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DISCUSSION PAPER

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The Effect of Staged Project Management on Product Innovation: Evidence From a Firm Survey

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The Effect of Staged Project Management on Product Innovation: Evidence from a Firm Survey

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Abstract

This study examines whether staged project management is beneficial or harmful for making product innovations. Using a unique firm survey for Japan, we find that firms that employed staged project management had a higher likelihood of introducing new products to the market. Additional estimations show that the positive effect of staged project management on product innovation is stronger when firms provided feedback at the interim stages. In contrast, whether and how firms set milestones was not associated with the likelihood of product innovation. The marginal effect of feedback was larger for new-to-market product innovation than for new-to-firm product innovation, and the feedback from non-R&D organizations within the firm in the initial stages was particularly beneficial for the introduction of new-to-market products. Our findings suggest that staged project management is beneficial for product innovation, but its effectiveness depends on how firms set milestones and feedback as well as the nature of innovation.

JEL classification: D22, G32, M11, O31, O32

Keywords: staged project management, product innovation, milestones, feedback, exploration, exploitation

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1. Introduction

A growing literature suggests that management quality is important for firms' productivity (e.g., Bloom and Van Reenen 2007, Bloom et al. 2013, Kambayashi et al. 2021). However, the link between specific management practices and innovation, which is a key driver of productivity growth, is less well understood. In this study, we focus on one particular management practice that may foster innovation: staged project management. The management and funding of R&D projects often proceeds in stages. For instance, the "Stage-Gate" method proposed by Cooper (1988) sets concrete interim goals, referred to as "gates" or "milestones," in each stage of an R&D project, and the project is continued if the milestones are met. In addition, the provision of feedback on interim evaluations to the R&D researchers in charge of the project is also common in staged project management. Similarly, venture capital investors typically make staged investments in venture firms that conduct R&D activities, holding open the option of abandoning a venture firm if it fails to meet milestones (Sahlman 1990). Despite the prevalence of staged project management, existing studies are not unanimous on whether it promotes innovation. On the one hand, in the presence of information asymmetry and/or incomplete contracts between a firm's headquarters and its R&D employees, staged project management may reduce agency costs and increase the probability of success of R&D projects. Conducting R&D activities in stages also allows firms to terminate projects that are less likely to succeed and reallocate resources to other, more promising projects (Klingebiel and Rammer 2014). On the other hand, staged project management may create incentives for R&D employees to aim for short-term success in the sense that they choose projects with a higher probability of success and easy-to-achieve goals, which may be detrimental to a firm's long-term growth and value creation (Sahlman 1988). At the same time, staged project management may inhibit "trial-and-error" by R&D employees and reduce their creativity (Lenfle and Loch 2010).

Against this background, this study, using firm-level microdata for Japan, examines whether and how staged project management increases or decreases the likelihood of product innovation. The unique feature of this study is that it examines how firms implement staged project management in detail. Specifically, we examine whether the use of milestones and feedback in staged project management affects product innovation. We also examine whether the effect of staged project management depends on the nature of product innovation, i.e., whether the innovation is explorative or exploitative.

To investigate these issues, we use a unique firm survey, the "Survey of R&D

Management Practices," which was implemented in January–February 2020. The survey is particularly suitable for our analysis because it contains detailed questions on whether and how respondent firms implemented staged project management, including the use of milestones and feedback. In addition, the survey identifies whether firms developed product innovations during the preceding three years and whether the new products that firms introduced were "new-to-market" and/or "new-to-firm," which we use as indicators of explorative and exploitative innovation respectively.[1]

Using the dataset constructed from the survey and other sources, we first conduct logit estimations to examine the effect of staged project management on product innovation. We find that firms that employed staged project management were more likely to make product innovations than firms that did not. While this result suggests that staged project management is beneficial for product innovation, it is possible that the positive link between staged project management and product innovation may be due to reverse causality, i.e., the potential tendency of R&D employees to choose projects with a higher probability of success (short-termism) when the project proceeds in stages. To check for this possibility, we run bivariate probit estimations in which the dependent variables are new-to-market and new-to-firm product innovations. While one would expect to find a positive link between staged project management and product innovation only for new-to-firm products if short-termism prevails, the estimation results show that the link is positive for both types of products. This suggests that the positive link found in the logit estimation is not entirely attributable to the possible short-termism induced by staged project management. To examine whether the estimates obtained in the logit and bivariate probit model are potentially biased due to the fact that the choice of staged project management is likely to be endogenous for the firms in our sample, we also implement propensity score matching estimations and obtain results that are consistent with the logit and bivariate probit estimations.

Next, to understand the mechanism through which staged project management increases the likelihood of product innovation, we conduct a logit estimation in which firms that implemented staged project management are differentiated by whether they set milestones and provide feedback. We find that firms that implemented staged project management with neither milestones nor feedback did not have a higher likelihood of making product innovations

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[1] Definitions of "new-to-market" and "new-to-firm" products are provided in Section 3.2.1. For studies that use new-to-market and new-to-firm products as indicators of explorative and exploitative innovation, see, e.g., Doran and Ryan (2014) and Rodriguez et al. (2017).

than firms that did not implement staged project management. In contrast, firms that implemented staged project management with milestones and feedback had a higher likelihood of making product innovations. Interestingly, we find that firms that implemented staged project management with milestones only were no more likely to make product innovations, but that firms with feedback only were more likely to make product innovations. These findings suggest that staged project management is more effective in increasing the likelihood of product innovation when combined with feedback.

To further understand the role of milestones and feedback in staged project management, we conduct bivariate probit estimations in which the dependent variables are new-to-market and new-to-firm product innovations using a subsample of firms that employed staged project management. In these estimations, we additionally examine to what extent innovation outcomes are affected by whether firms take the achievement of milestones into account when assessing whether to continue the R&D project. We conjecture that the effect of the importance of milestones is positive for new-to-firm innovation but ambiguous for new-to-market innovation because too much emphasis on milestones may discourage trial-and-error by R&D employees, which is necessary for explorative (new-to-market) innovation. However, we find no association between milestones and the likelihood of making product innovations in the case of either new-to-market or new-to-firm product innovation. Further analyses suggest that the insignificant results were obtained because milestones did not effectively serve as a threat of termination of R&D projects among the firms in our sample. In contrast, the provision of feedback on the interim evaluation of R&D projects to R&D employees is positively associated with both new-to-market and new-to-firm product innovation. Quantitatively, the marginal impact of feedback is larger for new-to-market than for new-to-firm products. Turning to the provider and timing of feedback, we find that feedback from non-R&D organizations within the firm in the initial stages is positively associated with the introduction of new-to-market products but not new-to-firm products. Interestingly, we also find that feedback from experts outside the firm in the late stages is negatively associated with the introduction of new-to-firm products. These results suggest that whether feedback is beneficial or harmful for product innovation depends on the way that feedback is provided and the nature of product innovation.

This study is closely related to the following strands of literature examining the role of staged project management and staged investment. First, studies on innovation and management have long discussed the advantages and disadvantages of conducting R&D

activities in stages. While numerous studies taking the form of case studies have examined this issue (Fichman et al. 2005, Lenfle and Loch 2010, van der Duin et al. 2014, Soenksen and Yazdi 2017, Smolnik and Bergmann 2020), the number of empirical studies using quantitative data is limited (Schultz et al. 2013, 2019, Andries and Hünermund 2014, 2020, Klingebiel and Adner 2015). In addition, most of these empirical studies used a particular firm survey, namely, the German edition of the Community Innovation Survey (CIS). This study contributes to the literature by providing additional empirical evidence on the effect of staged project management on product innovation using a firm survey for Japan. Most importantly, however, this study provides new findings on the role of milestones and feedback based on the specific information in the survey employed in this study, which the German CIS does not provide. This allows us to investigate in more detail the mechanism through which staged management affects product innovation.

Second, this study is related to the literature on staged investment by venture capitalists (VCs) in venture firms. Using the principal–agent framework, the literature on venture capital found that staging is a way for VCs (principals) to monitor venture firms (agents) and mitigate agency problems (Gompers 1995, Kaplan and Strömberg 2003, Tian 2011). Moreover, staging is used to mitigate the hold-up problem (Neher 1999) and to learn about the agent over time and sort good projects from bad ones (Sahlman 1988, 1990, Bergemann and Hege 1998, Ray 2007, Dahiya and Ray 2012). On the other hand, the literature identified that staging may lead to underinvestment by VCs at the early stage (Wang and Zhou 2004) and exacerbate venture firms' focus on short-term success to continually look attractive to VCs (Cornelli and Yosha 2003). In this study, we construct our empirical hypotheses based on studies on staged investment in the venture capital industry, as the principal–agent framework used in these studies may well apply to the relationship between firm headquarters (principal) and R&D units and employees (agents).

Finally, this study is also related to Manso's (2011) theoretical study on the creation of incentives for innovation. In our view, the two-period model presented in Manso (2011) concisely captures the advantages and disadvantages of staged investments. Moreover, Manso (2011) provides useful theoretical guidance on how milestones and feedback affect innovation. Several empirical studies have examined Manso's (2011) predictions in an experimental setting (Ederer and Manso 2013), and in the realm of scientific research (Azoulay et al. 2011) and venture capital (Tian and Wang 2014). To the best of our knowledge, this study is the first to empirically examine the effect of milestones and feedback in the context of corporate R&D

activities.

The remainder of this study is organized as follows. Section 2 reviews the related literature and develops our empirical hypotheses. Section 3 describes the data and key variables used and explains our empirical approach. Section 4 presents and discusses the results of our empirical analysis. Finally, Section 5 concludes.

2. Literature review and empirical hypotheses

2.1. The effect of staged project management on innovation

The economic effects of staged investment have been analyzed extensively in a variety of studies on venture capital.[2] A seminal field study on venture capital by Sahlman (1988, 1990) noted that staging in capital infusion is the most important mechanism through which VCs can control venture firms. Subsequent studies on venture capital have highlighted three advantages of staged investment. First, in the presence of information asymmetry and/or incomplete contracts between the entrepreneur who founded a venture firm and a VC, staging of capital infusions may reduce potential agency costs. These agency costs include the appropriation of the value-added by the entrepreneur when the cash flows generated are not verifiable, "shirking" by the entrepreneur when their effort is not verifiable, and the continuation of a project with a negative net present value when there are private benefits accruing to the entrepreneur from continuing the project. In this setting, staging is useful because it allows a VC to monitor the progress of the venture firm's projects and retain the right to terminate the projects if their intermediate performance is not good (Gompers 1995, Kaplan and Strömberg 2003, 2004). Second, if the human capital of an entrepreneur is inalienable (Hart and Moore 1994), then the entrepreneur can "hold up" the VC ex-post by threatening to leave the firm unless the VC agrees to reduce the claim stipulated in the contract ex-ante. Neher (1999) showed that staging mitigates this hold-up problem because it reduces the VC's committed investment in the venture firm at any given time, making the VC's claim less susceptible to being renegotiated down.[3] Third, in the presence of uncertainty, staging allows a VC to learn about a venture firm

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[2] The first study to theoretically examine the role of staging for explorative activities including R&D is Roberts and Weitzman (1981).

[3] Hold-up problem in the VC's staged investment may be mitigated through other control mechanisms such as vesting schedules, which limit the number of shares to which managers are entitled if they leave prematurely, and noncompete clauses, which ban those leaving from starting a similar project (Sahlman 1990, Kaplan and Strömberg 2001).

over time as uncertainty diminishes, thereby creating an option to abandon financing the project at each stage (Sahlman 1988, 1990, Bergemann and Hege 1998, Ray 2007, Dahiya and Ray 2012). In this vein, staging serves as a useful sorting instrument.

However, some studies have identified possible disadvantages of staged investment by VCs. First, it may lead venture firms to engage in "short-termism" in the sense that they focus on meeting the intermediate hurdle of the next stage and/or setting a modest goal with a high probability of success at the outset, both of which may be detrimental to long-term value creation (Sahlman 1988). In a similar vein, firms may set the conditions under which their interim performance looks favorable, which is described as "window dressing" (Cornelli and Yosha 2003). Second, staged investment may lead to underinvestment at venture firms with a viable project that needs upfront financing (Wang and Zhou 2004). Finally, staging inevitably incurs negotiation and contracting costs in interim stages and may lead to lags in the implementation of a project (Tian 2011).

Based on these considerations, in the context of staged project management in R&D activities, we put forward our first empirical hypothesis:

Hypothesis 1. (*The effect of staged project management on innovation*). Firms that employ staged project management in their R&D activities are more likely to make product innovations. Alternatively, firms that employ staged project management are less likely to make product innovations if the drawbacks of staging outweigh its advantages.

The number of empirical studies examining the effect of staged project management on innovation is limited and those that do exist have arrived at mixed results. In the field of management and innovation, Klingebiel and Adner (2015) empirically examined whether "sequencing," which is similar to the staged project management considered in this study, increased the sales of new products. Using firm-level data from the German CIS, they found that sequencing had a positive impact on new product sales. In a similar vein, using the same German CIS survey, Andries and Hünermund (2014) found that staged project management increased new product sales, although their primary research interest lay in the moderating effect of staged project management on the impact of innovation expenditures on new product sales. Schultz et al. (2013, 2019) examined whether the "stage-and-gate-type system" (SGS) increased new-product-development success, which was measured in terms of CEOs' subjective judgment on whether innovation activities had contributed to firm performance. The empirical results are mixed: Schultz et al. (2013) did not find a positive correlation between

SGS and new-product-development success, whereas Schultz et al. (2019) found a positive correlation between the two. In the literature on venture capital investment, Mao et al. (2014) argued that staged investment by VCs negatively affected innovation by venture firms. They found that VC-backed initial public offering firms were less innovative, as measured by the number of patents granted and the number of future citations received by each patent, when venture capital investors held a larger number of venture capital financing rounds. Our study differs from the previous studies in that we examine not only whether staged project management positively or negatively affects innovation but, by focusing on the role of milestones and feedback, whether the way in which staged project management is implemented affects innovation.

2.2. The effect of milestones and feedback on innovation

When R&D projects proceed in stages, firms often set intermediate goals for the interim evaluation of a project, which we shall call "(interim) milestones." Milestones can be either quantitative or qualitative targets, and firms may use milestones to assess whether to terminate or continue the project and/or whether to redesign the content and approach of the project if the interim outcomes do not meet expectations. In addition, firms often provide feedback on the interim evaluation results to the R&D employee in charge of the project. Feedback also gives the R&D employee an opportunity to redesign how to proceed with the project. In the following, we construct our empirical hypotheses on the effect of milestones and feedback based on the theoretical model developed by Manso (2011).

Manso (2011) presents a two-period principal-agent model of the innovation process that concisely captures the advantages and disadvantages of staged investments discussed above. In the model, the agent chooses between two actions in each stage: exploration or exploitation. Exploitation consists of well-known actions or work methods to achieve incremental innovations with a known probability of success, whereas exploration consists of new untested actions or work methods to achieve radical innovations. The probability of success for radical innovations is unknown, and the agent updates their beliefs about the probability of success once they have chosen exploration in the first stage. Because the principal does not observe the actions taken by the agent and both actions entail private costs to the agent, the agent has an incentive to shirk. Manso (2011) argued that the effects of the threat of termination, which is inherent in staged investment, on the incentives for exploration are ambiguous. The reason is that while the threat prevents the agent from shirking it encourages them to choose an exploitative project with a higher probability of success. Depending on which of these two effects is more important, staging innovation projects may encourage or discourage the agent from choosing exploration. In our context, Manso's argument implies that milestones will provide incentives for R&D employees to put in more effort, which increases the probability of success of a chosen project, but which also incentivizes them not to choose explorative projects. We also note that to what extent interim milestones serve as a threat of termination may depend on the purpose for which a firm uses milestones, i.e., whether it uses them to make decisions as to whether to terminate/continue a project or whether it uses them to make interim adjustments. Based on these considerations, our second hypothesis is as follows.

Hypothesis 2-1 (*The effects of milestones on exploration and exploitation*). Among firms that employ staged project management, milestones are positively associated with making exploitative innovations, whereas the association between milestones and explorative innovations is ambiguous.

Feedback on interim outcomes of the project may increase the probability of success because agents can make interim adjustments by incorporating opinions from others. However, Manso (2011) argues that feedback may have little impact – or even a negative impact – on exploitative innovation because this type of innovation usually involves well-known work practices and little uncertainty. For explorative innovation, outsider views through feedback may bring in additional knowledge and perspectives and may reduce the uncertainty of the project. Based on these considerations, we posit our third hypothesis as follows:

Hypothesis 2-2 (*The effect of feedback on exploration and exploitation*). Among firms that employ staged project management, the positive effect of feedback on making product innovations is stronger for explorative innovations than for exploitative innovations.

Several studies have examined Manso's (2011) predictions in contexts other than corporate R&D activities. Ederer and Manso (2013) provided experimental evidence on the effects of termination. Specifically, they conducted a laboratory experiment in which participants operate a hypothetical computerized lemonade stand and choose between exploitation (i.e., making minor adjustments to the business strategy) or exploration (i.e., making major adjustments to the business strategy). To study the effect of termination, they divided participants into two groups: one whose lemonade stands were eliminated if they underperformed in the first half of the experiment and another whose lemonade stands continued regardless of the performance in the first half. Ederer and Manso (2013) found that participants in the latter group were more likely to choose an explorative strategy, suggesting that the threat of termination undermines the incentives for explorative innovation. In the realm of scientific research, Azoulay et al. (2011) examined whether the funding program of the Howard Hughes Medical Institute (HHMI) encourages exploration more than the funding program of the National Institutes of Health (NIH). HHMI tolerates early failure and provides detailed and high-quality feedback to the researcher, while NIH is unforgiving of failures at interim reviews and provides limited feedback. Azoulay et al. (2011) found that researchers who used HHMI grants produced higher-impact articles than NIH-funded researchers, suggesting that more forgiving scientific research grants with extensive feedback led to more explorative innovations than grants with stricter interim reviews. To the best of our knowledge, this study is the first to examine the effect of milestones and feedback in corporate R&D activities and complements previous studies.

3. Data, variables, and empirical approach

3.1. Data

We construct our firm-level microdata for Japan using the following sources. First, we use the "Survey of R&D Management Practices," which was implemented in January–February 2020 and which we will refer to as the "R&D Management Survey" hereafter. The R&D Management Survey asked firms various questions about R&D management and innovation, from which we construct measures on staged project management and product innovations.[4] The survey focused on Japanese business enterprises that undertake R&D activities. Specifically, the survey targeted R&D-performing business enterprises with paid-in capital of 100 million yen or more in manufacturing (Japan Standard Industrial Classification (JSIC): 09–32), information and communications (JSIC: 37–41), and wholesale and retail trade (JSIC: 50–55). Smaller firms and firms in service industries were excluded because many of these firms do not conduct R&D at all. Firms meeting these criteria were selected from the 2017 and 2018 rounds of the Survey of Research and Development, which is implemented annually by the

[4] For details of the R&D Management Survey, see Haneda and Ono (2022).

Statistics Bureau of the Ministry of Internal Affairs and Communications.[5] Following this procedure, a total of 3,456 firms were sent questionnaires for the R&D Management Survey. The number of respondent firms was 611 for a response rate of 17.7%.

The second source we use is data from the 2019 round of the "Survey of Research and Development," which provides information on firms' basic characteristics as of FY2018, which we match to our survey data.[6] Information provided in the Survey of Research and Development includes firms' sales turnover, R&D expenditure, total number of employees, number of R&D employees, and employees with a doctorate degree – information that is not included in the R&D Management Survey. Third, to construct the industry-level variables used in some of our estimations, we use the "Basic Survey of Japanese Business Structure and Activities" conducted by the Ministry of Economy, Trade, and Industry, and the Nikkei Financial QUEST database provided by Nikkei Media Marketing, Inc.

Although 611 firms responded to the R&D Management Survey, the exact number of observations we can use for the analysis depends on which specification we use in our estimations and the number of missing observations for variables used in the estimation. The maximum number of observations in our estimation is 557.

3.2. Key variables

This subsection explains the key variables we employ to examine our empirical hypotheses. Tables 1 and 2 present the definitions and summary statistics of the variables used in our estimations. Details of the construction of key variables using the R&D Management Survey, summary statistics for the subsample of firms that employed staged project management and those that did not, and the correlation matrix for the variables used in the estimations are provided in the Appendix.

3.2.1. Dependent variables for product innovation

As proxies for innovation, we focus on product innovation rather than process innovation because staging is a management tool that is particularly relevant for the former. For example, it allows firms to change product design and/or development processes within a short period

[5] For details of the Survey of Research and Development, see the following website: https://www.stat.go.jp/english/data/kagaku/index.html (accessed 29 December 2022).

[6] We use the 2019 round of the Survey of Research and Development because the R&D Management Survey asked respondents to provide answers as of FY2018. For several firms for which data were not available in the 2019 round, we used data from either the 2018 or the 2017 round of the Survey of Research and Development.

of time in response to unexpected competitor behavior and/or consumer reactions (von Zedtwitz et al. 2014).

Specifically, we construct two types of dependent variables for product innovation. First, as a proxy for successful product innovation, we construct the dummy variable DUM_INNOV, which equals one if a firm between FY2016 and FY2018 introduced at least one new or improved product in the market and zero otherwise. Because our sample consists of firms that conduct R&D, it is likely that firms with $DUM\_INNOV = 0$ tried to generate product innovations during this period but were unsuccessful. In the following analysis, we therefore assume that non-innovators attempted to make product innovations but failed to do so.[7] The mean of DUM_INNOV is 0.548, meaning that 54.8% of firms made product innovations (Table 2).

Second, we construct the dummy variables DUM_NTM and DUM_NTF, which indicate whether a firm made a "new-to-market" or "new-to-firm" product innovation.[8] In the R&D Management Survey, a new-to-market product is defined as a new or significantly improved good or service that no competitors were offering. A new-to-firm product is a new or improved good or service that was identical or very similar to goods or services already offered by competitors. These definitions are based on the Oslo Manual 2018 by the Organisation for Economic Cooperation and Development, which provides international guidelines on innovation statistics. Similar to previous studies (e.g., Doran and Ryan 2014, Rodriguez et al. 2017), in the analysis that follows, we assume that firms that introduced new-to-market products made explorative product innovations, whereas firms that introduced new-to-firm products made exploitative product innovations. Note that DUM_NTM and DUM_NTF are not mutually exclusive; if a firm introduced both new-to-market and new-to-firm products during the period we examine, DUM_NTM and DUM_NTF for this firm both

[7] One may argue that firms that did not make product innovations pursued different objectives, such as aiming at process innovations or acquiring technological knowledge without the aim of introducing new products or processes. To check for these possibilities, we constructed the following alternative estimation samples and conducted the same estimations as those in Tables 3 to 8 in the main text: First, using the R&D Management Survey, we identified firms that made process innovations but did not make product innovations and constructed an alternative sample which excluded these firms. Second, using the Survey of Research and Development, we identified firm that did not make any development research expenditure at all and constructed another sample which excluded these firms. The estimation results using these samples (not reported; available from the authors on request) are qualitatively the same as those reported in Tables 3 to 8 below.

[8] In unreported estimations (available from the authors on request), instead of using dummy variables (DUM_INNOV, DUM_NTM and DUM_NTF), we employed the logarithm of the sales of newly introduced products, new-to-market products, and new-to-firm products as dependent variables. The results are qualitatively the same as those reported in Tables 3 to 8 below.

take a value of one. The percentage share of firms that developed a new-to-market and a new-to-firm product is 32.0% and 45.6%, respectively (Table 2), whereas the percentage share of firms that developed both product is 23.0% (not shown in Table 2).

3.2.2. Main independent variables for staged project management

The main independent variable to examine Hypothesis 1 is a dummy variable, $DUM\_STAGING$, that equals one if a firm implemented staged project management in FY2018 and zero otherwise.[9] The mean of $DUM\_STAGING$ is 0.530, indicating that about half of the firms in our sample implemented staged project management. Further, as alternatives, we construct NUM_STAGES, which represents the average number of stages used by a firm, and $DURATION\_STAGE$, which represents the average duration of each stage, i.e., the average number of years from the commencement of an R&D project to the achievement of final results divided by the average number of stages (NUM_STAGES). A larger value of NUM_STAGES indicates that a firm engages in *more* staging, whereas a larger value of $DURATION\_STAGE$ indicates that a firm engages in *less* staging. We use NUM_STAGES and $DURATION\_STAGE$ to check whether the estimation result using $DUM\_STAGING$ is robust to alternative proxies for staged project management. Table 2 shows that the means of NUM_STAGES and $DURATION\_STAGE$ are 2.90 and 2.18 years, respectively. These figures indicate that our sample firms, including those that did not implement staged project management, employed fewer than three stages, and the average duration of each stage was about 2 years.

Firms that employed staged project management, i.e., firms with $DUM\_STAGING = 1$, were asked further questions about milestones and feedback, and we construct the following variables to examine Hypotheses 2-1 and 2-2. Regarding milestones, $DUM\_MILESTONES$ is a dummy variable that equals one if a firm set milestones for the interim evaluation of projects and zero otherwise. The mean of $DUM\_MILESTONES$ is 0.414.[10] In addition, for firms that set milestones (i.e., $DUM\_MILESTONES = 1$) we construct dummy variables that represent the importance of milestones in firms' assessment of whether to terminate/suspend or continue the R&D project in the initial stages of the project. Specifically, we construct

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[9] In the R&D Management Survey, staged project management was defined as the management of R&D projects in consecutive stages (phases). Staged project management also entails a phase-based interim evaluation that affects the decision whether the project is continued, suspended, or abandoned, as well as revisions of the schedule.

[10] This figure includes firms that did not implement staged project management. For firms that implemented staged project management, the share of firms that employed milestones is 78.0%.

DUM_MS_FULLY, $DUM\_MS\_SOME\ EXTENT$, and $DUM\_MS\_NOT\ MUCH$, which respectively take a value of one if a firm took the achievement of milestones "fully," "to some extent," or "not very much/not at all" into account when deciding whether to continue the R&D project. The default for these dummy variables is firms that implemented staged project management but did not set milestones, DUM_NOMS (see the Appendix for details). In our estimation sample, less than half of firms that implemented staged project management answered that they took milestones "to some extent" into account and more than 20% of firms answered that they took them "fully" into account.

Regarding feedback to R&D employees, we construct $DUM\_FEEDBACK$, which equals one if a firm provided feedback on the interim evaluation results to R&D employees and zero otherwise. The mean of $DUM\_FEEDBACK$ is 0.451.[11] In addition, for firms that provided feedback (i.e., $DUM\_FEEDBACK = 1$) we construct the following dummy variables representing whose opinions were incorporated when providing feedback in the initial and late stages: $DUM\_FB\_INI\_RD$, $DUM\_FB\_INI\_NONRD$, $DUM\_FB\_INI\_EXP$, $DUM\_FB\_LATE\_RD$, $DUM\_FB\_LATE\_NONRD$, and $DUM\_FB\_LATE\_EXP$, where "INI" and "$LATE$" respectively stand for the initial and late stages and "RD, " "$NONRD$," and "EXP" respectively stand for opinions from other research teams within R&D units, opinions from non-R&D organizations (e.g., business units and the head office) within the firm, and opinions from experts outside the firm. For example, $DUM\_FB\_INI\_RD$ takes one if a firm incorporated opinions from other researchers in the firm's R&D units when providing feedback in the initial stages. Note that these variables are not mutually exclusive, as a firm may incorporate opinions from various sources at different stages. The means of these variables shown in Table 2 indicate, first, that the percentage shares of firms that incorporated opinions from external experts are about 20% in both stages (initial: 26.1%, late: 21.0%). These percentages are the lowest among the three options regarding whose opinions are incorporated. Second, while the percentage shares of firms that incorporated opinions from other teams within R&D units (60.8%) and from non-R&D organizations (60.1%) are roughly the same in the initial stages, the share is larger for non-R&D organizations (72.2%) than for other teams within R&D units (47.1%) in the late stages. A possible explanation of this pattern is that firms' main concern in the initial stages is the technological feasibility of product ideas, and as the project progresses, their concern gradually shifts to the commercialization of the innovation

[11] This figure includes firms that did not implement staged project management. For firms that implemented staged project management, the share of firms that provided feedback is 85.4%.

and product marketing.

Although understanding whether and how milestones and feedback in the staged project management of R&D activities affects product innovation is crucial, to the best of our knowledge, no empirical studies have examined this issue, presumably because of the lack of data. This study fills the gap in the literature and provides a more in-depth analysis of staged project management.

3.3. Empirical approach

3.3.1. Baseline estimation for Hypothesis 1

To examine Hypothesis 1, we first estimate the following logit model to examine whether firms that employed staged project management were more likely to introduce a product innovation:

$$\Pr(DUM\_INNOV_i) = \psi(\alpha + \beta_1 DUM\_STAGING_i + \mathbf{X_i}\boldsymbol{\gamma}), \quad (1)$$

where $\psi(\cdot)$ represents the cumulative density function of the logistic distribution. We expect $\widehat{\beta_1}$ to have a positive sign. As alternatives to $DUM\_STAGING$, we use NUM_STAGES, which is also expected to have a positive sign, and $DURATION\_STAGE$, which is expected to have a negative sign, as proxies for staged project management. We note that our baseline estimations do not allow us to interpret $\widehat{\beta_1}$ as a causal effect of staged project management on product innovation because staging may not be orthogonal to disturbances for innovation outcomes as firms endogenously choose whether and how they implement staged project management. We return to this issue in Section 3.3.2.

$\mathbf{X_{it}}$ denotes a vector of control variables that represent firm *i*'s characteristics. Definitions and summary statistics of the control variables are presented in Tables 1 and 2. Specifically, we use variables representing firm size and R&D inputs (following D'Este 2016, and Reeb and Zhao 2022), types of research (i.e., basic, development, and applied, following Mohnen et al. 2006, Robin and Schubert 2013), number of R&D projects in progress (Klingebiel and Rammer 2014, Andries and Hünermund 2020), and firms' internal organizational structure with regard to R&D (Azoulay and Lerner 2012). We provide more detailed expositions on these control variables in the Appendix.

3.3.2. Robustness and extension for Hypothesis 1

In this subsection, we explain our robustness checks to examine whether the result of the baseline estimations is driven by reverse causality and whether the estimates are biased due to the endogeneity of staged project management. In addition, we explain the extended logit estimation of Equation (1), which we conduct to understand the mechanism through which staged project management affects the likelihood of product innovation.

Bivariate probit model: As argued in Section 2.1, even if we obtain an estimate of β_1 in Equation (1) that is consistent with Hypothesis 1, this could be because R&D personnel at firms that implement staged project management potentially at the outset set more modest goals with a higher probability of success. To examine whether our findings reflect such reverse causality that would arise from this, we estimate the following bivariate probit model:

$$\Pr(DUM\_NTM_i) = \psi(\alpha + \beta_2 DUM\_STAGING_i + \mathbf{X_i}\boldsymbol{\gamma}), \tag{2}$$

$$\Pr(DUM\_NTF_i) = \psi(\alpha + \beta_3 DUM\_STAGING_i + \mathbf{X_i}\boldsymbol{\gamma}). \tag{3}$$

If staged project management fosters short-termism, one would expect this to affect only the likelihood of new-to-firm innovation and not the likelihood of new-to-market product innovation (i.e., $\widehat{\beta_2}$ to be insignificant and $\widehat{\beta_3}$ to be significant). Instead of estimating Equations (2) and (3) separately using a logit model, we employ a bivariate probit model because DUM_NTM and DUM_NTF are not mutually exclusive and it is possible that staged project management and other firm characteristics affect both the likelihood of new-to-market and new-to-firm innovation (Crowley and Jordan 2017, Doran and Ryan 2014). The bivariate probit model jointly estimates Equations (2) and (3) using maximum likelihood and allows for the possibility that the error terms of these equations are correlated.

Propensity Score Matching: Next, estimations in Equations (1)–(3) assume that staged project management is orthogonal to disturbances of the dependent variables for product innovation. This assumption is likely not valid since firms' choice as to whether to implement staged project management is endogenous. To take the endogeneity of staged project management into account, we conduct propensity score matching (PSM) estimation. To this end, we match firms that employed staged project management with their "identical twins" in terms of other firm characteristics but that did not employ staged project management. We then compare the average innovation outcomes of the former group of firms (treatment group) and the latter (control group). Although the PSM estimation results may still suffer from the hidden selection bias that arises due to unobservable factors, they serve as a robustness check for the baseline estimations.

The procedure is as follows. We start by conducting a logit estimation that models the probability that firms employ staged project management:

$$\Pr(DUM\_STAGING_i) = \psi(\alpha + \mathbf{X}_i'\boldsymbol{\gamma} + \mathbf{Z}_j\boldsymbol{\delta}), \tag{4}$$

where $\mathbf{X}_i'$ and $\mathbf{Z}_j$ are vectors of firm-level and industry-level variables, respectively. For firm characteristics $\mathbf{X}_i'$, we use the number of employees in logarithm ($lnEMPLOYEES$), the number of R&D projects in progress ($NUM\_RD\ PROJECTS$), and the dummy variables indicating whether a firm's R&D units were a combination of highly independent R&D units (such as a central research laboratory) and R&D units that are directly controlled by business units (DUM_HYBRID), since larger firms, firms with more R&D projects, and firms with complex R&D organizational structures are more likely to employ staged project management as a sorting instrument to determine which projects to continue. In addition, we use the dummy variable $DUM\_EXTERNAL\ FUNDS$, which takes a value of one if a firm received external funds specifically for its R&D activities (e.g., funds from central or local government, universities, or other firms) and zero otherwise. We conjecture that if a firm received external funds for R&D activities, it was likely to report interim outcomes periodically to external funders and hence employed staged project management. For industry-level variables $\mathbf{Z}_j$, we use the market-to-book ratio ($IND\_MB\ RATIO$) and the R&D expenditure-to-sales ratio, ($IND\_RD\ EXPENDITURE - SALES\ RATIO$) of the industry j to which firm i belongs. We use these variables following Gompers's (1995) empirical study on VC's staged investment. Gompers (1995) found that these industry-level variables were significant determinants of staging, because agency costs in venture capital investments increase with the growth opportunities and R&D intensity of investee firms. We also use industry dummies to control for any remaining industry characteristics that affect the use of staged project management.[12]

Based on the logit estimation results in Equation (4), we attach a propensity score to each observation. For each treatment observation that employed staged project management, we then identify matched observations from the subsample of firms that did not employ staged project management. The matched observations are those that have the "closest" propensity scores to a particular treatment observation and are labeled control observations. There are several matching algorithms to find the "closest" control observations; we employ nearest neighbor matching. Finally, we compare the likelihood of innovation outcomes,

[12] $IND\_MB\ RATIO$ and $IND\_RD\ EXPENDITURE - SALES\ RATIO$ are based on the three-digit categories in the Japan Standard Industrial Classification (JSIC), while the industry dummies are constructed by aggregating several JSIC three-digit categories (see Table 1 for details).

DUM_INNOV, DUM_NTM, and DUM_NTF, for the treatment group and the control group and obtain the average treatment effect on the treated (ATET). To be precise, we estimate $E(y_1 - y_0|DUM\_STAGING = 1)$, where y_1 and y_0 represent the innovation outcome of the treatment and the control observations, respectively.

Logit model with interaction terms: To understand the mechanism through which staged project management encourages or discourages product innovation, we focus on milestones and feedback and estimate the logit model with interaction terms using the following specification:

$$\Pr(DUM\_INNOV_i) = \psi(\alpha + \beta_4 DUM\_STAGING_i + \beta_5 DUM\_STAGING_i \times DUM\_MILESTONES_i + \beta_6 DUM\_STAGING_i \times DUM\_FEEDBACK_i + \mathbf{X_i}\boldsymbol{\gamma}). \quad (5)$$

In this specification, β_4, $\beta_4 + \beta_5$, $\beta_4 + \beta_6$, and $\beta_4 + \beta_5 + \beta_6$ respectively capture the effect of staged project management for firms without milestones and feedback, with milestones only, with feedback only, and with both milestones and feedback. From the estimates, we can examine whether firms that employ milestones and feedback in addition to staged project management are more likely to introduce new products to the market than firms that do not employ staged project management.

3.3.3. Estimation for Hypotheses 2-1 and 2-2

Next, we examine the role of milestones and feedback for product innovation using the subsample of firms that employed staged project management. Doing so reduces the maximum number of observations in the following estimations to 294. Specifically, we estimate the following bivariate probit model to examine whether milestones and feedback are particularly beneficial for exploitative innovation and may be harmful for explorative innovation:

$$\Pr(DUM\_NTM_i) = \psi(\alpha + \theta_1 \text{MILESTONES}_i + \varphi_1 \text{FEEDBACK}_i + \mathbf{X_i}\boldsymbol{\gamma}), \quad (6)$$

$$\Pr(DUM\_NTF_i) = \psi(\alpha + \theta_2 \text{MILESTONES}_i + \varphi_2 \text{FEEDBACK}_i + \mathbf{X_i}\boldsymbol{\gamma}), \quad (7)$$

where MILESTONES_i and FEEDBACK_i respectively represent proxies for milestones and feedback.

First, to examine Hypothesis 2-1, we use dummy variable $DUM\_MILESTONE$. A priori, the sign of $\widehat{\theta_1}$ is either ambiguous or negative, as the effect of milestones on explorative innovation is ambiguous (Manso 2011) or negative (Ederer and Manso 2013). On the other hand, the sign on $\widehat{\theta_2}$ is expected to be positive. Alternatively, in order to further investigate whether and how the threat of termination posed by milestones affects product innovation, we use dummy variables that represent the importance of the achievement of milestones in continuing R&D projects, DUM_MS_FULLY, $DUM\_MS\_SOME\ EXTENT$, and $DUM\_MS\_NOT\ MUCH$ (the default is DUM_NOMS). We expect that firms that do not put much weight on the achievement of milestones are more likely to make new-to-market product innovations, whereas firms that take the achievement of milestones to a considerable extent into account are more likely to make new-to-firm innovations.

Second, to examine Hypothesis 2-2, we use dummy variable $DUM\_FEEDBACK$. Hypothesis 2-2 predicts that feedback is more beneficial for explorative than exploitative innovation, and we therefore expect the positive marginal effects of $\widehat{\varphi_1}$ to be larger than that of $\widehat{\varphi_2}$. Alternatively, in order to further investigate whose opinion at which stage is more valuable for making product innovations, we use $DUM\_FB\_INI\_RD$, $DUM\_FB\_INI\_NONRD$, $DUM\_FB\_INI\_EXP$, $DUM\_FB\_LATE\_RD$, $DUM\_FB\_LATE\_NONRD$, and $DUM\_FB\_LATE\_EXP$. It is possible to conceive of a range of scenarios regarding the effect of these different types of feedback. For example, if early feedback from people with superior expertise is important for explorative innovation as suggested by Azoulay et al.'s (2011) empirical study on scientific research grants (see Section 2.2), we expect $\widehat{\varphi_1}$ for $DUM\_FB\_INI\_EX$ (opinions from experts outside the firm in the initial stages) in Equation (6) to be significantly positive and larger than for other variables such as $DUM\_FB\_INI\_NONRD$ (opinions from non-R&D organizations within the firm in the initial stages). Another example is if feedback on product marketability just before the launch of a new product is important for exploitative innovation, we expect $\widehat{\varphi_2}$ for $DUM\_FB\_LATE\_NONRD$ (opinions from non-R&D organizations within the firm in the late stages) in Equation (7) to be significantly positive.

4. Results

4.1. The effect of staged project management

4.1.1. Baseline estimation results

Table 3 presents the estimation results of the logit regressions using Equation (1), which examine whether staged project management increases the likelihood of product innovation,

DUM_INNOV (Hypothesis 1). Looking at the results for specification (1), we find that the average marginal effect estimate for $DUM\_STAGING$ is significantly positive, indicating that firms that employed staged project management were more likely to introduce a new product in the market. This result is consistent with Hypothesis 1. Ceteris paribus, staged project management increased the likelihood of product innovation by 24.2 percentage points. Given that 54.8% of firms in our sample innovated (see Table 2), the quantitative impact of implementing staged project management on product innovation is substantial. Looking at the marginal effect estimates for the control variables, we find that most are insignificant. However, the marginal effect estimate for $DUM\_INTERNATIONAL\ EXCHANGE$ is significantly positive, indicating that firms that exported or imported technology in the form of patents, know-how, and/or technical guidance to and from firms abroad were more likely to introduce a new product.

When we use NUM_STAGES or $DURATION\_STAGE$ instead of $DUM\_STAGING$ (specifications (2) and (3)), the marginal effect estimate for NUM_STAGES is significantly positive, whereas the marginal effect for $DURATION\_STAGE$ is significantly negative. These results indicate that firms with a larger number of stages and shorter average duration per stage were more likely to introduce a new product and are also consistent with Hypothesis 1.

4.1.2. Robustness: Bivariate probit model

Next, we estimate the bivariate probit model to examine the possibility that the results in Table 3 reflect reverse causality, namely, that firms that employed staged project management tended to pursue exploitative rather than explorative innovations. Table 4 presents the estimation results for the bivariate probit regressions using Equations (2) and (3), in which the dependent variables are DUM_NTM and DUM_NTF, respectively. As shown in the last row of Table 4, the likelihood-ratio (LR) test of the null that the correlation (rho) is zero is rejected, indicating that employing bivariate probit models is appropriate.

Table 4 shows that the average marginal effect estimates for $DUM\_STAGING$ are positive and significant for both DUM_NTM and DUM_NTF, and the quantitative impacts are similar: 0.209 in the case of DUM_NTM and 0.205 in the case of DUM_NTF. On the one hand, the significant marginal effect of $DUM\_STAGING$ on DUM_NTF suggests that staged project management induces R&D employees to aim for exploitative innovation. On the other hand, the significant marginal effect of $DUM\_STAGING$ on DUM_NTM indicates that firms engaging in staged project management were more likely to make explorative innovations. We obtain quantitatively similar results when using NUM_STAGES and $DURATION\_STAGE$ instead of $DUM\_STAGING$ (results not reported). Overall, Table 4 shows that staged project management is positively correlated with the introduction of both new-to-market and new-to-firm products, suggesting that the results in Table 3 are not entirely attributable to any short-termism that staged project management may induce.

Turning to the marginal effect of the control variables, we find that they are all insignificant for DUM_NTM. In contrast, for DUM_NTF we find that $lnEMPLOYEES$ and $RESEARCHER - EMPLOYEE\ RATIO$ are significantly positive, indicating that larger firms and firms with a higher ratio of R&D researchers to total employees were more likely to make new-to-firm innovations. The marginal effect of $RD\ EXPENDITURE - SALES\ RATIO$ for DUM_NTF is significantly negative, indicating that R&D-intensity is negatively associated with the likelihood of new-to-firm innovation. One possible interpretation of this result is that R&D-intensive firms tend to pursue explorative innovation and thus were less likely to introduce new-to-firm products. However, contrary to this possible interpretation, R&D intensity did not affect the likelihood of new-to-market innovation as the marginal effect of $RD\ EXPENSE - SALES\ RATIO$ for DUM_NTM is insignificant.

4.1.3. Robustness: Propensity score matching

In this subsection, we report the PSM estimation results, which take the endogeneity of staged project management into account. Table 5 presents the estimation result for the logit regressions using Equation (4), in which the dependent variable is $DUM\_STAGING$. The table shows that firms were more likely to employ staged project management if they had a larger number of employees, a larger number of R&D projects, employed a hybrid R&D organizational structure, and/or had received external funds for R&D activities. These results are consistent with our prior expectations outlined in Section 3.3.2. Meanwhile, the average marginal effect estimates for the industry-level market-to-book ratio and R&D intensity are insignificant. Firms that belonged to the machinery and other manufacturing industries were more likely to employ staged project management.

We use the results of the logit estimations in Table 5 to calculate the propensity score of each observation and conduct PSM estimations.[13] Table 6 reports the average treatment effect on the treated for staged project management. We find that the treatment effect is

[13] Appendix Figure A1 shows that the probability density functions of the propensity score for treated and control firms are well balanced.

significantly positive for DUM_INNOV, DUM_NTM, and DUM_NTF and that the marginal impact is 19.9, 15.9, and 15.6 percentage points, respectively. These estimates are slightly smaller than but similar to the marginal effects obtained in Tables 3 and 4, confirming that staged project management increases the likelihood of making product innovations (Hypothesis 1).

4.1.4. Extension: Logit model with interaction terms

So far, we have examined whether staged project management affects product innovation. To further examine whether the way firms implement staged project management affects product innovation, we estimate a logit model using Equation (5), which includes interaction terms with dummy variables representing whether a firm set milestones and provided feedback.

Table 7 shows the average marginal effects of different combinations of staged project management, milestones, and feedback on product innovation. The default is firms that did not employ staged project management. We find that firms that employed staged project management but did not set milestones or provide feedback were no more likely to make product innovations than firms that did not employ staged project management. In contrast, firms that employed both milestones and feedback have a 27.7 percentage point higher likelihood of making product innovation. This marginal effect is larger than the average marginal effect of staged project management in Table 3 (24.2 percentage points). Interestingly, the average marginal effect for firms that only set milestones is statistically insignificant, while the marginal effect for firms that only provided feedback is significant. Overall, the results in Table 7 suggest that the provision of feedback in staged project management increases the likelihood of product innovation, while setting milestones does not affect it.[14] The next subsection provides further investigation of the role of milestones and feedback.

4.2. The effect of milestones and feedback

Tables 8 presents the estimation results for the bivariate probit regressions using Equations (6) and (7) to examine the effect of milestones and feedback on new-to-market and new-to-firm

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[14] In Appendix Table A3, we report estimation results using propensity score matching in which the treatment observations correspond to the different combinations of staged project management, milestones, and feedback discussed in the main text and in which the control observations are chosen from firms that did not employ staged project management. Most results are qualitatively the same as those in Table 7, except for the case where the treatment group corresponds to firms that employed staged project management but did not set milestones or provide feedback. In this case, the average treatment effect on the treated is significantly negative, indicating that firms that employed staged project management without incorporating milestones and feedback had a lower likelihood of making product innovations than firms that did not employ staged project management.

innovation. We use the subsample of firms that implemented staged project management. As a result, the number of observations drops to 294 and 291.

Specification (1) in Table 8 examines Hypotheses 2-1 and 2-2. In Hypothesis 2-1, we argued that the effect of milestones is positive for exploitative innovation but ambiguous for explorative innovation. However, in the results for specification (1), we find that $DUM\_MILESTONES$ is insignificant for both DUM_NTM and DUM_NTF. We do not find evidence of the expected differential effects of milestones on new-to-market and new-to-firm innovation. In Hypothesis 2-2, we argued that the positive effect of feedback on explorative innovation is larger than that on exploitative innovation. The results for specification (1) show that $DUM\_FEEDBACK$ is positive and significant for both DUM_NTM and DUM_NTF and the marginal impact is larger for DUM_NTM (0.248) than for DUM_NTF (0.140), which is consistent with Hypothesis 2-2.

Specification (2) in Table 8 further examines the effect of milestones and feedback on new-to-market and new-to-firm innovation. First, we find that to what extent a firm regarded the achievement of milestones as important in assessing the continuation of R&D projects did not affect the likelihood of product innovation. Specifically, the average marginal effects of DUM_MS_FULLY, $DUM\_MS\_SOME\ EXTENT$, and $DUM\_MS\_NOT\ MUCH$ are all insignificant, indicating that these firms were no more likely to make new-to-market or new-to-firm product innovations than firms that did not set milestones. That said, looking at the size of the average marginal effect estimates shows that the estimate for $DUM\_MS\_NOT\ MUCH$ with regard to new-to-market product innovation (0.150) is larger than those for DUM_MS_FULLY (0.061) and $DUM\_MS\_SOME\ EXTENT$ (0.058), which is consistent with our argument in Section 3.3.3. However, the larger standard error for $DUM\_MS\_NOT\ MUCH$, which may reflect the fact that the number of firms that selected this choice was smaller, prevents us from rejecting the null that it is different from zero. Second, the average marginal effect estimates for specification (2) in Table 8 produce some notable results regarding the effect of feedback on the introduction of new-to-market and new-to-firm products. To begin with, the average marginal effect of $DUM\_FB\_INI\_NONRD$ is significantly positive for new-to-market products. Meanwhile, the marginal impact of $DUM\_FB\_INI\_EXP$ on new-to-market products is statistically insignificant, although it is weakly correlated with new-to-market products, as shown by its *p*-value of 0.11. These results suggest that opinions from outside the R&D unit in the early stages were especially beneficial for explorative innovation. Next, the average marginal effect of $DUM\_FB\_LATE\_EXP$ is significantly negative for new-to-firm products. This suggests that feedback from external experts in the late stages is detrimental to exploitative innovation.

4.3. Discussion

Let us consider our estimation results in relation to Hypotheses 1 and 2 and previous studies. Consistent with Hypothesis 1, we found that firms that employed staged project management were more likely to introduce a new product to the market. We also found that staged project management was positively correlated with both new-to-market and new-to-firm product innovation, which suggests that the positive correlation between staged project management and product innovation is not entirely attributable to the possible reverse causality that R&D employees tended to choose exploitative innovation when their firms employed staged project management. We also implemented PSM estimation and found that the effect of staged project management on product innovation was significantly positive when the endogeneity of the choice of staged project management was taken into account.

As noted, staged project management has both advantages and disadvantages, and our findings suggest that the advantages of staged project management outweigh the disadvantages in the case of Japanese firms' R&D activities. Our results are consistent with the findings of Andries and Hünermund (2014), Klingebiel and Adner (2015), and Schultz et al. (2019) that staged project management is positively associated with successful new product development, but inconsistent with Mao et al.'s (2014) finding that the number of VC financing rounds negatively affected venture firms' innovation output. Our contribution to the literature is that we investigated the heterogeneity among firms that employed staged project management by examining whether the use of milestones and feedback affects innovation. Specifically, we found a positive effect of staged project management on product innovation for firms that provided feedback. However, firms that only set milestones and firms that used neither feedback nor milestones in their staged project management were no more likely to introduce new products to the market than firms that did not employ staged project management in the first place. Our findings suggest that the effect of staged project management on innovation depends on how firms implement it and shed light on why previous studies produced mixed results.

Second, we found that milestones were not associated with the likelihood of product innovation – either new-to-market or new-to-firm – among firms that employed staged project management. In Hypothesis 2-1, we predicted that the use of milestones is positively associated with exploitative innovation, whereas the association between milestones and explorative innovation is ambiguous. While the insignificant effect of milestones on new-to-market innovation is consistent with Hypothesis 2-1, the insignificant effect on new-to-firm innovation is inconsistent with Hypothesis 2-1. We also found that to what extent a firm regarded the achievement of milestones as important in assessing the continuation of R&D projects did not affect the likelihood of new-to-market and new-to-firm innovation. Our results are inconsistent with Ederer and Manso's (2013) experimental finding that the threat of termination undermined incentives for the pursuit of explorative innovations. While a thorough examination of why we obtained insignificant results with regard milestones is beyond the scope of this study, the following explanation suggests itself. In Hypothesis 2-1, we implicitly assumed that R&D employees face a larger threat of termination of the project when their firm sets milestones than when their firm does not set milestones. To check whether this assumption holds in our data, we examine the share of firms that terminated or suspended an R&D project during the three years of our observation period (i.e., between FY2016 and FY2018) using information from the R&D Management Survey. We find that the share is 69.0% for firms that employed both staged project management and milestones, whereas it is 65.7% for firms that employed staged project management but did not set milestones. The difference between the two groups is statistically insignificant. Similarly, among firms that set milestones, the shares are not significantly different irrespective of the extent to which firms regarded the achievement of milestones as important.[15] These results remain qualitatively unchanged when we implement logit estimations for the termination/suspension of R&D projects in which proxies for milestones as well as other covariates are included as independent variables (results not reported). Taken together, the findings suggest that in the case of Japanese firms, whether and how firms set milestones does not serve as an effective threat of termination of R&D projects, which is inconsistent with the implicit assumption in Hypothesis 2.

Third, consistent with Hypothesis 2-2, we found that feedback was positively associated with product innovation among firms that employed staged project management and that the marginal impact of feedback was larger for new-to-market innovation than for new-to-firm innovation. Our results are consistent with Manso's (2011) theoretical prediction that feedback is especially beneficial for exploration and Azoulay et al.'s (2011) empirical finding

[15] Specifically, the share is largest for firms that did not take the achievement of milestones "very much/at all" into account ($DUM\_MS\_NOT\ MUCH$) when deciding whether to continue the R&D project (81.5%). However, the difference between firms with $DUM\_MS\_NOT\ MUCH = 1$ and other firms that employed milestones (DUM_MS_FULLY and $DUM\_MS\_SOME\ EXTENT$) is not statistically significant.

that high-quality feedback to researchers encourages exploration. In addition to Hypothesis 2-2, we examined whose opinions were most useful for product innovation. We found that feedback from non-R&D organizations within the firm in the initial stages was positively associated with the introduction of new-to-market products. This result suggests that – at least in the case of Japanese firms – while the provision of different perspectives from outside the R&D unit in the initial stages is beneficial for explorative innovation, the feedback useful for the introduction of new-to-market products is likely to be more of a business nature (focusing, e.g., on the marketability of the product) than a technical nature (regarding, e.g., the exploration of unknown research methods). We also found that opinions from external experts in the late stages were negatively associated with new-to-firm innovation. This suggests that obtaining different perspectives from outside the firm in the late stages may be detrimental to the development of new-to-firm products. For example, suppose developing new-to-firm products poses no technological challenges and the type of feedback that is useful for new-to-firm products in the late stages consists mostly of marketing research and pilot tests. In this case, technical advice from external experts may hinder the introduction of new-to-firm innovations.

5. Conclusion

Using a unique firm survey on R&D management practices in Japan, this study empirically examined whether staged project management is beneficial or harmful for product innovation. While some studies have empirically examined the link between staged project management and innovation, they all used one particular firm survey, the German CIS. This study contributes to the literature by providing additional empirical evidence using a firm survey for another country, Japan. The specific contribution of this study is that it is the first to examine the role of milestones and feedback in staged project management in the context of corporate R&D activities.

Our empirical analysis yielded the following results. First, we found that firms that employed staged project management were more likely to introduce a new product in the market, especially when they provide feedback in the interim stages. Second, among firms that employed staged project management, the use of milestones did not affect the likelihood of new-to-market and new-to-firm product innovation. Third, among firms that employed staged project management, feedback was positively associated with product innovation, and the marginal effect was larger for new-to-market product innovation than for new-to-firm innovation. We also found a positive link between feedback that incorporated opinions from non-R&D organizations such as business units within the firm in the initial stages and product innovation. In a nutshell, we found that managing R&D projects in stages is beneficial for product innovation when combined with the provision of feedback and that the positive effect of feedback is stronger for introducing new-to-market products.

The findings of this study have several practical implications for innovation management by firms and innovation policy by governments. Some studies argue that staged project management will "emphasize control over flexibility and novelty" (Lenfle and Loch 2010) and thereby stifle explorative innovation. However, our finding that staged project management is positively associated with the introduction of not only new-to-firm but also new-to-market products suggests that this is not necessarily the case. While we cannot pin down particular mechanisms through which staged project management has a positive effect on explorative innovation, our analysis suggests that the provision of effective feedback is one of the key factors. It should be noted, however, that feedback may not always be beneficial for product innovation, since we found a negative link between feedback from external experts in the late stages and new-to-firm product innovation. It is likely that the effectiveness of feedback depends on the nature of innovation as well as the timing and providers of feedback. Finally, from a policy perspective, the positive link between staged project management and product innovation suggests that it is better to provide government R&D subsidies in stages rather than in a lump sum. Finding R&D subsidy program designs that create the right incentives to promote innovation is an important issue that we leave for future research.

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Table 1. Definition of variables

This table presents the definitions of the variables used in our estimations (Tables 3 to 8). In the column showing the data sources, "RDMP" stands for the Survey of R&D Management Practices, which provides information on firms' R&D management as of FY2018 unless otherwise stated. "SRD" stands for the 2019 Survey of Research and Development conducted by the Statistics Bureau of Japan, which provides information on firms as of FY 2018; for several firms, information was not available in the 2019 edition of the survey and we use the 2018 or 2017 edition instead. "JBS" stands for the 2019 Basic Survey of Japanese Business Structure and Activities conducted by the Ministry of Economy, Trade, and Industry, while "NFQ" stands for the Nikkei Financial QUEST database provided by Nikkei Media Marketing, Inc.

Variable	Definition	Data source
Dependent variables: Product innovation		
DUM_INNOV	Equals one if a firm introduced new or significantly improved goods/services to the market (i.e., product innovations) from FY2016 to FY2018, and zero otherwise.	RDMP
DUM_NTM	Equals one if a firm made one or more product innovations from FY2016 to FY2018 and the products were ones no competitor offered in the market, and zero otherwise.	RDMP
DUM_NTF	Equals one if a firm made one or more product innovations from FY2016 to FY2018 and the products were almost identical or very similar to ones already offered by competitors in the market, and zero otherwise.	RDMP
Main independent variables: Staged project management		
DUM_STAGING	Equals one if a firm implemented staged project management, and zero otherwise.	RDMP
NUM_STAGES	Average number of stages for R&D projects.	RDMP
DURATION_STAGE	Average number of years from the commencement of an R&D project to the achievement of final results divided by the average number of stages.	RDMP
DUM_MILESTONES	Equals one if a firm set intermediate goals (milestones) for the interim evaluation of projects, and zero otherwise. This variable is for firms that implemented staged project management (*DUM_STAGING*=1).	RDMP
DUM_MS_FULLY *DUM_MS_SOME EXTENT* *DUM_MS_NOT MUCH*	Dummy variables that indicate to what extent a firm took into account whether milestones were achieved when assessing whether to terminate/suspend or continue the R&D project in the initial stages of the project: *DUM_MS_FULLY* equals one if the answer is that milestones were "fully" taken into account, *DUM_MS_SOME EXTENT* equals one if they were "to some extent" taken into account, *DUM_MS_NOT MUCH* if they were either "not very much" or "not at all" taken into account, and zero if a firm did not set milestones. The default is firms that did not set milestones (*DUM_NOMS*). This variable is for firms that implemented staged project management (*DUM_STAGING*=1).	RDMP
DUM_FEEDBACK	Equals one if a firm provided feedback on the interim evaluation results to the R&D personnel in charge of the project, and zero otherwise. This variable is for firms that implemented staged project management (*DUM_STAGEING*=1).	RDMP
DUM_FB_INI_RD *DUM_FB_LATE_RD*	Equals one if a firm incorporated opinions from other research teams in the same or other R&D organizations when providing feedback in the initial (*_INI*) or late (*_LATE*) stages of a project, and zero	RDMP

	otherwise. This variable is for firms that implemented staged project management (*DUM_STAGING*=1).	
DUM_FB_INI_NONRD *DUM_FB_LATE_NONRD*	Equals one if a firm incorporated opinions from non-R&D organizations (business units and head office) within the company when providing feedback in the initial (*_INI*) or late (*_LATE*) stages of a project, and zero otherwise. This variable is for firms that implemented staged project management (*DUM_STAGING*=1).	RDMP
DUM_FB_INI_EXP *DUM_FB_LATE_EXP*	Equals one if a firm incorporated opinions (including informal ones) from experts outside the company when providing feedback in the initial (*_INI*) or late (*_LATE*) stages of a project, and zero otherwise. This variable is for firms that implemented staged project management (*DUM_STAGING*=1).	RDMP
Control variables		
lnEMPLOYEES	Natural logarithm of the number of employees.	SRD
RD EXPENDITURE-SALES RATIO	Total amount of R&D expenditure relative to total sales. Winsorized at the upper 1 percentile of the sample.	SRD
RESEARCHER-EMPLOYEE RATIO	Total number of R&D researchers relative to employees.	SRD
RESEARCH EXPENDITURE RATIO	Basic research expenditure to total R&D expenditure.	SRD
DEVELOPMENT EXPENDITURE RATIO	Development research expenditure to total R&D expenditure.	SRD
NUM_RD PROJECTS	Number of R&D projects in progress. Winsorized at the upper 1 percentile of the sample.	RDMP
DUM_INTERNATIONAL EXCHANGE	Equals one if a firm exported/imported technology in relation to or in the form of patents, know-how, and/or technical guidance to/from firms abroad, and zero otherwise.	SRD
DUM_CENTRALIZED	Equals one if a firm had one or more R&D units that were highly independent of business units (BUs) and did not have R&D units that were directly controlled by BUs, and zero otherwise. This variable is used as the default for R&D organizational structure.	RDMP
DUM_DECENTRALIZED	Equals one if a firm had one or more R&D units that were directly controlled by BUs and did not have R&D units that were highly independent of BUs, and zero otherwise.	RDMP
DUM_HYBRID	Equals one if a firm had one or more R&D units that were highly independent of BUs and R&D units that were directly controlled by BUs, and zero otherwise.	RDMP
Industry dummies	Seven industry dummies based on the three-digit code in the Japan Standard Industrial Classification (JSIC): Food, beverages, and tobacco (JSIC: 090–106), Chemical, petroleum, coal, and plastic products (JSIC:160–199, 210–219), Iron, steel, and non-ferrous metals products (JSIC: 220–249), Machinery and equipment (JSIC: 250–319), Miscellaneous manufacturing (JSIC: 110–119, 120–159, 200–209, 320–329), Information and communication (JSIC: 370–410), and Wholesale and retail trade (JSIC: 500–550). The default is Wholesale and retail trade.	SRD
Control variables for the PSM estimations		
DUM_EXTERNAL FUNDS	Equals one if a firm received R&D funds from external organizations (e.g., government, university, other firms), and zero otherwise.	SRD
IND_MB RATIO	Industry (JSIC three-digit code) average of the market-to-book ratio (the market value of equity divided by the book value of equity) as of FY2018.	NFQ
IND_RD EXPENDITURE-SALES RATIO	Industry (JSIC three-digit code) average of the ratio of R&D expenditures relative to total sales as of FY2018.	JBS

Table 2. Summary statistics: Product innovators and non-innovators

This table presents summary statistics for the variables used in the estimations (Tables 3 to 8). Definitions of the variables are provided in Table 1. The bloc of columns labeled "*DUM_INNOV* = 1" reports summary statistics for firms that made product innovations and that labeled "*DUM_INNOV* = 0" reports summary statistics for firms that did not make product innovations.

	Entire sample				*DUM_INNOV* = 1				*DUM_INNOV* = 0			
	N	Mean	SD	p50	N	Mean	SD	p50	N	Mean	SD	p50
Dependent variables for product innovation												
DUM_INNOV	557	0.548	0.498	1	305	1	0	1	252	0	0	0
DUM_NTM	557	0.320	0.467	0	305	0.584	0.494	1	252	0	0	0
DUM_NTF	557	0.456	0.499	0	305	0.833	0.374	1	252	0	0	0
Main independent variables for staged project management												
DUM_STAGING	557	0.530	0.500	1	305	0.656	0.476	1	252	0.377	0.486	0
NUM_STAGES	555	2.900	3.600	2	305	3.440	3.840	3	250	2.230	3.160	1
DURATION_STAGE	542	2.180	2.100	1.670	304	1.770	1.660	1	238	2.720	2.460	2
DUM_MILESTONES	556	0.414	0.493	0	305	0.528	0.500	1	251	0.275	0.447	0
DUM_MS_FULLY	294	0.218	0.413	0	200	0.240	0.428	0	94	0.170	0.378	0
DUM_MS_SOME EXTENT	294	0.473	0.500	0	200	0.465	0.500	0	94	0.489	0.503	0
DUM_MS_NOT MUCH	294	0.092	0.289	0	200	0.100	0.301	0	94	0.074	0.264	0
DUM_NOMS	294	0.218	0.413	0	200	0.195	0.397	0	94	0.266	0.444	0
DUM_FEEDBACK	556	0.451	0.498	0	305	0.584	0.494	1	251	0.291	0.455	0
FEEDBACK_INI_RD	291	0.608	0.489	1	198	0.631	0.484	1	93	0.559	0.499	1
FEEDBACK_INI_NONRD	291	0.601	0.490	1	198	0.657	0.476	1	93	0.484	0.502	0
FEEDBACK_INI_EXP	291	0.261	0.440	0	198	0.278	0.449	0	93	0.226	0.420	0
FEEDBACK_LATE_RD	291	0.471	0.500	0	198	0.490	0.501	0	93	0.430	0.498	0
FEEDBACK_LATE_NONRD	291	0.722	0.449	1	198	0.742	0.438	1	93	0.677	0.470	1
FEEDBACK_LATE_EXP	291	0.210	0.408	0	198	0.217	0.413	0	93	0.194	0.397	0
Control variables												
lnEMPLOYEES	557	5.790	1.240	5.720	305	5.980	1.290	5.870	252	5.560	1.140	5.530
RD EXPENDITURE-SALES RATIO	557	3.870	8.300	1.900	305	3.900	8.600	1.930	252	3.840	7.940	1.880
RESEARCHER-EMPLOYEE RATIO	557	9.160	11.200	5.910	305	9.510	11.600	5.590	252	8.740	10.600	6
RESEARCH EXPENDITURE RATIO	557	0.038	0.102	0	305	0.041	0.111	0	252	0.033	0.091	0
DEVELOPMENT EXPENDITURE RATIO	557	0.752	0.315	0.922	305	0.749	0.309	0.893	252	0.755	0.322	0.953
NUM_RD PROJECTS	557	23.100	53.700	7	305	29.800	63.900	10	252	15.000	36.500	5
DUM_INTERNATIONAL EXCHANGE	557	0.228	0.420	0	305	0.285	0.452	0	252	0.159	0.366	0
DUM_CENTRALZED	557	0.460	0.499	0	305	0.452	0.499	0	252	0.468	0.500	0
DUM_DECENTRALIZED	557	0.408	0.492	0	305	0.374	0.485	0	252	0.448	0.498	0
DUM_HYBRID	557	0.133	0.340	0	305	0.174	0.380	0	252	0.083	0.277	0
IND_FOOD	557	0.099	0.299	0	305	0.131	0.338	0	252	0.060	0.237	0
IND_CHEMICAL	557	0.275	0.447	0	305	0.252	0.435	0	252	0.302	0.460	0
IND_IRON	557	0.093	0.291	0	305	0.095	0.294	0	252	0.091	0.289	0
IND_MACHINERY	557	0.363	0.481	0	305	0.348	0.477	0	252	0.381	0.487	0
IND_OTHER_MANUF	557	0.093	0.291	0	305	0.105	0.307	0	252	0.079	0.271	0
IND_INFO	557	0.043	0.203	0	305	0.039	0.195	0	252	0.048	0.213	0
IND_WHOLESALES	557	0.034	0.182	0	305	0.030	0.170	0	252	0.040	0.196	0
Additional control variables for PSM estimations												
DUM_EXTERNAL FUNDS	575	0.447	0.498	0	314	0.484	0.501	0	261	0.402	0.491	0
IND_MB RATIO	575	2.010	1.740	1.440	314	1.940	1.650	1.440	261	2.090	1.830	1.460
IND_RD EXPENDITURE-SALES RATIO	575	4.170	3.230	3.840	314	3.930	3.180	3.210	261	4.450	3.270	3.920

Table 3. The effect of staged project management on product innovation: Logit regressions

This table presents the logit estimation results on the effect of staged project management ($DUM\_STAGING,\ NUM\_STAGES, DURATION\_STAGE$) on product innovations (DUM_INNOV). The column labeled "dy/dx" reports the average marginal effects, while the column labeled "S.E." reports their standard errors. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Estimation method: Logit	(1)		(2)		(3)	
Dependent variables:	*DUM_INNOV*		*DUM_INNOV*		*DUM_INNOV*	
	dy/dx	S.E.	dy/dx	S.E.	dy/dx	S.E.
DUM_STAGING	0.242 ***	0.043				
NUM_STAGES			0.033 ***	0.009		
DURATION_STAGE					-0.051 ***	0.011
lnEMPLOYEES	0.029	0.021	0.035	0.022	0.033	0.021
RD EXPENDITURE-SALES RATIO	-0.002	0.003	-0.001	0.003	0.000	0.003
RESEARCHER-EMPLOYEE RATIO	0.003	0.003	0.003	0.003	0.003	0.003
RESEARCH EXPENDITURE RATIO	-0.099	0.225	-0.035	0.229	-0.060	0.229
DEVELOPMENT EXPENDITURE RATIO	0.070	0.071	0.076	0.072	0.058	0.073
NUM_RD PROJECTS	0.000	0.001	0.001	0.001	0.001	0.001
DUM_INTERNATIONAL EXCHANGE	0.094 *	0.052	0.113 **	0.052	0.115 **	0.051
DUM_DECENTRALIZED	0.002	0.044	-0.011	0.045	-0.020	0.045
DUM_HYBRID	0.075	0.068	0.070	0.070	0.089	0.069
Industry dummies	YES		YES		YES	
Number of observations	557		555		542	
LR chi^2	73.49 ***		56.32 ***		68.46 ***	
Pseudo R^2	0.10		0.07		0.09	
Log likelihood	-346.81		-353.81		-337.43	

Table 4. The effect of staged project management on new-to-market and new-to-firm product innovation: Bivariate probit regression

This table presents the bivariate probit estimation results on the effect of staged project management ($DUM\_STAGING$) on new-to-market innovation (DUM_NTM) and new-to-firm innovation (DUM_NTF). The column labeled "dy/dx" reports the average marginal effects, while the column labeled "S.E." reports their standard errors. The row labeled "LR test: rho=0" reports the correlation coefficient of the error terms and the result of the likelihood-ratio test for the null that the correlation coefficient is zero. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Estimation method: Bivariate probit				
Dependent variables:	*DUM_NTM*		*DUM_NTF*	
	dy/dx	S.E.	dy/dx	S.E.
DUM_STAGING	0.209 ***	0.040	0.205 ***	0.043
lnEMPLOYEES	0.011	0.020	0.057 ***	0.021
RD EXPENDITURE-SALES RATIO	0.000	0.003	-0.008 **	0.003
RESEARCHER-EMPLOYEE RATIO	0.002	0.002	0.006 **	0.003
RESEARCH EXPENDITURE RATIO	0.010	0.201	-0.290	0.218
DEVELOPMENT EXPENDITURE RATIO	-0.014	0.068	0.063	0.071
NUM_RD PROJECTS	0.000	0.000	0.001	0.001
DUM_INTERNATIONAL EXCHANGE	0.016	0.049	0.074	0.052
DUM_DECENTRALIZED	0.054	0.043	0.036	0.044
DUM_HYBRID	-0.033	0.060	0.093	0.068
Industry dummies	YES		YES	
Number of observations	557			
Wald chi^2	88.63 ***			
Log likelihood	-647.37			
LR test: rho=0	0.52 ***			

Table 5. The determinants of staged project management: Logit regression

This table presents the logit estimation results on the determinants of staged project management ($DUM\_STAGING$). The column labeled "dy/dx" reports the average marginal effects, while the column labeled "S.E." reports their standard errors. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Estimation method: Logit			
Dependent variable:	*DUM_STAGING*		
	dy/dx		S.E.
lnEMPLOYEES	0.048	***	0.018
NUM_RD PROJECTS	0.002	**	0.001
DUM_HYBRID	0.180	***	0.064
DUM_EXTERNAL FUNDS	0.084	**	0.041
IND_MB RATIO	0.033		0.020
IND_RD EXPENDITURE-SALES RATIO	-0.009		0.012
IND_FOOD	0.089		0.123
IND_CHEMICAL	0.165		0.106
IND_IRON	0.010		0.129
IND_MACHINERY	0.204	*	0.110
IND_OTHER_MANUF	0.218	**	0.106
IND_INFO	-0.202		0.146
Constant			
Number of observations	576		
LR chi^2	76.05	***	
Pseudo R^2	0.10		
Log likelihood	-360.55		

Table 6. The effect of staged project management on product innovation: Propensity score matching regressions

This table presents the propensity score matching estimation results on the effect of staged project management ($DUM\_STAGING$) on product innovation (DUM_INNOV), new-to-market innovation (DUM_NTM) and new-to-firm innovation (DUM_NTF). The row labeled "ATET" reports the average treatment effects on the treated, while the row labeled "S.E." reports their standard errors. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Estimation method: Propensity score matching	(1)	(2)	(3)
Outcome variables:	*DUM_INNOV*	*DUM_NTM*	*DUM_NTF*
ATET	0.199 ***	0.159 ***	0.156 ***
S.E.	0.054	0.049	0.054
Number of observations	575	575	575

Table 7. The effect of different combinations of staged project management, milestones, and feedback on product innovation: Logit regression

This table presents the logit estimation results on the effect of different combinations of staged project management, milestones, and feedback ($DUM\_STAGING, DUM\_MILESTONES,\ DUM\_FEEDBACK$) on product innovation (DUM_INNOV). The column labeled "dy/dx" reports the average marginal effects, while the column labeled "S.E." reports their standard errors. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Estimation method: Logit			
Dependent variables:		*DUM_INNOV*	
		dy/dx	S.E.
DUM_STAGING	β_4	0.064	0.090
DUM_STAGING × *DUM_MILESTONES*	β_5	0.037	0.070
DUM_STAGING × *DUM_FEEDBACK*	β_6	0.177 **	0.082
Control variables		YES	
Industry dummies		YES	
Combined effects of staged project management, milestones, and feedback			
(*DUM_STAGING, DUM_MILESTONES, DUM_FEEDBACK*) = (1, 0, 0)	β_4	0.064	0.090
(*DUM_STAGING, DUM_MILESTONES, DUM_FEEDBACK*) = (1, 1, 0)	$\beta_4 + \beta_5$	0.100	0.085
(*DUM_STAGING, DUM_MILESTONES, DUM_FEEDBACK*) = (1, 0, 1)	$\beta_4 + \beta_6$	0.241 ***	0.072
(*DUM_STAGING, DUM_MILESTONES, DUM_FEEDBACK*) = (1, 1, 1)	$\beta_4 + \beta_5 + \beta_6$	0.277 ***	0.045
Number of observations		556	
LR chi^2		79.76 ***	
Pseudo R^2		0.10	
Log likelihood		-342.88	

Table 8. The effect of milestones and feedback on new-to-market and new-to-firm product innovation: Bivariate probit regressions

This table presents the bivariate probit estimation results on the effect of milestones ($DUM\_MILESTONES$, DUM_MS_FULLY, $DUM\_MS\_SOME\ EXTENT$, $DUM\_MS\_NOT\ MUCH$) and feedback ($DUM\_FEEDBACK$, $FEEDBACK\_INI\_RD$, $FEEDBACK\_INI\_NONRD$, $FEEDBACK\_INI\_EXP$, $FEEDBACK\_LATE\_RD$, $FEEDBACK\_LATE\_NONRD$, $FEEDBACK\_LATE\_EXP$) on new-to-market innovation (DUM_NTM) and new-to-firm innovation (DUM_NTF). The column labeled "dy/dx" reports the average marginal effects, while the column labeled "S.E." reports their standard errors. The row labeled "LR test: rho=0" reports the correlation coefficient of the error terms and the result of the likelihood-ratio test for the null that the correlation coefficient is zero. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Estimation method: Bivariate probit	(1)				(2)			
Dependent variables:	*DUM_NTM*		*DUM_NTF*		*DUM_NTM*		*DUM_NTF*	
	dy/dx	S.E.	dy/dx	S.E.	dy/dx	S.E.	dy/dx	S.E.
DUM_MILESTONES	0.044	0.071	0.039	0.070				
DUM_MS_FULLY					0.061	0.090	0.109	0.082
DUM_MS_SOME EXTENT					0.058	0.074	0.034	0.072
DUM_MS_NOT MUCH					0.150	0.115	0.018	0.111
DUM_FEEDBACK	0.248 ***	0.070	0.140 *	0.081				
DUM_FB_INI_RD					0.027	0.074	-0.060	0.071
DUM_FB_INI_NONRD					0.137 **	0.067	0.063	0.066
DUM_FB_INI_EXP					0.125	0.079	0.079	0.075
DUM_FB_LATE_RD					0.057	0.075	0.111	0.072
DUM_FB_LATE_NONRD					-0.020	0.075	-0.012	0.072
DUM_FB_LATE_EXP					-0.059	0.081	-0.169 **	0.081
Control variables	YES		YES		YES		YES	
Industry dummies	YES		YES		YES		YES	
Number of observations	294				291			
Wald chi^2	45.69 *				53.44			
Log likelihood	-358.94				-351.04			
LR test: rho=0	0.49 ***				0.50 ***			

Appendix: Construction of key variables and control variables

This appendix presents how we constructed our key variables outlined in Section 3.2 and control variables in Section 3.3 in the main text.

Dependent variables for product innovation: The R&D Management Survey asked respondent firms whether they introduced new or improved products in the market during the preceding three years, from FY2016 to FY2018. We construct DUM_INNOV using this question. In the survey, product innovation refers to new or significantly improved goods or services with respect to their technical specifications, components and materials, software in the product, user friendliness, or other functional characteristics that include new combinations of existing technologies or technology upgrades of existing goods or services.

For firms that introduced product innovations in the market, the survey asked follow-up questions on the novelty of the product innovations, namely whether they involved "new-to-market" products and/or "new-to-firm" products. We construct DUM_NTM and DUM_NTF using these questions. In the survey, new-to-market products are new or significantly improved goods or services that no competitor offered in the market, while new-to-firm products are new or significantly improved goods or services that were almost identical or very similar to ones already offered by competitors in the market. The definition of product innovation and the novelty of innovations in our survey is based on the Oslo Manual 2018 by the Organisation for Economic Co-operation and Development, which provides international guidelines on innovation statistics.

Independent variables for staged project management: The R&D Management Survey asked firms whether they implemented staged project management of their R&D projects in FY2018. Using this information, we construct $DUM\_STAGING$. For firms that implemented staged project management, the survey then asked about the average number of stages (NUM_STAGES) and the duration of each stage ($DURATION\_STAGE$).

The survey also asked firms whether they set milestones for the interim evaluation of a project ($DUM\_MILESTONES$) and whether they provided feedback on the interim evaluation results to the R&D employee in charge of the project ($DUM\_FEEDBACK$). In addition, for firms that set milestones, the survey asked about the importance of intermediate goals (milestones) in assessing whether to terminate/suspend or continue the R&D project in the "initial stages" (e.g., idea/basic research) and "late stages" (e.g., preparation for launch of new goods/services). Concretely, the survey asked to what extent firms took into account whether milestones were achieved on a four-point scale (4: milestones fully taken into account, 3: to some extent taken into account, 2: not very much taken into account, 1: not at all taken into account). Using this question for the initial stages, we construct the dummy variables DUM_MS_FULLY for firms that chose "4", $DUM\_MS\_SOME\ EXTENT$ for firms that chose "3", $DUM\_MS\_NOT\ MUCH$ for firms that chose "2" or "1", and DUM_NOMS for firms that did not set milestones. The default is DUM_NOMS. We choose the initial stages because the threat of termination of an R&D project posed by milestones is likely to be higher in the initial stages than in the late stages. It should be noted, however, that we obtain qualitatively similar estimation results when we use these dummies for the late stages.

For firms that provided feedback to R&D employees, the survey additionally asked whether they incorporated opinions of the following people in the interim evaluation of projects: (a) opinions from other research teams in the same or other R&D organizations, (b) opinions from non-R&D organizations within the same firm, and (c) opinions from experts outside the firm. The three options are not mutually exclusive, and we again divided project management stages into the initial and late stages and asked respondents in which stage these opinions were incorporated to construct $DUM\_FB\_INI\_RD$, $DUM\_FB\_INI\_NONRD$, $DUM\_FB\_INI\_EXP$, $DUM\_FB\_LATE\_RD$, $DUM\_FB\_LATE\_NONRD$, and $DUM\_FB\_LATE\_EXP$.

Control variables: Control variables are constructed from the R&D Management Survey and the Survey of Research and Development. Innovation output is likely to be influenced by firm size and R&D inputs (D'Este 2016, Reeb and Zhao 2022). We use the number of employees in natural logarithm ($lnEMPLOYEES$) as a proxy for firm size, total R&D expenditure relative to a firm's total sales ($RD\ EXPENDITURE - SALES\ RATIO$) and total number of R&D researchers relative to employees ($RESEARCHER - EMPLOYEE\ RATIO$) as proxies for the intensity of R&D inputs. In addition, to control for the possibility that firms pursing explorative innovations spend more on basic research than on development and applied research (Mohnen et al. 2006, Robin and Schubert 2013), we include the ratio of expenditure on basic research to total R&D expenditure ($RESEARCH\ EXPENDITURE\ RATIO$) and the ratio of development research expenditure to total R&D expenditure ($DEVELOPMENT\ EXPENDITURE\ RATIO$). [16] Because our dependent variable does not take the number of product innovations that a firm made into account, we use the number of R&D projects in progress ($NUM\_RD\ PROJECTS$) to control for the possibility that firms having more R&D projects in progress have a higher likelihood of making at least one product innovation (Klingebiel and Rammer 2014, Andries and Hünermund 2020). We also use industry dummy variables to control for industry-specific factors.

In addition to the above-mentioned variables on firm size, R&D inputs, and the number of R&D projects, we include the following control variables representing firms' internal organizational structure with regard to R&D (see Azoulay and Lerner (2012) for a review on how firms' organization structure affects innovation). First, to capture the possibility that international knowledge spillovers of technological information through, e.g., foreign direct investment, sponsorships, and collaborations, affect innovation (Branstetter 2006, Penner-Hahn and Shaver 2005), we use a dummy variable indicating whether a firm implemented international technological exchanges, i.e., whether it exported or imported technology in the form of patents, know-how, and/or technical guidance to and from firms abroad ($DUM\_INTERNATIONAL\ EXCHANGE$). Second, firms with "centralized" R&D organizational structures may generate more explorative innovations than firms with "decentralized" R&D structures (Argyres and Silverman 2004). To control for this possibility, we construct dummy variables indicating whether a firm's R&D units were highly independent R&D units (e.g., a central research laboratory), R&D units that are directly controlled by business units, or a combination of both, and denote these by $DUM\_CENTRALIZED$, $DUM\_DECENTRALIZED$, and DUM_HYBRID, respectively.

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[16] In the Survey of Research and Development, firms report their total R&D expenditure in three categories: basic, development, and applied research.

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Appendix Table A1. Summary statistics: Firms with and without staged project management

This table presents summary statistics for the variables used in the estimations (Tables 3 to 8). Definitions of the variables are provided in Table 1. The bloc of columns labeled "*DUM_STAGING*=1" reports summary statistics for firms that employed staged project management and that labeled "*DUM_STAGING*=0" reports summary statistics for firms that did not employ staged project management.

	Entire sample				*DUM_STAGING* = 1				*DUM_STAGING* = 0			
	N	Mean	SD	p50	N	Mean	SD	p50	N	Mean	SD	p50
Dependent variables for product innovation												
DUM_INNOV	557	0.548	0.498	1	295	0.678	0.468	1	262	0.401	0.491	0
DUM_NTM	557	0.320	0.467	0	295	0.420	0.494	0	262	0.206	0.405	0
DUM_NTF	557	0.456	0.499	0	295	0.573	0.496	1	262	0.324	0.469	0
Main independent variables for staged project management												
DUM_STAGING	557	0.530	0.500	1	295	1	0	1	262	0	0	0
NUM_STAGES	555	2.900	3.600	2	293	4.590	4.290	4	262	1	0	1
DURATION_STAGE	542	2.180	2.100	1.670	293	1.070	0.899	0.8	249	3.490	2.350	3
DUM_MILESTONES	556	0.414	0.493	0	294	0.782	0.413	1	262	0	0	0
DUM_MS_FULLY	294	0.218	0.413	0	294	0.218	0.413	0	------	------	------	------
DUM_MS_SOME EXTENT	294	0.473	0.500	0	294	0.473	0.500	0	------	------	------	------
DUM_MS_NOT MUCH	294	0.092	0.289	0	294	0.092	0.289	0	------	------	------	------
DUM_NOMS	294	0.218	0.413	0	294	0.218	0.413	0	------	------	------	------
DUM_FEEDBACK	556	0.451	0.498	0	294	0.854	0.354	1	262	0	0	0
FEEDBACK_INI_RD	291	0.608	0.489	1	291	0.608	0.489	1	------	------	------	------
FEEDBACK_INI_NONRD	291	0.601	0.490	1	291	0.601	0.490	1	------	------	------	------
FEEDBACK_INI_EXP	291	0.261	0.440	0	291	0.261	0.440	0	------	------	------	------
FEEDBACK_LATE_RD	291	0.471	0.500	0	291	0.471	0.500	0	------	------	------	------
FEEDBACK_LATE_NONRD	291	0.722	0.449	1	291	0.722	0.449	1	------	------	------	------
FEEDBACK_LATE_EXP	291	0.210	0.408	0	291	0.210	0.408	0	------	------	------	------
Control variables												
lnEMPLOYEE	557	5.790	1.240	5.720	295	6.070	1.230	5.900	262	5.480	1.180	5.530
RD EXPENDITURE-SALES RATIO	557	3.870	8.300	1.900	295	4.270	8.340	2.290	262	3.430	8.240	1.400
RESEARCHER-EMPLOYEE RATIO	557	9.160	11.200	5.910	295	9.570	11.100	6.580	262	8.700	11.200	5.310
RESEARCH EXPENDITURE RATIO	557	0.038	0.102	0	295	0.047	0.117	0	262	0.027	0.081	0
DEVELOPMENT EXPENDITURE RATIO	557	0.752	0.315	0.922	295	0.732	0.318	0.870	262	0.774	0.310	0.984
NUM_RD PROJECTS	557	23.100	53.700	7	295	32.400	65.100	10	262	12.700	34.200	4
DUM_INTERNATIONAL EXCHANGE	557	0.228	0.420	0	295	0.298	0.458	0	262	0.149	0.357	0
DUM_CENTRALZED	557	0.460	0.499	0	295	0.458	0.499	0	262	0.462	0.499	0
DUM_DECENTRALIZED	557	0.408	0.492	0	295	0.349	0.478	0	262	0.473	0.500	0
DUM_HYBRID	557	0.133	0.340	0	295	0.193	0.395	0	262	0.065	0.247	0
IND_FOOD	557	0.099	0.299	0	295	0.095	0.294	0	262	0.103	0.305	0
IND_CHEMICAL	557	0.275	0.447	0	295	0.285	0.452	0	262	0.263	0.441	0
IND_IRON	557	0.093	0.291	0	295	0.075	0.263	0	262	0.115	0.319	0
IND_MACHINERY	557	0.363	0.481	0	295	0.403	0.491	0	262	0.317	0.466	0
IND_OTHER_MANUF	557	0.093	0.291	0	295	0.105	0.307	0	262	0.080	0.272	0
IND_INFO	557	0.043	0.203	0	295	0.017	0.129	0	262	0.073	0.260	0
IND_WHOLESALES	557	0.034	0.182	0	295	0.020	0.141	0	262	0.050	0.218	0
Additional control variables for PSM estimations												
DUM_EXTERNAL FUNDS	575	0.447	0.498	0	302	0.520	0.500	1	273	0.366	0.483	0
IND_MB RATIO	575	2.010	1.740	1.440	302	2.060	1.770	1.460	273	1.950	1.700	1.440
IND_RD EXPENDITURE-SALES RATIO	575	4.170	3.230	3.840	302	4.480	3.370	3.920	273	3.830	3.040	3.210

Appendix Table A2. Correlation matrix

This table presents the correlation matrix for the variables used in the estimations (Tables 3 to 8). Definitions of the variables are provided in Table 1.

Panel A: Entire sample (N=537)

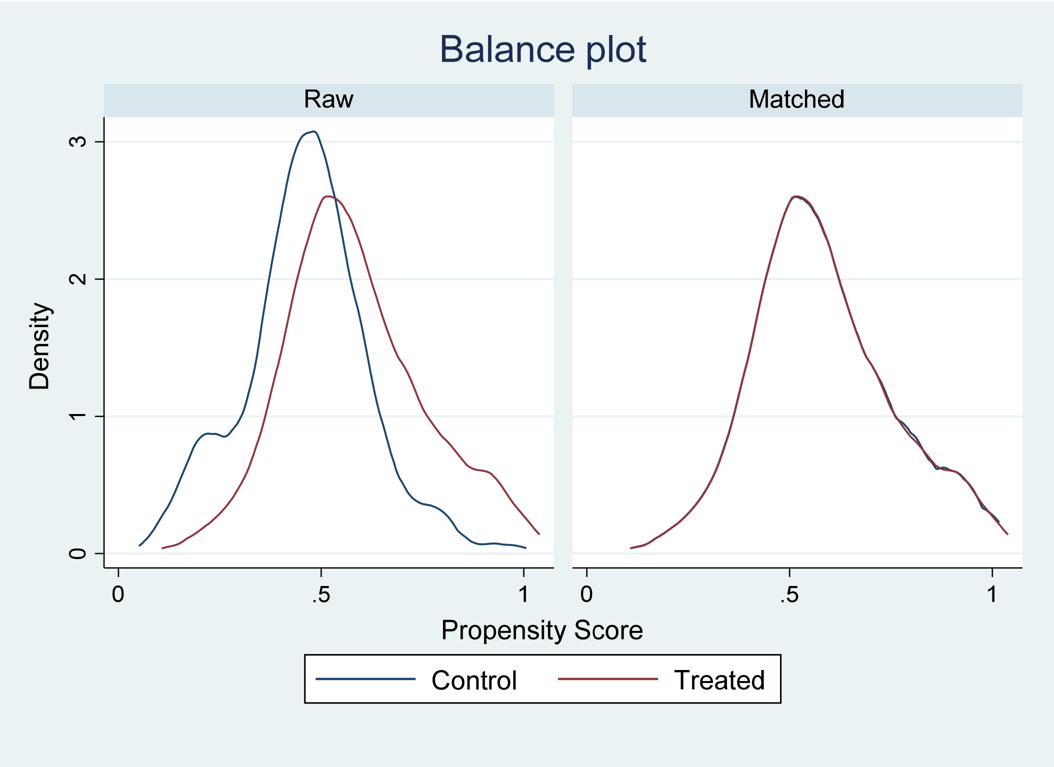
Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)	(33)	(34)	(35)	(36)	(37)	(38)
Dependent variables for product innovation																																						
(1) *DUM_INNOV*	1																																					
(2) *DUM_NTM*	0.62	1																																				
(3) *DUM_NTF*	0.83	0.35	1																																			
Main independent variables for staged project management																																						
(4) *DUM_STAGING*	0.27	0.22	0.24	1																																		
(5) *NUM_STAGES*	0.16	0.13	0.12	0.49	1																																	
(6) *DURATION_STAGE*	-0.23	-0.17	-0.20	-0.57	-0.37	1																																
(7) *DUM_MILESTONES*	0.24	0.20	0.22	0.79	0.39	-0.44	1																															
(8) *DUM_MS_FULLY*	0.13	0.13	0.14	0.33	0.23	-0.18	0.42	1																														
(9) *DUM_MS_SOME EXTENT*	0.13	0.09	0.13	0.54	0.18	-0.30	0.69	-0.21	1																													
(10) *DUM_MS_NOT MUCH*	0.08	0.08	0.04	0.21	0.18	-0.13	0.27	-0.08	-0.14	1																												
(11) *DUM_NOMS*	0.05	0.03	0.04	0.33	0.16	-0.21	-0.31	-0.13	-0.21	-0.08	1																											
(12) *DUM_FEEDBACK*	0.28	0.26	0.25	0.85	0.41	-0.49	0.74	0.38	0.47	0.16	0.19	1																										
(13) *FEEDBACK_INI_RD*	0.21	0.20	0.17	0.65	0.32	-0.37	0.55	0.34	0.32	0.11	0.16	0.76	1																									
(14) *FEEDBACK_INI_NONRD*	0.26	0.24	0.20	0.64	0.33	-0.37	0.51	0.37	0.25	0.11	0.21	0.75	0.61	1																								
(15) *FEEDBACK_INI_EXP*	0.14	0.15	0.11	0.37	0.15	-0.19	0.35	0.22	0.18	0.10	0.04	0.44	0.36	0.41	1																							
(16) *FEEDBACK_LATE_RD*	0.17	0.18	0.17	0.54	0.21	-0.31	0.48	0.26	0.29	0.12	0.11	0.63	0.73	0.52	0.33	1																						
(17) *FEEDBACK_LATE_NONRD*	0.23	0.20	0.20	0.74	0.33	-0.41	0.65	0.31	0.40	0.20	0.15	0.86	0.64	0.66	0.43	0.65	1																					
(18) *FEEDBACK_LATE_EXP*	0.11	0.12	0.04	0.33	0.18	-0.16	0.29	0.20	0.13	0.11	0.06	0.38	0.35	0.41	0.57	0.40	0.41	1																				
Control variables																																						
(19) *lnEMPLOYEES*	0.16	0.07	0.21	0.25	0.16	-0.14	0.29	0.13	0.16	0.14	-0.06	0.21	0.17	0.12	0.09	0.14	0.20	0.07	1																			
(20) *RD EXPENDITURE-SALES RATIO*	0.01	0.06	-0.06	0.07	0.02	-0.03	0.09	0.01	0.07	0.03	-0.03	0.08	0.04	0.05	0.09	0.04	0.09	0.12	-0.21	1																		
(21) *RESEARCHER-EMPLOYEE RATIO*	0.05	0.07	0.03	0.04	0.02	-0.03	0.04	0.00	0.04	0.01	-0.01	0.04	0.03	0.05	0.03	0.01	0.05	0.06	-0.21	0.66	1																	
(22) *RESEARCH EXPENDITURE RATIO*	0.04	0.04	-0.02	0.10	0.01	-0.04	0.11	0.03	0.06	0.09	0.00	0.06	0.08	-0.03	-0.01	0.04	0.07	0.06	0.14	0.01	-0.01	1																
(23) *DEVELOPMENT EXPENDITURE RATIO*	-0.01	-0.03	0.01	-0.07	-0.02	-0.01	-0.08	-0.03	-0.03	-0.08	0.01	-0.04	-0.05	0.03	0.03	-0.03	-0.06	-0.04	-0.17	-0.02	0.00	-0.42	1															
(24) *NUM_RD PROJECTS*	0.15	0.12	0.17	0.20	0.15	-0.12	0.22	0.17	0.07	0.11	-0.02	0.18	0.15	0.12	0.09	0.12	0.15	0.12	0.43	0.09	0.17	0.04	-0.04	1														
(25) *DUM_INTERNATIONAL EXCHANGE*	0.15	0.07	0.15	0.19	0.08	-0.07	0.21	0.07	0.16	0.06	-0.03	0.18	0.11	0.09	0.08	0.11	0.20	0.08	0.32	0.00	0.08	0.09	-0.11	0.24	1													
(26) *DUM_CENTRALZED*	-0.02	-0.03	-0.05	-0.01	-0.07	0.06	0.00	-0.05	0.04	-0.01	-0.02	0.00	0.02	-0.04	0.02	0.02	0.00	0.03	0.04	-0.06	-0.02	0.02	-0.10	-0.09	0.02	1												
(27) *DUM_DECENTRALIZED*	-0.08	0.02	-0.06	-0.13	-0.09	0.01	-0.14	0.00	-0.13	-0.05	0.01	-0.13	-0.08	-0.03	-0.07	-0.11	-0.12	-0.08	-0.26	0.04	-0.02	-0.10	0.16	-0.13	-0.14	-0.76	1											
(28) *DUM_HYBRID*	0.14	0.03	0.16	0.20	0.24	-0.10	0.19	0.08	0.12	0.08	0.01	0.19	0.10	0.11	0.08	0.12	0.18	0.07	0.32	0.03	0.07	0.11	-0.08	0.31	0.18	-0.36	-0.33	1										
(29) *IND_FOOD*	0.14	0.07	0.07	0.00	-0.02	-0.04	-0.04	0.06	-0.08	-0.02	0.06	0.00	0.01	-0.04	-0.11	0.00	0.00	-0.02	0.03	-0.09	-0.12	0.22	-0.12	-0.03	0.00	0.03	-0.02	-0.02	1									
(30) *IND_CHEMICAL*	-0.06	-0.01	-0.03	0.02	0.03	0.00	0.01	0.00	0.02	-0.03	0.03	0.04	0.01	0.04	0.04	0.04	0.03	0.06	-0.08	-0.04	0.01	0.01	-0.02	-0.02	0.06	0.14	-0.11	-0.05	-0.20	1								
(31) *IND_IRON*	0.01	-0.02	0.02	-0.07	-0.01	0.09	-0.02	-0.02	-0.03	0.04	-0.08	-0.03	0.00	0.01	-0.02	0.01	0.00	-0.03	0.09	-0.09	-0.12	-0.03	0.01	0.05	-0.04	0.00	-0.05	0.08	-0.11	-0.20	1							
(32) *IND_MACHINERY*	-0.03	0.00	-0.02	0.08	0.07	-0.07	0.06	0.03	0.04	0.02	0.03	0.05	0.01	0.05	0.05	0.00	0.04	-0.02	0.10	0.10	0.09	-0.07	0.09	0.04	0.06	-0.16	0.11	0.08	-0.25	-0.47	-0.25	1						
(33) *IND_OTHER_MANUF*	0.03	0.00	0.02	0.05	-0.04	-0.03	0.04	0.00	0.07	-0.05	0.00	0.02	0.03	0.01	-0.02	0.00	0.00	0.03	0.03	-0.08	-0.12	-0.03	-0.01	-0.04	-0.04	0.01	0.01	-0.03	-0.11	-0.20	-0.10	-0.25	1					
(34) *IND_INFO*	-0.03	0.00	-0.04	-0.14	-0.09	0.08	-0.09	-0.08	-0.04	-0.01	-0.08	-0.11	-0.09	-0.11	-0.04	-0.09	-0.12	-0.05	-0.12	0.22	0.28	-0.04	-0.02	-0.03	-0.10	0.04	0.00	-0.06	-0.07	-0.13	-0.07	-0.16	-0.07	1				
(35) *IND_WHOLESALES*	-0.02	-0.05	-0.01	-0.08	-0.04	0.07	-0.06	-0.06	-0.05	0.06	-0.03	-0.07	-0.03	-0.07	0.06	-0.03	-0.05	0.01	-0.18	-0.02	0.04	-0.05	0.06	-0.02	-0.07	-0.03	0.08	-0.07	-0.06	-0.11	-0.06	-0.13	-0.06	-0.04	1			
Additional control variables for PSM estimations																																						
(36) *DUM_EXTERNAL FUNDS*	0.06	0.06	0.04	0.14	0.03	0.02	0.19	0.04	0.17	0.04	-0.07	0.13	0.11	0.09	0.15	0.13	0.14	0.17	0.21	0.10	0.07	0.13	-0.24	0.16	0.16	0.08	-0.18	0.14	0.07	0.01	0.02	-0.03	-0.03	-0.06	0.01	1		
(37) *IND_MB RATIO*	-0.04	-0.02	-0.09	0.02	0.09	0.03	0.04	0.06	-0.02	0.05	-0.03	0.03	0.05	0.05	0.05	0.02	0.03	0.18	-0.01	0.20	0.15	0.00	-0.05	-0.03	-0.07	0.06	-0.04	-0.04	0.02	0.16	-0.18	-0.14	-0.07	0.34	-0.05	0.06	1	
(38) *IND_RD EXPENDITURE-SALES RATIO*	-0.08	0.00	-0.11	0.10	0.15	-0.03	0.10	0.04	0.04	0.09	0.00	0.07	0.05	0.08	0.07	0.03	0.08	0.13	0.07	0.18	0.11	-0.08	0.04	0.01	0.05	-0.02	-0.01	0.05	-0.31	0.14	-0.29	0.40	-0.16	-0.06	-0.11	0.04	0.62	1

Panel B: Subsample of firms that implemented staged project management, DUM_STAGING=1 (N=289)

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)	(33)	(34)	(35)	(36)	(37)	(38)
Dependent variables for product innovation																																						
(1) *DUM_INNOV*	1																																					
(2) *DUM_NTM*	0.58	1																																				
(3) *DUM_NTF*	0.79	0.31	1																																			
Main independent variables for staged project management																																						
(4) *DUM_STAGING*	.	.	.	.																																		
(5) *NUM_STAGES*	0.04	0.04	0.00	.	1																																	
(6) *DURATION_STAGE*	-0.08	-0.08	-0.05	.	-0.33	1																																
(7) *DUM_MILESTONES*	0.06	0.05	0.07	.	0.00	0.08	1																															
(8) *DUM_MS_FULLY*	0.06	0.08	0.09		0.00	0.04	0.27	1																														
(9) *DUM_MS_SOME EXTENT*	-0.02	0.08	0.09		0.08	0.04	0.50	-0.50	1																													
(10) *DUM_MS_NOT MUCH*	0.04	0.04	-0.01		0.09	-0.01	0.17	-0.17	-0.31	1																												
(11) *DUM_NOMS*	-0.06	-0.05	-0.07		0.00	-0.08	-1.00	-0.27	-0.50	-0.17	1																											
(12) *DUM_FEEDBACK*	0.14	0.17	0.10	.	-0.02	-0.01	0.19	0.24	0.21	-0.04	-0.19	1																										
(13) *FEEDBACK_INI_RD*	0.06	0.10	0.02	.	-0.01	0.03	0.09	0.14	0.10	-0.04	-0.09	0.52	1																									
(14) *FEEDBACK_INI_NONRD*	0.16	0.17	0.08	.	0.02	-0.01	0.01	0.08	0.02	-0.03	-0.01	0.51	0.33	1																								
(15) *FEEDBACK_INI_EXP*	0.06	0.10	0.03	.	-0.04	0.09	0.10	0.11	0.13	0.03	-0.10	0.24	0.16	0.24	1																							
(16) *FEEDBACK_LATE_RD*	0.05	0.10	0.07	.	-0.08	0.02	0.09	0.11	0.10	0.00	-0.09	0.39	0.60	0.26	0.17	1																						
(17) *FEEDBACK_LATE_NONRD*	0.06	0.07	0.03	.	-0.06	0.05	0.15	0.15	0.18	0.07	-0.15	0.67	0.32	0.35	0.24	0.43	1																					
(18) *FEEDBACK_LATE_EXP*																																						
Control variables	0.03	0.06	-0.1	.	0.02	0.09	0.06	0.08	0.09	0.04	-0.06	0.21	0.2	0.28	0.51	0.28	0.26	1																				
(19) *lnEMPLOYEES*	0.04	0.02	0.11	.	0.06	0.10	0.21	0.17	0.21	0.12	-0.21	0.00	0.00	-0.08	0.00	0.00	0.03	-0.02	1																			
(20) *RD EXPENDITURE-SALES RATIO*	-0.04	-0.01	-0.04	.	-0.02	0.06	0.07	0.06	0.09	0.03	-0.07	0.06	0.00	0.01	0.09	0.01	0.09	0.14	-0.15	1																		
(21) *RESEARCHER-EMPLOYEE RATIO*	0.06	0.00	0.11	.	0.00	0.00	0.03	0.02	0.06	0.01	-0.03	0.02	0.01	0.04	0.03	-0.01	0.04	0.08	-0.09	0.62	1																	
(22) *RESEARCH EXPENDITURE RATIO*	-0.05	-0.02	-0.10	.	-0.06	0.05	0.05	0.00	0.03	0.09	-0.05	-0.06	0.02	-0.15	-0.06	-0.02	-0.02	0.03	0.09	0.04	0.04	1																
(23) *DEVELOPMENT EXPENDITURE RATIO*	0.06	-0.02	0.06	.	0.02	-0.10	-0.05	-0.02	-0.06	-0.09	0.05	0.06	0.00	0.14	0.09	0.02	-0.02	-0.02	-0.23	-0.02	0.01	-0.45	1															
(24) *NUM_RD PROJECTS*	0.15	0.12	0.17	.	0.06	0.01	0.10	0.10	0.09	0.07	-0.10	0.02	0.02	-0.01	0.02	0.02	0.00	0.06	0.53	0.10	0.19	0.01	-0.05	1														
(25) *DUM_INTERNATIONAL EXCHANGE*	0.10	0.00	0.10	.	-0.01	0.13	0.12	0.11	0.14	0.02	-0.12	0.04	-0.02	-0.05	0.01	0.01	0.10	0.02	0.38	-0.05	0.06	0.10	-0.12	0.27	1													
(26) *DUM_CENTRALZED*	-0.06	-0.03	-0.09	.	-0.11	-0.02	0.02	0.00	-0.01	-0.01	-0.02	0.02	0.04	-0.07	0.03	0.04	0.00	0.05	0.02	-0.04	0.02	0.06	-0.04	-0.09	0.02	1												
(27) *DUM_DECENTRALIZED*	-0.02	0.06	0.01	.	-0.04	0.01	-0.08	-0.04	-0.05	-0.04	0.08	-0.05	0.00	0.09	-0.04	-0.06	-0.05	-0.05	-0.32	0.02	-0.08	-0.13	0.13	-0.18	-0.20	-0.67	1											
(28) *DUM_HYBRID*	0.09	-0.04	0.11	.	0.19	0.01	0.07	0.05	0.07	0.05	-0.07	0.03	-0.05	-0.02	0.00	0.02	0.05	0.00	0.35	0.03	0.06	0.08	-0.11	0.32	0.21	-0.45	-0.36	1										
(29) *IND_FOOD*	0.05	0.05	-0.05	.	-0.03	-0.03	-0.09	-0.05	-0.07	-0.02	0.09	0.00	0.02	-0.07	-0.17	-0.01	-0.01	-0.02	-0.03	-0.08	-0.10	0.26	-0.17	0.00	-0.01	-0.06	0.10	-0.04	1									
(30) *IND_CHEMICAL*	-0.07	-0.04	0.01	.	0.02	0.09	-0.03	-0.01	0.00	-0.04	0.03	0.04	0.00	0.04	0.05	0.05	0.03	0.08	-0.11	-0.01	0.02	0.03	-0.01	-0.04	-0.01	0.14	-0.14	0.00	-0.21	1								
(31) *IND_IRON*	0.05	0.05	0.03	.	0.04	-0.01	0.09	0.05	0.04	0.09	-0.09	0.08	0.09	0.10	0.01	0.09	0.12	-0.02	0.13	-0.09	-0.14	-0.07	0.01	0.10	-0.02	-0.03	-0.05	0.09	-0.09	-0.18	1							
(32) *IND_MACHINERY*	-0.04	-0.01	-0.04	.	0.04	-0.08	0.00	-0.01	0.01	0.00	0.00	-0.06	-0.07	0.00	0.03	-0.07	-0.05	-0.07	0.09	0.14	0.14	-0.12	0.15	0.04	0.08	-0.16	0.13	0.06	-0.27	-0.52	-0.24	1						
(33) *IND_OTHER_MANUF*	0.07	0.02	0.05	.	-0.09	0.03	0.02	0.03	0.00	-0.07	-0.02	-0.05	0.00	-0.04	-0.05	-0.04	-0.06	0.02	-0.03	-0.09	-0.16	-0.03	-0.04	-0.08	-0.01	0.09	-0.04	-0.06	-0.11	-0.22	-0.10	-0.28	1					
(34) *IND_INFO*	0.03	-0.01	0.06	.	-0.04	-0.03	0.07	0.03	0.05	0.05	-0.07	0.05	0.00	-0.05	0.04	-0.02	-0.04	0.00	0.07	0.14	0.32	0.04	-0.07	0.04	-0.09	0.09	-0.04	-0.07	-0.04	-0.08	-0.04	-0.11	-0.05	1				
(35) *IND_WHOLESALES*	-0.02	-0.06	0.01	.	0.01	0.03	0.00	-0.04	0.00	0.14	0.00	-0.02	0.05	-0.05	0.16	0.03	0.02	0.06	-0.15	-0.03	-0.05	-0.05	0.00	-0.06	-0.09	0.04	0.01	-0.07	-0.04	-0.08	-0.04	-0.11	-0.05	-0.02	1			
Additional control variables for PSM estimations																																						
(36) *DUM_EXTERNAL FUNDS*	0.00	0.03	-0.03	.	-0.07	0.17	0.18	0.16	0.18	0.01	-0.18	0.01	0.02	-0.01	0.13	0.08	0.06	0.18	0.22	0.14	0.12	0.12	-0.19	0.18	0.26	0.00	-0.11	0.13	0.00	0.01	0.03	-0.01	-0.02	-0.04	0.02	1		
(37) *IND_MB RATIO*	-0.12	-0.05	-0.16	.	0.12	0.12	0.06	0.06	0.09	0.06	-0.06	0.02	0.06	0.06	0.06	0.01	0.03	0.24	0.04	0.20	0.16	0.03	-0.01	-0.04	-0.11	0.12	-0.09	-0.04	0.03	0.23	-0.16	-0.13	-0.09	0.22	-0.05	0.09	1	
(38) *IND_RD EXPENDITURE-SALES RATIO*	-0.14	-0.02	-0.19	.	0.15	0.09	0.05	0.03	0.09	0.10	-0.05	-0.02	-0.03	0.03	0.04	-0.03	0.01	0.14	0.08	0.25	0.16	-0.10	0.12	-0.02	0.03	-0.01	-0.04	0.06	-0.32	0.12	-0.27	0.38	-0.20	-0.06	-0.05	0.09	0.66	1

Appendix Figure A1. Probability density functions of the propensity score for treated and control firms

This figure shows the probability density functions (PDF) of the propensity score for implementing staged project management used in Table 6. The figure labeled "Raw" plots the PDFs of the unmatched sample, while the figure labeled "Matched" plots the PDFs of the matched sample.



Appendix Table A3. The effect of different combinations of staged project management, milestones, and feedback on product innovation feedback: Propensity score matching regressions

This table presents the propensity score matching estimation results on the effect of different combinations of staged project management ($DUM\_STAGING$), milestones ($DUM\_MILESTONES$), and feedback ($DUM\_FEEDBACK$) on product innovation (DUM_INNOV), new-to-market innovation (DUM_NTM), and new-to-firm innovation (DUM_NTF). The control group consists of firms that did not implement staged project management ($DUM\_STAGING = 0$). The rows labeled "ATET" report the average treatment effects on the treated, while the rows labeled "S.E." report their standard errors. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Estimation method: Propensity score matching			
Outcome variables:	*DUM_INNOV*	*DUM_NTM*	*DUM_NTF*
Treatment observations: (*DUM_STAGING, DUM_MILESTONES, DUM_FEEDBACK*)= (1,0,0)			
ATET	-0.211 *	-0.053	-0.263 *
S.E.	0.112	0.089	0.141
Number of observations	292	292	292
Treatment observations: (*DUM_STAGING, DUM_MILESTONES, DUM_FEEDBACK*)= (1,1,0)			
ATET	0.192	-0.077	0.192
S.E.	0.161	0.156	0.142
Number of observations	299	299	299
Treatment observations: (*DUM_STAGING, DUM_MILESTONES, DUM_FEEDBACK*)= (1,0,1)			
ATET	0.435 ***	0.326 ***	0.326 ***
S.E.	0.109	0.087	0.106
Number of observations	319	319	319
Treatment observations: (*DUM_STAGING, DUM_MILESTONES, DUM_FEEDBACK*)= (1,1,1)			
ATET	0.257 ***	0.248 ***	0.200 ***
S.E.	0.061	0.058	0.058
Number of observations	483	483	483

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