	0.053	-0.050	0.057	-0.045	0.054	-0.118	0.081
Family members of founders	0.055 *	0.030	0.044	0.032	0.062 **	0.030	0.072 **	0.033
Educational backgroud: Graduate shools	0.086	0.027	0.084	0.129	0.085	0.130	0.096	0.159
Educational background: Universities	-0.001	0.027	0.011	0.029	0.005	0.028	-0.014	0.030
Supplier network	0.011	0.013	0.016	0.014	0.012	0.013	0.004	0.015
Buyer network	-0.003	0.013	0.000	0.013	-0.005	0.013	-0.014	0.016
Industry dummies				Yes				
Nb. Of observations		1,468		1,316		1,419		1,174
Log likelihood		-971.285		-883.69		-942.264		-792.614
Chai^2		86.23 ***		54.61 ***		78.440 ***		42.230 ***
Psuedo R^2		0.043		0.030		0.040		0.026

*Significant at 10%, ** at 5%, *** at 1%.

Table 5. Covariate balance summary statistics.

		Standardized differences	Variance ration
Log of employees(2012)	Raw	0.154	1.212
	Matched	-0.042	0.946
Log of number of market	Raw	0.166	1.309
	Matched	0.040	1.043
R&D/Sales (2014)	Raw	0.139	4.293
	Matched	0.061	1.779
Collaboration Breadth	Raw	0.323	1.608
	Matched	0.042	1.076
Amount of debt to new stock worth	Raw	-0.057	1.366
	Matched	0.017	1.347
ROA	Raw	-0.084	1.032
	Matched	0.069	0.847
Financial institutions	Raw	0.045	1.145
	Matched	-0.020	0.941
Family members of founders	Raw	0.043	0.992
	Matched	0.024	0.995
Educational backgroud: Graduate shools	Raw	0.052	1.625
	Matched	0.012	1.098
Educational background: Universities	Raw	0.048	0.975
	Matched	0.026	0.986
Supplier network	Raw	0.073	1.404
	Matched	0.000	1.126
Buyer network	Raw	0.070	1.216
	Matched	0.003	0.998

Table 6. Average treatment effect on staged project management implementation and firm performance: Propensity-score matching treatment effect estimations.

		Incremental Innovation		Radical Innovation		
		New-to-firm products	Sales ratio of new-to-firm products	New-to-market processes	New-to-market products	Sales ratio of new-to-market products
All firms	Implement in staged project management	0.070 **	2.273 **	0.019	0.072 **	2.192 ***
	s.d.	0.036	1.033	0.018	0.031	0.721
Subsample 1	Implement in staged project management	0.061 *	2.322 *	0.033 *	0.071 **	1.674 **
	s.d.	0.036	1.246	0.019	0.031	0.790
Subsample 2	Implement in staged project management	0.112 ***	3.095 **	0.034 **	0.060 **	1.938 **
	s.d.	0.036	1.401	0.017	0.031	0.958
Subsample 3	Implement in staged project management	0.082 *	3.174 ***	0.027	0.075 **	1.727 *
	s.d.	0.042	1.221	0.018	0.034	0.920

Staged project management: firms have abandoned or hold on to ongoing projects.

For propensity score matching treatment effect estimations using all firms, we exclude 17 observations of which the absolute difference in the score is more than 0.03. Similarly, we exclude 9 observations on the estimation with subsample 1, 11 observations with subsample 2, and 4 observations with subsample 3.

Appendix Table1. Correlation matrix.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
(1) New-to-market product sales ratio	1.000																
(2) New-to-firm product sales ratio	0.062	1.000															
(3) New-to-firm product innovator	0.222	0.283	1.000														
(4) New-to-market product innovator	0.476	0.043	0.464	1.000													
(5) New-to-market process innovator	0.140	0.025	0.042	0.182	1.000												
(6) Log of employees (2012)	-0.042	0.021	0.108	0.069	0.038	1.000											
(7) Log of number of market	0.106	0.075	0.176	0.218	0.043	0.297	1.000										
(8) R&D/sales(2014)	0.165	0.000	0.049	0.082	0.045	-0.028	0.091	1.000									
(9) Collaboration breadth	0.106	0.039	0.170	0.193	0.083	0.258	0.197	0.086	1.000								
(10) Amount of debt to new stock worth	0.006	-0.047	-0.066	0.027	0.028	-0.113	-0.049	-0.070	-0.051	1.000							
(11) ROA	-0.008	0.016	0.036	0.000	0.006	0.013	0.025	-0.005	-0.032	0.000	1.000						
(12) Financial institutions	-0.025	-0.003	0.116	0.024	0.000	0.346	0.201	-0.010	0.129	-0.250	0.013	1.000					
(13) Family members of founders	0.034	-0.008	-0.060	0.027	-0.005	-0.337	-0.099	0.017	-0.078	0.313	0.004	-0.287	1.000				
(14) Educational background: Gradate schools	-0.019	-0.009	-0.004	0.034	0.008	0.100	0.088	-0.003	0.033	-0.030	0.003	0.029	-0.028	1.000			
(15) Educational background: Universities	0.032	-0.032	0.039	0.087	-0.009	0.135	0.147	-0.016	0.060	0.077	0.028	0.086	0.014	0.038	1.000		
(16) Supplier network	-0.011	-0.031	0.014	0.054	0.014	0.132	0.143	0.006	0.081	0.068	0.019	0.115	-0.002	-0.003	0.137	1.000	
(17) Buyer network	-0.045	-0.033	-0.007	0.024	0.012	0.296	0.159	-0.005	0.116	0.021	0.015	0.185	-0.088	0.008	0.160	0.571	1.000

Appendix Table 2. Estimated marginal effects for the Probit model of innovation: Initiating innovation

	dy/dx	s.e.
Log of employees(2012)	0.044 ***	0.006
Log of market	0.133 ***	0.021
R&D/Sales (2014)	3.043 **	1.377
Amount of debt to new stock worth	-0.002	0.004
ROA	0.017	0.044
Financial institutions	0.078 **	0.036
Familymembers of founders	-0.003	0.016
Educational backgroud: Graduate schools	0.118	0.103
Educational background: Universities	0.249 ***	0.013
Supplier network	0.032 ***	0.008
Buyer network	-0.010	0.008
Industry dummies	YES	
Nb. Of observations	3,636	
Log likelihood	-2082.603	
Chai^2	739.750 ***	
Psuedo R^2	0.1508	

*Significant at 10%, ** at 5%, *** at 1%.
For the estimation, we define "willing to innovate firms" as following: (1) firms answer that they had developed new or changed products or services, or new or changed processes in preceding three years, or (2) firms answer that they have an experience with abandonment of innovation projects, or they have uncompleted projects in preceding three years, or (3) firms answer that they have not experienced hampering factors and reasons of no innovation activity.

Collaboration Breadth that was employed in Table 2 cannot be used here because the variable is available only for "innovation-active" firms.

Appendix Figure 1. Box plot of the propensity score.