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ステージ型プロジェクト管理が
プロダクト・イノベーションの実現に及ぼす影響：
企業向け設問票調査に基づく定量分析

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

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文部科学省　科学技術・学術政策研究所
第 1 研究グループ
羽田 尚子　栗原 仰基　小野 有人

【執筆者】

羽田 尚子	中央大学商学部　教授 文部科学省科学技術・学術政策研究所 客員研究官
栗原 仰基	中央大学企業研究所　客員研究員
小野 有人	中央大学商学部　教授 文部科学省科学技術・学術政策研究所 客員研究官（2022 年 3 月まで）

【Authors】

HANEDA Shoko	Professor, Faculty of Commerce, Chuo University Affiliated Fellow, National Institute of Science and Technology Policy (NISTEP), MEXT
KURIHARA Koki	Affiliated Fellow, Institute of Business Research, Chuo University
ONO Arito	Professor, Faculty of Commerce, Chuo University Affiliated Fellow, National Institute of Science and Technology Policy (NISTEP), MEXT（until March 2022）

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ステージ型プロジェクト管理がプロダクト・イノベーションの実現に及ぼす影響：企業向け設問票調査に基づく定量分析

文部科学省 科学技術・学術政策研究所　第１研究グループ

要旨

本研究は，日本企業を対象とする独自の設問票調査を用いて，研究開発プロジェクトの進捗を段階的に管理する「ステージ型管理」がプロダクト・イノベーションの実現に及ぼす影響を検証している。実証分析の結果，ステージ型管理を採用している企業は，非採用企業よりもプロダクト・イノベーションを実現する確率が高いことが分かった。この結果は，企業がステージ型管理を採用するかどうかを内生的に選択していることを考慮した追加的な推定においても頑健であった。ステージ型管理を実施している企業のみを分析対象として，プロジェクトの中止・継続を判断するための中間目標（マイルストーン）について検証したところ，企業がマイルストーンを設定するかどうか，マイルストーンの達成状況をどの程度重視するかは，プロダクト・イノベーションの実現と相関がなかった。一方，研究開発者に対して中間評価結果のフィードバックを実施することは，プロダクト・イノベーションの実現と正の相関があった。さらに，フィードバックがプロダクト・イノベーションに及ぼす正の限界効果は，市場新規プロダクトの方が非市場新規プロダクトよりも大きいことも判明した。本研究の結果は，ステージ型管理および中間評価結果のフィードバックの実施が，企業のイノベーション活動に有益であることを示唆している。

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

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

ABSTRACT

We examine 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 in the market. Additional estimations show that this finding is robust when we take the endogeneity of staged project management into account. Among firms that employed staged project management, whether firms set milestones and to what extent milestones were important in assessing the continuation of R&D projects were not associated with the likelihood of product innovations. In contrast, providing feedback on the interim evaluation of R&D projects to R&D employees was positively associated with the likelihood of product innovations. The marginal effect on feedback was larger for new-to-market product innovations than for new-to-firm product innovations. Our findings suggest that staged project management and feedback are beneficial for product innovation.

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概要

1. はじめに

研究開発プロジェクトは，しばしば複数の段階（ステージ）を踏むことが知られている。ステージごとに中間評価を行って，プロジェクトの中止・継続や継続する場合の戦略の見直し等に関する意思決定が行われる。中間評価の方法としては，ステージごとに設定された中間目標（マイルストーン）に基づいて研究プロジェクトを選別するものもある（たとえば Cooper 1988 の Stage-Gate 法）。また，中間評価結果のフィードバックを担当者に実施することも多い。本研究では，複数のステージを踏み，中間評価に基づいてプロジェクトの進捗を管理する方法を「ステージ型管理」と呼ぶ[1]。

本研究では，ステージ型管理を採用する企業ではイノベーションの生産性が高いのか，独自の設問票調査を用いて検証する[2]。本研究の貢献は 2 点ある。第一に，ステージ型管理がイノベーションに及ぼす影響を定量的に分析した研究は少なく，そのほとんどがドイツの Community Innovation Survey を用いているなか，本研究は，日本企業のデータを用いて新たな知見を提供する。第二に，ステージ型管理におけるマイルストーンの設定やフィードバックの実施がイノベーションに及ぼす影響を検証した実証研究は筆者らの知る限りでは存在せず，本研究が最初の研究となる。

2. 先行研究と分析仮説

先行研究に基づき，本研究では 3 つの分析仮説を設定する。

仮説 1 では，ステージ型管理がプロダクト・イノベーションに及ぼす影響について検証する。ステージ型管理は，研究開発以外の場でも用いられている。たとえばベンチャーキャピタル（VC）はベンチャー企業に対して段階的に資金を投じることが知られている（Sahlman 1990）。VC に関する先行研究は，ステージ型投資の利点として，ベンチャー企業と VC との間に情報の非対称性や契約の不完備が存在する場合に生じうる非効率性（エージェンシーコスト）を軽減できること（Gompers 1995）や，不確実性が低下した段階で中止・継続を判断できるオプション価値があること（Dahiya and Ray 2012）などをあげている。一方，ステージ型投資のデメリットとして，ベンチャー企業が実現性の高い中間目標やプロジェクトを選ぶ「短期主義(short-termism)」に陥ること（Cornelli and Yosha 2003）や，多額の先行資金を必要とするベンチャー企業への投資が過小になる問題（Wang and Zhou 2004）なども指摘されている。これらの議論を踏まえ，本研究ではまず，以下の仮説 1 を設定する。

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[1] 本研究でいうステージ型管理法とは，企業が研究開発プロジェクトを進めるうえでの実施を対象としている。なお，ここでいう研究開発プロジェクトとは，具体的な研究成果を達成することを目的として，担当する研究開発者，予算，期限等を定めた研究開発活動を指している。基礎研究のように，特定の期限までに達成すべき目標を必ずしも定めない研究開発活動を含まない可能性がある。
[2] したがって，本研究における分析単位は企業であって，プロジェクトではないことに留意されたい。

仮説 1. ステージ型プロジェクト管理がイノベーションに及ぼす影響

ステージ型管理を採用している企業は，非採用企業よりもプロダクト・イノベーションの実現確率が高い。ステージ型管理のデメリットが利点を上回る場合には，ステージ型管理を採用している企業のプロダクト・イノベーション実現確率は相対的に低い。

仮説 2，仮説 3 では，ステージ型管理を採用している企業における，マイルストーン，フィードバックとプロダクト・イノベーションとの関係について検証する。これらの仮説では，既存の知識を土台とした不確実性の小さい深化型（exploitation）と，未知の領域の開拓を伴う不確実性の大きい探索型（exploration）の 2 種類のプロダクト・イノベーションとの関係についても考察する。

ステージ型管理を実施している企業の研究開発者は，「中止の脅威(threat of termination)」(Manso 2011)に直面している。中止の脅威は，ステージ型管理を実施している企業のなかでもマイルストーンを設定している，あるいはマイルストーンの達成度合いを重視している企業で大きいと考えられる。また Manso (2011)は，中止の脅威は，研究開発者の怠惰(shirking)を抑制してプロジェクトの成功確率を高める一方，不確実性の大きい探索型プロジェクトを選択する誘因を低下させると指摘している。Manso (2011)の議論を踏まえ，以下の仮説 2 を設定する。

仮説 2. マイルストーンがイノベーションに及ぼす影響

ステージ型管理を採用している企業のうち，マイルストーンを設定している，あるいはマイルストーンを重視している企業は，プロダクト・イノベーションの実現確率が高い。また，マイルストーンは深化型イノベーションの実現確率と正の相関があるが，探索型イノベーションとの相関は不明確である。

中間評価結果のフィードバックは，プロジェクトの中間段階での戦略の見直しを通じて，イノベーションを実現しやすくすると考えられる。また Manso (2011)によれば，フィードバックがイノベーションの実現確率を高める効果は，未知の領域の探求を伴う探索型イノベーションの方が，深化型イノベーションよりも大きい。そこで，以下の仮説 3 を設定する。

仮説 3. フィードバックがイノベーションに及ぼす影響

ステージ型管理を採用している企業のうち，中間評価結果のフィードバックを実施している企業は，プロダクト・イノベーションの実現確率が高い。また，フィードバックがプロダクト・イノベーションの実現確率を高める効果は，探索型イノベーションの方が深化型イノベーションよりも大きい。

3. 分析に利用したデータと主な変数

本研究で主に用いたのは，『研究開発マネジメントに関する実態調査』の調査データである。本調査は，日本企業の研究開発活動に関する組織マネジメントの現状を明らかにすることを目的に，研究開発を実施する資本金 1 億円以上の民間企業 3,456 社を対象に 2020 年 1～2 月に実施された。調査対象の産業分野（経済活動）は，製造業，情報通信業，及び卸売業である。調査の参照期間は，一部の項目を除き 2018 年度の 1 年間または 2016 年度～2018 年度までの 3 年間である。本研究では，本調査データを『2019 年 科学技術研究調査』（総務省統計局）と接合した企業レベルのデータを用いる [3]。なお『研究開発マネジメントに関する実態調査』の回答企業数は 611 社であったが，欠損値等により，本研究に用いる分析サンプルの企業数は最大で 557 社である。また，仮説 2，3 の検証では，ステージ型管理を実施している企業に分析サンプルを限定するため，企業数は最大で 295 社である。

イノベーションの代理変数には，2016～2018 年度にプロダクト・イノベーションを実現した場合に 1，そうでない場合に 0 の値をとるダミー変数を用いる。また，探索型イノベーション，深化型イノベーションの代理変数として，それぞれ，市場新規プロダクト・イノベーション，非市場新規プロダクト・イノベーションの実現有無を表すダミー変数を用いる。

ステージ型管理の変数には，研究開発プロジェクトにおけるステージ型プロジェクト管理の実施有無を表すダミー変数を用いる。さらにステージ型管理に関する他の代理変数として，平均的なステージ数，1 ステージあたりの平均年数も用いる。マイルストーンの変数には，プロジェクトの中間評価のためにマイルストーンを設定したかどうかを表すダミー変数と，プロジェクトの初期・後期の各段階において中止・継続を判断するうえでマイルストーンがどの程度重要かを表すインデックス変数（0～4 の値，重要であるほど高い値をとる）を用いる。フィードバックの変数には，中間評価結果のフィードバックを研究開発者に行ったかどうかを表すダミー変数と，プロジェクトの初期・後期の各段階に研究開発部門内の他の研究チームからの意見，研究開発部門以外の社内組織（事業部や本社部門）からの意見，社外の有識者からの意見，をそれぞれフィードバックに取り入れたかどうかを表すダミー変数を用いる。

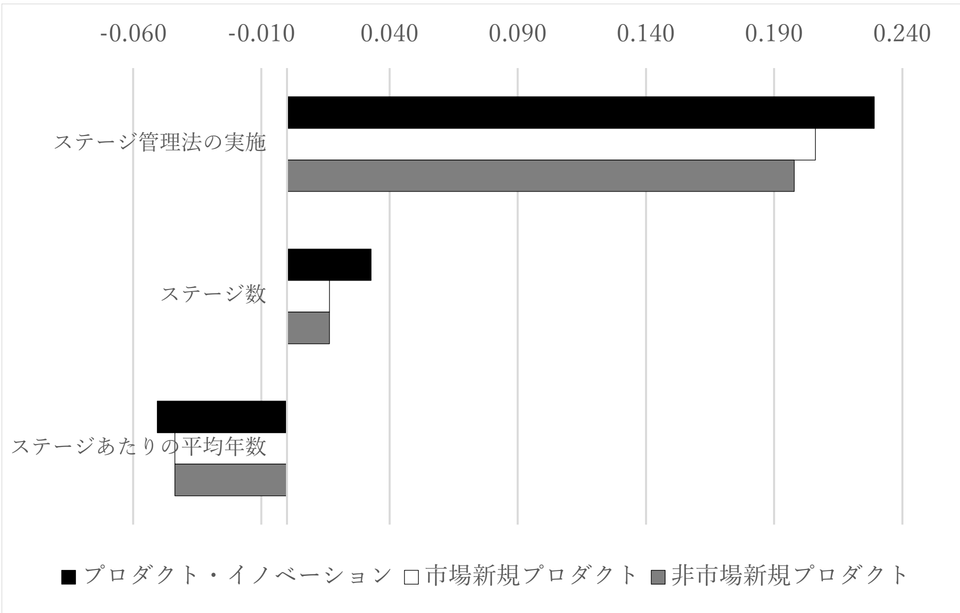
3『2019 年科学技術研究調査』からデータを得られなかった企業については，2018 年および 2017 年の調査データを利用している。また，企業が属する産業の特性を表すコントロール変数を構築するため，『2019 年経済産業省企業活動基本調査』（経済産業省），日経 NEEDS Financial QUEST（日経メディアマーケティング社）を用いた。

4. 分析モデルと分析結果

仮説 1〜3 の検証のため，プロダクト・イノベーションの実現を従属変数とするロジットモデルによる推計と，市場新規プロダクト，非市場新規プロダクトの実現を従属変数とする二変量プロビットモデルによる推計を行う。

ステージ型管理がプロダクト・イノベーションの実現確率に与える平均限界効果を図示したものが概要図表 1 である。ロジットモデルによる推定結果から，ステージ型管理の実施は，企業のプロダクト・イノベーションの実現確率を 23%高めたことがわかった。分析サンプルのうちプロダクト・イノベーションを実現した企業の割合が 55%であることを踏まえると，ステージ型管理の採用がイノベーションに及ぼすインパクトは大きいといえる。また，ステージ数が多い企業や，1 ステージあたりの平均期間が短い企業ほどプロダクト・イノベーションを実現しやすいことも確認された。

概要図表 1. ステージ型プロジェクト管理がプロダクト・イノベーションに及ぼす影響



注：横軸は本文の Table 3, Table 4 の平均限界効果

ロジットモデルによる推定結果は，ステージ型管理を採用する企業ほど，成功確率が高いプロジェクトを選択する逆の因果関係（短期主義）を反映している可能性がある。そこで次に，二変量プロビットモデルを推定した。ロジットモデルの推定結果が，企業の短期志向を反映している場合，ステージ型管理の実施は成功確率が高い非市場新規プロダクトの実現とのみ正の相関関係がある予想される。しかし，概要図表 1 からは，ステージ型管理が市場新規プロダクト，非市場新規プロダクトの実現に及ぼす平均限界効果が同程度であることが読み取れる。このことは，ステージ型管理とプロダクト・イノベーションの正の相関は，企業の短期指向にのみ起因するものではないことを示唆している。また頑健性チェックのため，企業がステージ型管理を採用するかどうかを内生的に選択していること

を考慮した傾向スコアマッチングによる平均処置効果を推定したところ，概要図表 1 とほぼ同じ結果が得られた。以上の分析結果より，仮説 1 は支持されたといえる。

次に，ステージ型管理を実施している企業に分析サンプルを限定し，マイルストーン（仮説 2），フィードバック（仮説 3）がプロダクト・イノベーションに及ぼす平均限界効果を推定した。まず，企業がマイルストーンを設定したかどうか，どの程度重視したかは，イノベーションの実現と相関がなく，仮説 2 は支持されない。この点をさらに検証するため，『研究開発マネジメントに関する実態調査』の調査項目を用いて，過去 3 年以内にプロジェクトの中止または中断を経験している企業の割合をマイルストーン有無別に計測したところ，両者の間に有意な差はないことが分かった。これは，ステージ型管理を採用する日本企業の間では，マイルストーンが「中止の脅威」となっていない可能性を示唆している。

一方，プロジェクトの中間評価結果のフィードバックの実施は，プロダクト・イノベーションの実現確率を約 17%高めた。イノベーションの新規性別にみると，市場新規プロダクトの実現に対するフィードバックの平均限界効果（28%）は，非市場新規プロダクトの実現に対する同効果（15%）を大きく上回る。これらの結果は仮説 3 と整合的であり，中間評価結果のフィードバックの実施が，とくに探索型イノベーションの実現確率を高めるうえで有効であることを示唆している。

さらに，フィードバックにおいて誰の意見を取り入れることがイノベーションの実現確率を高めるかを検証したところ，プロジェクトの初期段階に，事業部や本社部門など研究開発部門以外の社内組織からの意見を取り入れることは，プロダクト・イノベーションの実現，市場新規プロダクトの実現をともに 13%程度高めることが分かった。この結果は，プロジェクトの初期段階に研究開発部門とは異なる観点からのフィードバックを得ることが，プロダクト・イノベーション，特に探索型イノベーションの実現確率を高めるうえで有効なことを示唆している。

本文（英語）

The effect of staged project management on product innovation: Evidence from a firm survey[*]

Shoko Haneda[†]
Chuo University
National Institute of Science and Technology Policy (NISTEP)

Koki Kurihara[‡]
Chuo University

Arito Ono[§]
Chuo University
National Institute of Science and Technology Policy (NISTEP)

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[†] Chuo University. Email: shaneda@tamacc.chuo-u.ac.jp

[‡] Chuo University. Email: kurihara.k.rese@gmail.com

[§] Chuo University. Email: a-ono@tamacc.chuo-u.ac.jp

The effect of staged project management on product innovation: Evidence from a firm survey

Shoko Haneda, Koki Kurihara, Arito Ono

Abstract

We examine 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 in the market. Additional estimations show that this finding is robust when we take the endogeneity of staged project management into account. Among firms that employed staged project management, whether firms set milestones and to what extent milestones were important in assessing the continuation of R&D projects were not associated with the likelihood of product innovations. In contrast, providing feedback on the interim evaluation of R&D projects to R&D employees was positively associated with the likelihood of product innovations. The marginal effect on feedback was larger for new-to-market product innovations than for new-to-firm product innovations. Our findings suggest that staged project management and feedback are beneficial for product innovation.

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

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

1. Introduction

The importance of innovation for firm growth is widely recognized. However, understanding what drives innovation is lacking among both researchers and practitioners. Although the growing literature suggests that management practices are important factors in explaining differences in productivity and growth across firms (e.g., Bloom and Van Reenen 2007), there are relatively few studies that have empirically examined the link between R&D management practices and innovation. This study focuses on a particular R&D management practice that may foster innovation: staged project management. The management and funding of R&D projects often proceed 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. When the project is continued, providing feedback on the interim evaluations to the R&D researchers in charge of the project is also common. Despite its prevalence, existing studies are not unanimous on whether staged project management promotes or demotes innovation. On the one hand, in the presence of asymmetric information 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 in R&D projects. In addition, conducting R&D activities in stages allows firms to terminate projects that are less likely to succeed and reallocate resources to other more promising projects. On the other hand, staged project management may induce "short-termism" by R&D employees in the sense that they choose projects with a higher probability of success (i.e., exploitative innovation), which may be detrimental to firms' long-term growth. At the same time, staged project management may inhibit "trial-and-error" by R&D employees and reduce their creativity.

Against this background, this study addresses the following three major questions using a firm-level micro data in Japan. First, does staged project management increase or decrease the likelihood of product innovations? Does staged project management have different effects on explorative and exploitative product innovations? These questions are to understand whether staged project management is beneficial or harmful for product innovation and whether the effect depends on product innovation's nature. Second, do milestones affect the likelihood of product innovations among firms that employ staged project management? Does the effect of milestones on product innovations differ between explorative and exploitative innovations? Third, does providing feedback to R&D employees affect the likelihood of product innovations among firms that employ staged project management? Does the effect of feedback differ between explorative and exploitative innovations? In addition, do the effects of feedback on making product innovations depend on whose opinions are incorporated in the feedback and at which stages (e.g., early or late stages) feedback is provided? The second and third major questions are to understand whether the effects of staged project management on product innovations depend on how firms use milestones and feedback.

To answer these questions, we use a unique firm survey, "Survey of R&D Management Practices," which was implemented by a research team including the authors 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 as of fiscal year (FY) 2018. In addition, the survey identifies whether firms developed product innovations during the past three years, from FY 2016 to FY 2018, and whether the new products that firms introduced were "new-to-market" and/or "new-to-firm."[1] Throughout this study, we assume that new-to-market and new-to-firm product innovations correspond to explorative and exploitative innovations, respectively. We match the survey data with data taken from other sources to obtain basic characteristics of respondent firms and construct our dataset.

Using the dataset, 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. We obtain similar results when we alternatively use variables that represent the firm's average number of stages and the average duration of a stage instead of the variable that represents whether a firm employed staged project management. These results indicate that staged project management is beneficial for product innovation. However, we note that a positive link may exist between staged project management and product innovation because R&D employees of firms that employed staged project management were more likely to choose projects with a higher probability of success (short-termism). To check for this possibility, we run

[1] The definitions of "new-to-market" and "new-to-firm" products are provided in Section 3.2.1.

bivariate probit estimations in which dependent variables are new-to-market and new-to-firm product innovations. We expect to find a positive link between staged project management and product innovations only for new-to-firm products if the short-termism prevails, but the results for bivariate probit estimations show that the link is positive for both types of innovation. 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. We also examined the possibility that the estimates obtained in logit and bivariate probit may be biased because firms endogenously choose whether and how they implement staged project management. To deal with the possible endogeneity problem concerning staged project management, we conduct propensity score matching estimations. The results of propensity score matching estimations are similar to those of logit and bivariate probit estimations.

Next, we conduct logit and bivariate probit estimations using a subsample of firms that employed staged project management to examine our second and third research questions on milestones and feedback. We do not find association between setting milestones and the importance of milestones in assessing the continuation of R&D projects, and the likelihood of making product innovations, either new-to-market or new-to-firm product innovations. Although thoroughly examining the reasons for insignificant results is beyond the scope of this study, we conduct additional test regarding whether firms that set milestones were more likely to terminate R&D projects than firms that did not and find that the likelihood of terminating R&D projects is the same between the two groups. This finding suggests that the "threat of termination" (Manso 2011) is indifferent between firms that used milestones and firms that did not, among firms that employed staged project management.

In contrast, providing feedback on the interim evaluation of R&D projects to R&D employees is positively associated with making product innovations. Quantitatively, the marginal impact of providing feedback is larger for new-to-market product innovations than for new-to-firm product innovations. We also find that opinions from non-R&D organizations within the company in the initial stages are positively associated with making product and new-to-market innovations, suggesting that different perspectives obtained from outside the R&D units in initial stages are beneficial for making product innovations, especially for explorative innovations.

This study is closely related to the following strands of literature that examined the role of staged project management and staged investment. First, studies on innovation and management have long discussed the advantages and disadvantages of proceeding R&D activities in stages. On the one hand, staged project management drives firms to terminate projects that are less likely to succeed and reallocate resources to other more promising projects in interim stages, thus contributing to a more efficient R&D projects portfolio. On the other hand, staged project management may discourage experimentation and trial-and-errors by R&D researchers and reduce the flexibility in R&D activities, which may be detrimental to innovation. Although many studies have examined the advantages and disadvantages of staged project management taking the form of case studies (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, to the best of our knowledge, most of these empirical studies used a particular firm survey, namely, the German edition of the Community Innovation Survey. This study contributes to the literature by providing additional empirical evidence on the effect of staged project management on product innovations using another firm survey in Japan, which contains detailed information on how firms implemented staged project management.

Second, this study is related to a number of theoretical and empirical studies investigating the effect of staged investment by venture capitalists (VCs) on 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 hypothesis based on studies on staged investment in the venture capital industry, as the principal–agent framework used in these studies applies to the relationship between firm headquarters (principal) and R&D units and employees (agent).

Finally, this study is also related to Manso's (2011) theoretical study on creating incentives for innovation. In our view, the two-period model presented in Manso (2011) captures the advantages and disadvantages of staged investments concisely. 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). 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 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. Empirical hypothesis

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, although the role of staging for explorative activities (e.g., R&D) has been examined in a theoretical model with a more general setting (Roberts and Weitzman 1981). A seminal field study on venture capital by Sahlman (1988, 1990) noted that staging in capital infusion is the most important mechanism for controlling a venture firm by a VC. The subsequent studies on venture capital pointed out three advantages of staged investment. First, in the presence of asymmetric information and/or incomplete contracts between an entrepreneur who found 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 cash flows he/she generated are not verifiable, shirking by the entrepreneur when his/her effort is not verifiable, and continuing 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 performances are not good (Gompers 1995, Kaplan and Strömberg 2003, 2004). Second, if the human capital of an entrepreneur is inalienable

(Hart and Moore 1994), then entrepreneurs can "hold-up" the VC ex-post by threatening to leave the firm unless the VC agrees to reduce his/her claim that was contracted ex-ante. Neher (1999) showed that staging mitigates this hold-up problem because it reduces the amount of the VC's committed investment in the venture firm at any given time, making its claim less susceptible to being renegotiated down.[2] Third, in the presence of uncertainty, staging allows a VC to learn about a venture firm over time as uncertainty vanishes, 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 a VC. First, it may induce "short-termism" by a venture firm in the sense that the firm focuses on meeting the intermediate hurdle of the next stage and/or the firm sets 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, the firm may make the conditions under which interim performance looks favorable, which is described as "window dressing" (Cornelli and Yosha 2003). Second, staged investment may induce an underinvestment problem for a venture firm with a viable project and needs upfront financing (Wang and Zhou 2004). Finally, staging inevitably incurs negotiation and contracting costs and may lead to lags in implementing a project (Tian 2011).

In our view, the two-period model of the innovation process presented by Manso (2011) concisely captures the advantages and disadvantages of staged investments discussed earlier. 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 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 his/her beliefs about the probability of success once he/she has chosen exploration in the first

[2] Hold-up problem may be mitigated through other control mechanisms including vesting schedule, which limits the number of shares entitled to managers if they leave prematurely, and noncomplete clauses, which restricts starting a similar project by those who leave (Sahlman 1990, Kaplan and Strömberg 2001).

stage. Both actions entail private costs to the agent; hence, the agent has an incentive to shirk. Manso (2011) argued that the effects of threat of termination, which is inherent in staged investment, on the incentives for exploration are ambiguous because it prevents the agent from shirking (decrease in agency costs) but encourages the agent to choose an exploitative project with a higher probability of success (short-termism). Depending on which of these two effects is more important, staging innovation projects may encourage or discourage an agent from choosing exploration.

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.

As noted in the Introduction, the number of empirical studies that examined the effect of staged project management on innovations is limited and these studies found mixed results. In the field of management and innovation, Klingebiel and Adner (2015) empirically examined whether “sequencing,” which is similar to staged project management in this study, increased sales amount concerning new products. They used firm-level data from the German edition of the Community Innovation Survey and found that sequencing positively impacted firms’ sales amount achieved with new products. In a similar vein, using the same survey as Klingebiel and Adner (2015), Andries and Hünermund (2014) found that staged project management increased the sales amount achieved with new products, although their primary research interest lied in the moderating effect of staged project management on the effect 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 by CEO’s subjective judgment on whether innovation activities had contributed to firm performance (e.g., profitability). 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 positive correlation between the two. In the realm of the literature on venture capital investment, Mao et al. (2014) argued that staged investment by VCs negatively affected the 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.

2.2. The effect of milestones and feedback on innovation

When R&D projects proceed in stages, firms often set milestones as a screening device, terminating an R&D project if the interim outcome is not positive. In addition, firms that employ staged project management often provide feedback on the interim evaluation results to the R&D employee in charge of the project. In the following, we construct our empirical hypotheses on the effect of milestones and feedback based on Manso's (2011) theoretical model.

As we outlined in the previous subsection, Manso (2011) argued whether the threat of termination increases the likelihood of making explorative innovations is ambiguous because of the following tradeoff: Although the threat of termination decreases agency costs (e.g., shirking), which increases the probability of success of a project, it also decreases the agent's incentive to choose a project with a smaller likelihood of success, i.e., exploration. To put Manso's argument in our context, we conjecture that R&D employees face a significant threat of termination if their firm sets milestones to decide whether to terminate or continue R&D projects in progress. In addition, among firms that set milestones, the threat of termination may differ depending on to what extent the firm takes into account whether milestones are achieved. Thus, on the one hand, we expect that the existence and importance of milestones may be positively associated with the likelihood of making product innovations in general and exploitative innovations in particular. On the other hand, we expect that the link between milestones and the likelihood of making explorative innovations is ambiguous.

Feedback on interim outcomes of the project also increases the likelihood of product innovations because agents can make interim adjustments by incorporating opinions from other people. However, based on Manso' s (2011) theoretical prediction, the effects of feedback on the interim adjustments depend on whether the goal is exploitation or exploration. Feedback may have little or a smaller impact on the likelihood of making exploitative innovations because adjusting interim research performances through feedback has little benefit to encourage exploitation, which entails the repetition of behavior and work practices well-known to R&D employees. In contrast, feedback may increase the likelihood of making explorative innovations because the benefit of outsiders' opinions that enable interim adjustments is likely to be larger for explorative projects than for exploitive projects.

Based on these considerations, we put forward our second and third empirical hypothesis as follows:

Hypothesis 2-1 (*The effects of milestones on innovation*). Setting milestones and/or emphasizing the achievement of milestones in terminating/continuing the project is positively associated with making product innovations among firms that employ staged project management.

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

Hypothesis 3-1 (*The effect of feedback on innovation*). Providing feedback to R&D employees is positively associated with making product innovations among firms that employ staged project management.

Hypothesis 3-2 (*The effect of feedback on exploration and exploitation*). Feedback is positively associated with making explorative innovations among firms that employ staged project management. If any, the positive correlation between feedback and exploitative innovations is weaker than that between feedback and explorative innovations.

To the best of our knowledge, few studies have empirically examined the effect of milestones and feedback on innovation in the context of corporate R&D activities. However, several studies have examined Manso's (2011) predictions in other contexts. 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.

3. Data, variables, and empirical approach

3.1. Data

We construct firm-level microdata using the following sources. First, the data used in this study are mainly taken from the "Survey of R&D Management Practices," which was implemented by a research team including the authors in January–February 2020 and referred to as the "R&D management survey" hereafter. The survey focused on R&D management practices among business enterprises with systematic R&D operations. Specifically, the survey targeted business enterprises with paid-in capital of 100 million yen or more that undertake R&D activities and firms in manufacturing (Japan Standard Industrial Classification (JSIC): 09–32), information and communications (JSIC: 37–41), and wholesale and retail trade (JSIC: 50–55) because many small firms and firms in service industries do not conduct R&D at all. We construct the sample of the Management survey meeting these criteria by identifying firms in the 2017 and 2018 rounds of the Survey of Research and Development, which is conducted annually by the Statistics Bureau of the Ministry of Internal Affairs and Communications.[3] A total of 3,456 such firms received questionnaires of the R&D management survey, and the number of respondent firms was 611 for a response rate of 17.7%.

Second, we match our survey data with data taken from the Survey of Research and Development. Specifically, we use the 2019 Survey of Research and Development, which reports the basic characteristics of the firms as of FY2018. Data from the 2019 round were unavailable in several firms; thus we use data from either the 2018 or 2017 round of Survey of Research and Development for these firms. The Survey of Research and Development has the characteristics of respondent firms, such as their sales turnover and R&D expenditure and the total number of employees, number of R&D employees, and employees with doctorate degree–information that is not included in the R&D management survey. Third, in addition to firm characteristics, we use industry-level variables in some of our estimations. For these variables, 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

In this subsection, we explain the key variables to examine our empirical hypotheses. The R&D management survey asked firms about various issues of R&D management and innovation.[4] In particular, the survey has notable features that are particularly suitable for constructing our key variables,

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[3] For details of the Survey of Research and Development, see the following website: https://www.stat.go.jp/english/data/kagaku/index.html (accessed 3 February 2022).

[4] Haneda and Ono (2022) provides detailed account of what firms do in their R&D activities using the R&D management survey.

which we briefly explain in the following. In the Appendix, we provide details on the construction of key variables using the R&D management survey. Tables 1 and 2 present the definitions and summary statistics of the variables used in our estimations.[5]

3.2.1. Dependent variables for product innovations

Using the R&D management survey, we construct two types of dependent variables for product innovations. First, as a proxy for making successful product innovations, we construct a dummy variable DUM_INNOV, which equals one if a firm introduced new or improved products in the market from FY2016 to FY2018 and zero otherwise. Because our sample consists of firms with systematic operations, it is likely that non-innovators (i.e., firms with $DUM\_INNOV = 0$) had tried creating product innovations but failed in the same period. In the following analysis, we therefore assume that non-innovators had attempted to make product innovations but failed to do so. The mean of DUM_INNOV is 54.8% (Table 2).

Second, we construct dummy variables DUM_NTM and DUM_NTF, which are distinguished by whether the new products introduced to the market from FY2016 to FY2018 are "new-to-market" or "new-to-firm." In the R&D management survey, we define new-to-market products as new or significantly improved goods or services that no competitors were offering, and new-to-firm products as new or improved goods or services that were the same as or very similar to ones already offered by competitors. The following analysis assumes 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 in the market in the past three years, DUM_NTM and DUM_NTF of this firm are both equal to one. The means of DUM_NTM and DUM_NTF are 32.0% and 45.6%, respectively (Table 2). Although not shown in

[5] In the Appendix, we provide the summary statistics for the subsamples of firms that employed staged project management and those that did not (Table A1) and the correlation matrix for the variables used in the estimations (Table A2).

Table 2, the percentage share of firms that developed both new-to-market and new-to-firm product innovations is 23.0%.

3.2.2. Main independent variables for staged project management

Regarding the main independent variables to examine Hypothesis 1, we construct the following three variables that represent whether and to what extent firms implement staged project management: DUM_STAGE, NUM_STAGE, and $DURATION\_STAGE$. DUM_STAGE is a dummy variable that equals one if a firm implemented staged project management in FY2018 and zero otherwise.[6] NUM_STAGE represents the average number of stages for a respondent firm. We assume that NUM_STAGE equals one if a firm did not implement staged project management.[7] Finally, $DURATION\_STAGE$ represents the average duration of each stage for a respondent firm. We define $DURATION\_STAGE$ as 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_STAGE). A larger value of NUM_STAGE indicates that a firm engages in staging *more*, whereas a larger value of $DURATION\_STAGE$ indicates that a firm engages in staging *less*. The mean of DUM_STAGE is 53.0%, indicating that about half of the firms in our sample implemented staged project management. Table 2 shows that the means of NUM_STAGE 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, had less than 3 stages and the average duration of each stage was about 2 years.

Firms that employed staged project management (i.e., firms with $DUM\_STAGE = 1$) were

[6] In the R&D management survey, we defined staged project management 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 about whether the project is continued, suspended, or abandoned, as well as revisions of the schedule.

[7] In the R&D management survey, there are ten firms which responded that they implemented staged project management and reported that the average number of stages is one. The estimation results we report below are qualitatively the same when we exclude these firms from our estimation sample (the results not reported).

asked further questions about milestones and feedback. Regarding milestones, we construct the following variables to examine Hypothesis 2-1 and 2-2. First, $DUM\_MILESTONE$ is a dummy variable that equals one if a firm set milestones for the interim evaluation of projects and zero otherwise. The mean of $DUM\_MILESTONE$ is 78.0%, indicating that about 80% of firms that implemented staged project management set milestones. Next, we construct $MILESTONE\_INI$ and $MILESTONE\_LATE$, which represent the importance of milestones in assessing whether to terminate/suspend or continue the R&D project in "initial stages" and "late stages," respectively. Specifically, $MILESTONE\_INI$ and $MILESTONE\_LATE$ are index variables that take the value from zero to four and a higher value represents that a firm regards the achievement of milestones more important (see Table 1 and Appendix for details). For firms that implemented staged project management but did not set milestones, we assign the value of zero. The means of $MILESTONE\_INI$ and $MILESTONE\_LATE$ are respectively 2.45 and 2.80. These figures indicate that firms in our sample thought achieving milestones was more important in the late stages than in the initial stages in their assessment for continuing the R&D project.

Regarding feedback to R&D employees, we construct the following dummy variable to examine Hypothesis 3-1 and 3-2. $DUM\_FEEDBACK$ is a dummy variable that 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 85.4%, indicating that more than 80% of firms that implemented staged project management provided feedback.

In addition to $DUM\_FEEDBACK$, we construct the following variables that represent whose opinions were incorporated when providing feedback in the initial and late stages. Although it is vital to understand whose opinions at which stages are more effective in making product innovations, 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 using the R&D management survey.

Specifically, we construct following 6 dummy variables: $FEEDBACK\_INI\_RD$, $FEEDBACK\_INI\_NONRD$, $FEEDBACK\_INI\_EXP$, $FEEDBACK\_LATE\_RD$, $FEEDBACK\_LATE\_NONRD$, and $FEEDBACK\_LATE\_EXP$, where "INI" and "$LATE$" respectively represent the initial and late stages and "RD, " "$NONRD$," and "EXP" respectively represent opinions from other research teams within R&D units, opinions from non-R&D organizations (business units and head office) within the company, and opinions from external experts outside the company. For example, $FEEDBACK\_INI\_RD$ takes the value of 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%) and the smallest among the three options for whose opinions are incorporated. Second, the percentage shares of firms that incorporated opinions from other teams within R&D units (60.9%) and those from non-R&D organizations (60.5%) are the same in the initial stages, whereas the share is larger for non-R&D organizations (72.1%) than for other teams within R&D units (47.3%) in the late stages. The latter finding suggests 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 commercialize the invention and product marketing.

3.3. Empirical approach

3.3.1. Baseline estimations for Hypothesis 1

We first estimate the logit model to examine whether firms that employed staged project management were more likely to make product innovation (Hypothesis 1),

$$\Pr\,(DUM\_INNOV_i) = \psi(\alpha + \beta_1 \mathrm{STAGING}_i + \mathbf{X_i}\boldsymbol{\gamma}), \tag{1}$$

where $\psi(\cdot)$ represents the cumulative density function of the logistic distribution. DUM_INNOV_i is a binary variable that represents whether firm *i* made product innovations from FY 2016 to FY 2018. $\mathrm{STAGING}_i$ represents whether and how firm *i* employed staged project management in FY 2018, and we alternatively use DUM_STAGE_i, NUM_STAGE_i, and $DURATION\_STAGE_i$, which we explained in the previous subsection. We expect $\widehat{\beta_1}$ to have a positive sign for DUM_STAGE_i and NUM_STAGE_i and a negative sign for $DURATION\_STAGE_i$ if a firm that implemented staged project management were more likely to make product innovations. 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 innovations, because our data are cross-sectional, and $\mathrm{STAGING}_i$ may not be orthogonal to disturbances for innovation outcomes as firms endogenously choose whether and how they implement staged project management. We turn to this issue in Section 3.3.3.

Further, $\mathbf{X_{it}}$ denotes a vector of control variables that represent firm i's characteristics at FY 2018. Definitions and summary statistics of the control variables are presented in Tables 1 and 2. Innovation activities are likely to be influenced by firm size and R&D inputs (D'Este 2016, Reeb and Zhao 2021). We use the number of employees in the natural logarithm ($lnEMPLOYEE$) as a proxy for firm size, total amount of R&D expenditures relative to its total sales ($RD\ EXPENSE - SALES\ RATIO$) 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 research, we include the ratio of basic research expenditures to total R&D expenditures ($RESEACH\ EXPENSE\ RATIO$) , and the ratio of development research expenditures to total R&D expenditures ($DEVEOPMENT\ EXPENSE\ RATIO$) as proxies for proximity to basic research (Mohnen et al. 2006, Robin and Schubert 2013). Because our dependent variable does not account for the number of product innovations that a firm made, we use the number of R&D projects in progress ($NUM\_RD\ PROJECT$) 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 variables representing a firm's basic characteristics on R&D activities listed, we include the following control variables that represent a firm's internal organizational structure on R&D (Azoulay and Lerner 2012). First, we use the dummy variable indicating whether a firm implemented international technological exchanges to promote R&D activities ($DUM\_INTERNATIONAL\ EXCHANGE$) as a proxy for international spillovers of technological information (Branstetter 2006, Penner-Hahn and Shaver 2005). Second, firms with "centralized" R&D

organizational structures may generate more explorative innovations than firms with "decentralized" R&D structure (Argyres and Silverman 2004). To control for this possibility, we construct dummy variables indicating whether the firm's R&D unit(s) was highly independent of business units (e.g., central research laboratory), which we denote as $DUM\_CENTRALIZED$, directly controlled by business units ($DUM\_DECENTRALIZED$), or whether the firm had both "centralized" and "decentralized" R&D units (DUM_HYBRID).

Even if we obtain $\widehat{\beta_1}$ that is consistent with the hypothesis that staged project management increases the likelihood of product innovations, it may be because of short-termism it induced. That is, R&D researchers of firms that implement staged project management may set a modest goal with a higher probability of success at the outset, as we argued in Section 2.1. To examine such a possibility, we estimate the following bivariate probit model,

$$\Pr\left(DUM\_NTM_i\right) = \psi(\alpha + \beta_2 \text{STAGING}_i + \mathbf{X_i}\boldsymbol{\gamma}), \quad (2)$$

$$\Pr\left(DUM\_NTF_i\right) = \psi(\alpha + \beta_3 \text{STAGING}_i + \mathbf{X_i}\boldsymbol{\gamma}), \quad (3)$$

where DUM_NTM and DUM_NTF respectively represent whether the product(s) introduced by a firm is new-to-market or new-to-firm. If staged project management induces short-termism, we expect that it does not affect the likelihood of new-to-market product innovations and only affects the likelihood of new-to-firm innovations (i.e., $\widehat{\beta_2}$ is insignificant and $\widehat{\beta_3}$ is significant), or that the marginal effect is larger for new-to-firm innovations than for new-to-market innovations (i.e., $\beta_2 < \beta_3$ in absolute terms) . Instead of estimating Equations (2) and (3) separately by logit, we employ bivariate probit 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 making new-to-market and new-to-firm product innovations (Crowley and Jordan 2017, Biscione et al. 2021, Doran and Ryan 2014). The bivariate probit model jointly estimates Equations (2) and (3) by maximum-likelihood and allows for the possibility that the error terms of these equations are correlated.

3.3.2. Baseline estimations for Hypothesis 2 and 3

Next, we examine Hypothesis 2 and 3 using the subsample of firms that implemented staged project management. The maximum number of observations in the following estimations is reduced to 295.

First, we estimate the following logit model to examine the effect of milestones on product innovation (Hypothesis 2-1),

$$\Pr\,(DUM\_INNOV_i) = \psi(\alpha + \beta_4 \text{MILESTONE}_i + \mathbf{X_i}\boldsymbol{\gamma}), \tag{4}$$

where MILESTONE_i represents whether firm *i* set milestone and to what extent the firm put emphasis on the achievement of milestone in terminating or continuing the project. As explained in the previous subsection, we use the dummy variable, $DUM\_MILESTONE_i$, which represents whether a firm that implemented staged project management set milestones. Alternatively, we use $MILESTONE\_INI_i$ and $MILESTONE\_LATE_i$, which measure the importance of milestone in the initial and late stages, respectively. As we put forward in Hypothesis 2-1, we expect $\widehat{\beta_4}$ to have a positive sign because milestones decrease agency costs and increases the likelihood of making product innovations.

To further examine whether milestone is particularly beneficial for exploitative innovation and may be harmful for explorative innovation (Hypothesis 2-2), we estimate the following bivariate probit model,

$$\Pr\,(DUM\_NTM_i) = \psi(\alpha + \beta_5 \text{MILESTONE}_i + \mathbf{X_i}\boldsymbol{\gamma}), \tag{5}$$

$$\Pr\,(DUM\_NTF_i) = \psi(\alpha + \beta_6 \text{MILESTONE}_i + \mathbf{X_i}\boldsymbol{\gamma}). \tag{6}$$

We expect that the sign of $\widehat{\beta_5}$ is ambiguous or negative, as the effect of milestone on explorative innovations is ambiguous (Manso 2011) or negative (Ederer and Manso 2013), whereas the sign of $\widehat{\beta_6}$ is positive.

Second, to examine the effect of feedback to R&D employees on product innovations and on explorative and exploitative innovations, we estimate the following logit model,

$$\Pr\,(DUM\_INNOV_i) = \psi(\alpha + \beta_7 \text{FEEDBACK}_i + \mathbf{X_i}\boldsymbol{\gamma}), \tag{7}$$

and the bivariate probit model,

$$\Pr\,(DUM\_NTM_i) = \psi(\alpha + \beta_8 \text{FEEDBACK}_i + \mathbf{X_i}\boldsymbol{\gamma}), \tag{8}$$

$$\Pr\,(DUM\_NTF_i) = \psi(\alpha + \beta_9 \text{FEEDBACK}_i + \mathbf{X_i}\boldsymbol{\gamma}), \tag{9}$$

where FEEDBACK_i represents whether firm *i* provided feedback and whose opinions were incorporated in its feedback. Specifically, in Equation (7), we use the dummy variable

$DUM\_FEEDBACK_i$ that indicates whether a firm provided feedback. In Hypothesis 3-1, we hypothesized that feedback is beneficial for product innovations, and we therefore expect that the sign of $\widehat{\beta_7}$ is positive. In Hypothesis 3-2, we hypothesized that feedback is more beneficial for explorative innovations than for exploitative innovations, and we therefore expect that the positive marginal effects of $\widehat{\beta_8}$ is larger than that of $\widehat{\beta_9}$.

In order to further investigate whose opinion at which stage is more valuable for making product innovations, we use $FEEDBACK\_INI\_RD$, $FEEDBACK\_INI\_NONRD$, $FEEDBACK\_INI\_EXP$, $FEEDBACK\_LATE\_RD$, $FEEDBACK\_LATE\_NONRD$, and $FEEDBACK\_LATE\_EXP$. We can infer several scenarios on the effect of these variables. For example, if early feedback from people who have superior expertise is important for explorative innovations as suggested by Azoulay et al.'s (2011) empirical study on scientific research grant (see Section 2.2), we expect that $\widehat{\beta_8}$ for $FEEDBACK\_INI\_EX$ (opinions from external experts outside the firm in initial stages) in Equation (8) is significantly positive and its marginal effect is larger than that for others', say, $FEEDBACK\_INI\_NONRD$ (opinions from non-R&D organizations within the company in initial stages). As another example, if the feedback from the viewpoint of product marketability just before launching the new product is important for exploitative innovations, we expect that $\widehat{\beta_9}$ for $FEEDBACK\_LATE\_NONRD$ (opinions from non-R&D organizations (e.g., business units) within the company in the late stages) in Equation (9) is significantly positive.

3.3.3. Propensity score matching estimations

Our baseline estimations in Equations (1)–(9) assume that staged project management is orthogonal to disturbances for the dependent variables for product innovations. This assumption is likely to be not valid as firms endogenously choose whether and how they implement staged project management. To take the endogeneity of staged project management into account, we conduct propensity score matching (PSM) estimation. The basic idea of using PSM is to compare the average innovation outcomes of firms that employed staged project management (treatment group) to the average innovation outcomes of treatment firms' identical "twins" that did not employ staged project management (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 baseline estimations.

The procedure is as follows. First, we implement a logit estimation that models the probability of employing staged project management:

$$\Pr(DUM\_STAGE_i) = \psi\big(\alpha + \mathbf{X}_i'\boldsymbol{\gamma} + \mathbf{Z}_j\boldsymbol{\delta}\big), \tag{10}$$

where $\mathbf{X}_i'$ and $\mathbf{Z}_j$ denotes a vector of firm-level and industry-level variables, respectively. For firm characteristics $\mathbf{X}_i'$, we use $lnEMPLOYEE$, $NUM\_RD\ PROJECT$, and DUM_HYBRID, because larger firms, firms with more R&D projects, and firms with complex R&D organizational structure 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 $DUM\_EXTERNAL\ \ FUND$, which takes the value of one if a firm received external funds specifically for its R&D activities (e.g., funds from central and local government, university, and other firms) and zero otherwise. We conjecture that if a firm received external funds for R&D activities, the firm is likely to report interim outcomes periodically to external investors and hence employed staged project management. For industry-level variables $\mathbf{Z}_j$, we use $IND\_MB\ RATIO$, market-to-book ratio, and $IND\_RD\ EXPENSE - SALES\ RATIO$, R&D expenditures-to-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 growth opportunities and R&D intensity of invested firms.

Next, based on logit estimation results, we attach a propensity score to each observation. Then, for each treatment observation that employed staged project management, we 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. Several matching algorithms exist to find the "closest" control observations, and we employ the nearest neighbor matching. Finally, we compare the likelihood of innovation outcomes, DUM_INNOV, DUM_NTM, and DUM_NTF, for the treatment group and control group and obtain the average treatment effect on the treated (ATET). To be precise, we estimate

$E(y_1 - y_0|DUM\_STAGE = 1)$ where y_1 and y_0 represent the innovation outcome of the treatment and the control observations, respectively.

4. Results

4.1. Results for baseline estimations

4.1.1. The effect of staged project management

Table 3 presents the estimation results for the logit regressions using Equation (1), which examines whether staged project management increases the likelihood of product innovations (Hypothesis 1). The dependent variable is DUM_INNOV.

We find that the coefficient on DUM_STAGE is significantly positive, indicating that a firm that employed staged project management had a higher likelihood of making product innovations. This result is consistent with Hypothesis 1. The marginal effect on DUM_STAGE shows that, ceteris paribus, staged project management increased the likelihood of making product innovations by 23%. Given that the mean of DUM_INNOV in our sample is 54%, the quantitative impact of implementing staged project management on product innovation is substantial. Looking at the coefficients on other control variables, we find that most of them are insignificant. The coefficient on $DUM\_INTERNATIONAL\ EXCHANGE$ is significantly positive and suggests that firms that engaged in international technological exchanges were more likely to make product innovations.

When we use NUM_STAGE or $DURATION\_STAGE$ instead of DUM_STAGE, the coefficient on NUM_STAGE is significantly positive, whereas the coefficient on $DURATION\_STAGE$ is significantly negative. These results indicate that a firm with a larger number of stages and shorter average duration per stage was more likely to make product innovations and are also consistent with Hypothesis 1.

Next, Table 4 presents the estimation results for the bivariate probit regressions using Equations (2)–(3) in which the dependent variables are DUM_NTF and DUM_NTM, respectively. As noted, we estimate the bivariate probit model to examine the possibility that the results in Table 3 indicate that firms that employed staged project management tended to fall into short-termism and set modest goal, pursuing exploitative innovations rather than explorative innovations. We employ a bivariate probit model to allow the error terms in Equations (2)–(3) to be correlated. Indeed, as shown at the end row of Table 4, the likelihood-ratio (LR) test of the null that the correlation (rho) is zero is rejected in all estimations, which indicates that employing bivariate probit models is appropriate.

In Table 4, we find that the coefficients on DUM_STAGE are significantly positive for both DUM_NTF and DUM_NTM, and the marginal effects are similar: 0.198 for DUM_NTF and 0.206 for DUM_NTM. On the one hand, the significant marginal effect on DUM_STAGE for DUM_NTF suggests that staged project management might induce short-termism. On the other hand, the significant marginal effect on DUM_STAGE for DUM_NTM indicates that firms engaging in staged project management were more likely to make explorative product innovations. We also find that the results are qualitatively similar when we use NUM_STAGE and $DURATION\_STAGE$. If anything, we find that the statistical significance for the coefficient on NUM_STAGE is weaker for DUM_NTF than that for DUM_NTM. Overall, Table 4 shows that staged project management is positively correlated with making both new-to-firm and new-to-market product innovations, suggesting that the results in Table 3 are not entirely attributable to the short-termism that staged project management may induce.

Regarding the coefficients on control variables, we find that they are all insignificant for DUM_NTM. In contrast, we find that $lnEMPLOYEE$ and $RESEARCHER - EMPLOYEE\ RATIO$ are significantly positive for DUM_NTF, 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 coefficient on $RD\ EXPENSE - SALES\ RATIO$ for DUM_NTF is significantly negative, indicating that R&D-intensity is negatively associated with the likelihood of making new-to-firm innovations. One possible interpretation of this result is that R&D-intensive firms pursued explorative innovations and thus were less likely to make exploitative innovations. However, contrary to this possible interpretation, R&D intensity did not affect the likelihood of making new-to-market innovations as the coefficient on $RD\ EXPENSE - SALES\ RATIO$ for DUM_NTM is insignificant.

4.1.2. The effect of milestones

Table 5 presents the estimation results for the logit regressions using Equation (4) to examine the effect of milestones on product innovations, DUM_INNOV (Hypothesis 2-1). We use the subsample of firms that implemented staged project management; thus, the number of observations is reduced to 295. We find that the coefficient on $DUM\_MILESTONE$, which represents whether a firm set milestones, is positive but insignificant. The coefficients on $MILESTONE\_INI$ and $MILESTONE\_LATE$, which measure the importance of milestones in the initial and late stages, respectively, are also insignificant. Overall, these results indicate that Hypothesis 2-1 is not supported: whether a firm set milestones, and to what extent a firm took into account the achievement of milestones when assessing the continuation of R&D projects, did not affect the likelihood of making product innovations.

In Hypothesis 2-2, we argued that the effect of milestones is positive for exploitative innovations but is ambiguous for explorative innovations. Tables 6 presents the estimation results for the bivariate probit regressions using Equations (5)–(6) to examine the effect of milestones on new-to-firm and new-to-market innovations. We find that $DUM\_MILESTONE$ is insignificant for both DUM_NTF and DUM_NTM. The coefficients on $MILESTONE\_INI$ and $MILESTONE\_LATE$ are also insignificant. Hence, we do not find evidence that milestones had differential effects on new-to-firm and new-to-market innovations, as we hypothesized in Hypothesis 2–2.

4.1.3. The effect of feedback

Table 7 presents the estimation results for the logit regressions using Equation (7) to examine the effect of feedback on product innovations (Hypothesis 3-1) using the subsample of firms that implemented staged project management. We find that the coefficient on $DUM\_FEEDBACK$, which represents whether a firm provided feedback on the interim evaluation results to R&D employees, is significantly positive. The marginal effect on $DUM\_FEEDBACK$ shows that, ceteris paribus, providing feedback increased the likelihood of making product innovations by 17%. The result is consistent with Hypothesis 3-1. We further investigate whose opinions in the initial or late stages contributed to making product innovations, and Table 7 shows that the coefficient on $FEEDBACK\_INI\_NONRD$ is significantly positive, and its marginal effect is 13%. The result suggests that the feedback from non-R&D organizations (business units and head office) in initial stages was especially beneficial for making product innovations.

In Hypothesis 3-2, we argued that the positive effect of feedback on explorative innovations is larger than that for exploitative innovations. Table 8 presents the estimation results for the bivariate probit regressions using Equations (8)–(9) to examine the effect of feedback on new-to-firm and new-to-market innovations. We find that the coefficient on $DUM\_FEEDBACK$ is positively significant for both DUM_NTF and DUM_NTM and the marginal impact is larger for DUM_NTM (0.28) than for DUM_NTF (0.15), which is consistent with Hypothesis 3-2.

In addition, Table 8 shows some notable observations on the effect of feedback on making new-to-firm and new-to-market innovations. First, the coefficient on $FEEDBACK\_LATE\_EXP$ is significantly negative for new-to-firm product innovations. This suggests that feedback from external experts in late stages was detrimental to exploitative innovations. Second, the coefficient on $FEEDBACK\_INI\_NONRD$ is significantly positive for new-to-market product innovations. The coefficient on $FEEDBACK\_INI\_EXP$ is statistically insignificant, but it is weakly correlated with new-to-market product innovations as shown by its p-value being 0.108. These results suggest that opinions from outside the R&D units in early stages was beneficial for explorative innovations.

4.2. Results for propensity score matching estimations

In this subsection, we report the results of PSM estimations. To begin with, Table 9 presents the estimation results for the logit regressions using Equation (10) in which the dependent variable is DUM_STAGE. Table 9 shows that firms were more likely to employ staged project management if: they had a larger number of employees; they had a larger number of R&D projects; they employed hybrid R&D organizational structures; they obtained external funds for R&D activities; and if they belonged to more R&D-intensive industry. These results are consistent with our prior expectations explained in Section 3.3.3. The coefficient on the industry-level market-to-book ratio is insignificant. This result is inconsistent with Gompers (1995), who found that the industry-level market-to-book ratio was positively associated with staged investment by venture capital firms. However, it is consistent with Tian (2011), who found that industry-level market-to-book ratio was not correlated with VCs' staged investment.

We use the result of logit estimations in Table 9 to calculate a propensity score of each observation and conduct PSM estimations. Table 10 reports the average treatment effects of the treated on staged project management. We find that the treatment effects are significantly positive for DUM_INNOV, DUM_NTF, and DUM_NTM, and the marginal impacts are 22%, 21%, and 19%, respectively. These estimates are similar to the marginal effects obtained in Tables 3 and 4, confirming that staged project management increases the likelihood of making product innovations.

4.3. Discussion

Let us consider our estimation results in relation to Hypotheses 1–3 and previous studies. To start with, consistent with Hypothesis 1, we found that firms that employed staged project management were more likely to make product innovations. We also found that staged project management was positively correlated with both new-to-market and new-to-firm innovations, which suggests that the positive correlation between staged project management and product innovations that we found is not entirely caused by the possibility that R&D employees tended to choose exploitative innovations (short-termism) when their firms employed staged project management. As noted, staged project management has both advantages such as decreasing agency costs and creating an option to abandon the project and disadvantages such as inducing short-termism and an underinvestment problem for making innovation. Our findings suggest that the advantages of staged project management outweigh the disadvantages in the case of R&D activities by Japanese firms. Although many case studies (Cooper 1988, Fichman et al. 2005, Smolnik and Bergmann 2020, van der Duin et al. 2014) have acknowledged that staged project management is beneficial for firms' R&D activities, this study provides empirical evidence for the positive impact of staged project management on product innovations. Our results are consistent with Andries and Hünermund (2014), Klingebiel and Adner (2015), and Schultz et al. (2019), who found that staged project management is positively associated with successful new product development, but inconsistent with Mao et al. (2014), who found that the number of VC financing rounds negatively affected venture firms' innovation outputs.

Second, we found that milestones were not associated with the likelihood of making product innovations, being new-to-market or new-to-firm product innovations, among firms that employed staged project management. In Hypotheses 2 (2-1 and 2-2), we predicted that milestones are positively associated with making product and exploitative innovations, whereas the association between milestones and explorative innovations is ambiguous, based on Manso's (2011) argument regarding how the threat of termination affects the innovation. Although the insignificant effect of milestones on new-to-market innovations is partially consistent with Hypothesis 2, the insignificant effect on product innovations and on new-to-firm innovations are inconsistent with Hypothesis 2. Our results are also inconsistent with Ederer and Manso's (2013) experimental finding that the threat of termination undermined incentives for pursuing explorative innovations. Although examining why we obtained insignificant results thoroughly is beyond the scope of this study, the following explanation suggests themselves. In Hypothesis 2, we implicitly assumed that R&D employees face a larger threat of termination when their firms employ staged project management and set milestones than when the firms employ staged project management but do not set milestones. To check whether this assumption holds in our data, we examine the percentage share of firms that have any R&D projects that had been terminated or suspended within the past three years, using information in 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. This finding indicates that the shares of firms that terminated R&D projects are the same among firms that employed stage project management irrespective of whether they set milestones, suggesting that setting milestones in addition to employing staged project management does not effectively serve as a threat of terminating R&D projects in the case of Japanese firms, which is inconsistent with the implicit assumption in Hypothesis 2.

Third, consistent with Hypothesis 3 (3-1 and 3-2), we found that feedback was positively associated with making product innovations among firms that employed staged project management and the marginal impact on feedback was larger for new-to-market innovations than for new-to-firm innovations. 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 that high-quality feedback to the researcher encourages exploration. In addition to Hypothesis 3, we examined whose opinions were useful for making product innovations and found that opinions from non-R&D organizations within the company in the initial stages were positively associated with product and new-to-market innovations whereas opinions from external experts outside the company in late stages were negatively associated with new-to-firm innovations. While examining why opinions from particular people in particular stages were beneficial or harmful for product innovations is beyond the scope of this study, the positive link between opinions from non-R&D organizations in the initial stages and product and new-to-market innovations suggests that different perspectives obtained from outside the R&D units in initial stages may promote trial-and-errors in R&D activities, which are especially important for the exploration of unknown behavior and research methods. In contrast, the negative link between opinions from external experts outside the company in the late stages and new-to-firm innovations suggests that different perspectives obtained from outside the company in late stages may disturb the development of new-to-firm products. For example, suppose developing new-to-firm products has no technological challenges, and useful feedback for new-to-firm products in the late stages is mostly the review results from market evaluation by marketing research and pilot tests. In these cases, opinions from external experts may be disturbing when they are challenging for R&D employees to address.

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 innovations. Although some studies have empirically examined the link between staged project management and innovation, they used a particular firm survey, the German edition of the Community Innovation Survey. This study contributes to the literature by providing additional empirical evidence using another firms survey for Japanese firms. The specific contribution of this study is that it examined the role of milestones and feedback in staged project management for the first time 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 make product innovations. Second, among firms that employed staged project management, setting milestones and the importance of milestones in assessing whether to terminate or continue R&D projects did not affect the likelihood of making product innovations. Third, among firms that employed staged project management, providing feedback on the interim evaluation results to the researcher in charge of the R&D project was positively associated with making product innovations. In a nutshell, we conclude that managing R&D projects in stages is beneficial rather than harmful for corporate R&D activities.

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Table 1. Definition of variables

This table presents the definitions of the variables used in our estimations (Tables 3–10). Regarding the data sources, "RDMP" stands for the Survey of R&D Management Practices, which reports on corporate R&D management activities as of FY2018 unless otherwise stated. "SRD" stands for the 2019 Survey of Research and Development conducted by the Statistics Bureau of Japan, which reports firm characteristics as of FY 2018; for several firms for which the 2019 round was not available, we use either the 2018 or 2017 round of the survey. "JBS" stands for the 2019 Basic Survey of Japanese Business Structure and Activities conducted by the Ministry of Economy, Trade, and Industry, and "NFQ" stands for the Nikkei Financial QUEST database provided by Nikkei Media Marketing, Inc.

Variable	Definition	Data source
Dependent variables: Product innovations		
DUM_INNOV	Equals one if a firm made new or significantly improved goods/services (i.e., product innovations) from FY2016 to FY2018, and zero otherwise.	RDMP
DUM_NTM	Equals one if a firm made product innovations from FY2016 to FY2018 and the products introduced were ones no competitor offered in the market, and zero otherwise.	RDMP
DUM_NTF	Equals one if a firm made product innovations from FY2016 to FY2018 and the products introduced were almost the same as or very similar to ones already offered by competitors in the market, and zero otherwise.	RDMP
Main independent variables: Staged project management		
DUM_STAGE	Equals one if a firm implemented staged project management, and zero otherwise.	RDMP
NUM_STAGE	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 final achievement divided by the average number of stages.	RDMP
DUM_MILESTONE	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_STAGE*=1).	RDMP
MILESTONE_INI *MILESTONE_LATE*	Index variable that indicates 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 (*_INI*) or late (*_LATE*) stages of a project: four if the answer is "fully" (taken into account), three if it is "to some extent", two if it is "not very much," one if it is "not at all," and zero if a firm did not set milestones. This variable is for firms that implemented staged project management (*DUM_STAGE*=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 projects, and zero otherwise. This variable is for firms that implemented staged project management (*DUM_STAGE*=1).	RDMP
FEEDBACK_INI_RD *FEEDBACK_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 otherwise. This variable is for firms that implemented staged project management (*DUM_STAGE*=1).	RDMP

(continued)

FEEDBACK_INI_NONRD *FEEDBACK_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_STAGE*=1).	RDMP
FEEDBACK_INI_EXP *FEEDBACK_LATE_EXP*	Equals one if a firm incorporated opinions (including informal ones) from external 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_STAGE*=1).	RDMP
Control variables		
lnEMPLOYEE	Natural logarithm of the number of employees.	SRD
RD EXPENSE-SALES RATIO	Total amount of R&D expenditures relative to total sales.	SRD
RESEARCHER-EMPLOYEE RATIO	Total number of R&D researchers relative to employees.	SRD
RESEARCH EXPENSE RATIO	Basic research expenditures to total R&D expenditures.	SRD
DEVELOPMENT EXPENSE RATIO	Development research expenditures to total R&D expenditures.	SRD
NUM_RD PROJECT	Number of R&D projects in progress.	RDMP
Industry dummies	7 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
DUM_INTERNATIONAL EXCHANGE	Equals one if a firm exchanged technology in relation to or in the form of patents, know-how and technical guidance with 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 those 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 those 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 those directly controlled by BUs, and zero otherwise.	RDMP
Control variables for the PSM estimations		
DUM_EXTERNAL FUND	Equals one if a firm received R&D funds from external organizations (e.g., government, university, other firms), and zero otherwise.	SRD
IND_RD EXPENSE-SALES RATIO	The industry (JSIC three-digit code) average for the ratio of R&D expenditures relative to its total sales as of FY2018.	NFQ
IND_MB RATIO	The industry (JSIC three-digit code) average for market-to-book ratio (the market value of equity divided by the book value of equity) as of FY2018.	JBS

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

This table presents the summary statistics for the variables used in the estimations (Tables 3–10). 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 those 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 innovations												
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_STAGE	557	0.530	0.500	1	305	0.656	0.476	1	252	0.377	0.486	0
NUM_STAGE	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_MILESTONE	295	0.780	0.415	1	200	0.805	0.397	1	95	0.726	0.448	1
MILESTONE_INI	295	2.450	1.430	3	200	2.540	1.400	3	95	2.260	1.490	3
MILESTONE_LATE	295	2.800	1.570	3	200	2.920	1.520	4	95	2.560	1.650	3
DUM_FEEDBACK	294	0.854	0.354	1	200	0.890	0.314	1	94	0.777	0.419	1
FEEDBACK_INI_RD	294	0.609	0.489	1	200	0.635	0.483	1	94	0.553	0.500	1
FEEDBACK_INI_NONRD	294	0.605	0.490	1	200	0.660	0.475	1	94	0.489	0.503	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	294	0.473	0.500	0	200	0.490	0.501	0	94	0.436	0.499	0
FEEDBACK_LATE_NONRD	294	0.721	0.449	1	200	0.740	0.440	1	94	0.681	0.469	1
FEEDBACK_LATE_EXP	291	0.210	0.408	0	198	0.217	0.413	0	93	0.194	0.397	0
Control variables												
lnEMPLOYEE	557	5.790	1.240	5.720	305	5.980	1.290	5.870	252	5.560	1.140	5.530
RD EXPENSE-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 EXPENSE RATIO	557	0.038	0.102	0	305	0.041	0.111	0	252	0.033	0.091	0
DEVELOPMENT EXPENSE RATIO	557	0.752	0.315	0.922	305	0.749	0.309	0.893	252	0.755	0.322	0.953
NUM_RD PROJECT	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 FUND	576	0.446	0.498	0	314	0.484	0.501	0	261	0.402	0.491	0
IND_MB RATIO	576	2.010	1.740	1.440	314	1.940	1.650	1.440	261	2.090	1.830	1.460
IND_RD EXPENSE-SALES RATIO	576	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 innovations: Logit regressions

This table presents the logit estimation results on the effect of staged project management (DUM_STAGE, NUM_STAGE, $DURATION\_STAGE$) on product innovations (DUM_INNOV). ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. The column labeled "dy/dx" reports the average marginal effect.

Estimation method: Logit												
Dependent variables:	DUM_INNOV				DUM_INNOV				DUM_INNOV			
	Coef.		S.E.	dy/dx	Coef.		S.E.	dy/dx	Coef.		S.E.	dy/dx
DUM_STAGE	1.057	***	0.192	0.229								
NUM_STAGE					0.146	***	0.043	0.033				
DURATION_STAGE									-0.233	***	0.053	-0.051
lnEMPLOYEE	0.135		0.099	0.029	0.156		0.097	0.035	0.154		0.100	0.033
RD EXPENSE-SALES RATIO	-0.009		0.015	-0.002	-0.007		0.015	-0.001	0.001		0.015	0.000
RESEARCHER-EMPLOYEE RATIO	0.014		0.012	0.003	0.015		0.011	0.003	0.012		0.012	0.003
RESEARCH EXPENSE RATIO	-0.457		1.040	-0.099	-0.154		1.022	-0.035	-0.277		1.053	-0.060
DEVELOPMENT EXPENSE RATIO	0.323		0.328	0.070	0.338		0.324	0.076	0.268		0.334	0.058
NUM_RD PROJECT	0.002		0.003	0.000	0.002		0.003	0.001	0.003		0.003	0.001
DUM_INTERNATIONAL EXCHANGE	0.432	*	0.242	0.094	0.504	**	0.237	0.113	0.531	**	0.245	0.116
DUM_DECENTRALIZED	0.011		0.201	0.002	-0.051		0.198	-0.011	-0.091		0.204	-0.020
DUM_HYBRID	0.347		0.317	0.075	0.313		0.316	0.070	0.414		0.328	0.090
Industry Dummy			YES				YES				YES	
Constant	-1.536	**	0.769		-1.625	**	0.761		-0.314		0.806	
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-firm and new-to-market product innovations: Bivariate probit regressions

This table presents the bivariate probit estimation results on the effect of staged project management (DUM_STAGE, NUM_STAGE, $DURATION\_STAGE$) on new-to-firm innovations (DUM_NTF) and new-to-market innovations (DUM_NTM). ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. The column labeled “dy/dx” reports the average marginal effect. The row labeled “LR test: rho=0” reports the correlation coefficient of the error terms and the result of a likelihood-ratio test for the null that the correlation coefficient is zero.

Estimation method: Bivariate probit																		
Dependent variables:	DUM_NTM			DUM_NTF			DUM_NTM			DUM_NTF			DUM_NTM			DUM_NTF		
	Coef.	S.E.	dy/dx	Coef.	S.E.	dy/dx	Coef.	S.E.	dy/dx	Coef.	S.E.	dy/dx	Coef.	S.E.	dy/dx	Coef.	S.E.	dy/dx
DUM_STAGE	0.615 ***	0.122	0.206	0.555 ***	0.117	0.198												
NUM_STAGE							0.048 ***	0.015	0.017	0.029 *	0.016	0.011						
DURATION_STAGE													-0.127 ***	0.034	-0.044	-0.127 ***	0.033	-0.046
lnEMPLOYEE	0.032	0.060	0.011	0.161 ***	0.061	0.057	0.051	0.060	0.017	0.174 ***	0.060	0.064	0.046	0.061	0.016	0.173 ***	0.061	0.062
RD EXPENSE-SALES RATIO	0.000	0.009	0.000	-0.022 **	0.010	-0.008	0.002	0.009	0.001	-0.019 **	0.009	-0.007	0.006	0.009	0.002	-0.018 *	0.010	-0.006
RESEARCHER-EMPLOYEE RATIO	0.006	0.007	0.002	0.016 **	0.008	0.006	0.006	0.007	0.002	0.016 **	0.007	0.006	0.006	0.007	0.002	0.016 **	0.008	0.006
RESEARCH EXPENSE RATIO	0.029	0.601	0.010	-0.814	0.613	-0.290	0.215	0.597	0.074	-0.650	0.609	-0.240	0.133	0.604	0.046	-0.713	0.615	-0.256
DEVELOPMENT EXPENSE RATIO	-0.042	0.204	-0.014	0.176	0.200	0.063	-0.022	0.202	-0.007	0.184	0.197	0.068	-0.067	0.207	-0.023	0.152	0.203	0.055
NUM_RD PROJECT	0.001	0.001	0.000	0.002	0.002	0.001	0.002	0.001	0.001	0.002	0.001	0.001	0.002	0.001	0.001	0.002	0.002	0.001
DUM_INTERNATIONAL EXCHANGE	0.047	0.144	0.016	0.204	0.143	0.073	0.090	0.143	0.031	0.247 *	0.141	0.091	0.111	0.144	0.038	0.246 *	0.144	0.089
DUM_DECENTRALIZED	0.160	0.128	0.054	0.101	0.124	0.036	0.122	0.127	0.042	0.067	0.123	0.025	0.118	0.129	0.041	0.065	0.126	0.023
DUM_HYBRID	-0.101	0.185	-0.034	0.256	0.186	0.091	-0.133	0.187	-0.046	0.263	0.187	0.097	-0.075	0.186	-0.026	0.304	0.189	0.110
Industry Dummy	YES			YES			YES			YES			YES			YES		
Constant	-1.315 ***	0.504		-1.482 ***	0.480		-1.308 ***	0.499		-1.446 ***	0.475		-0.717	0.521		-0.825	0.502	
Number of observations	557						555						542					
Wald chi^2	88.63 ***						63.67 ***						74.69 ***					
Log likelihood	-647.37						-659.33						-639.99					
LR test: rho=0	0.52 ***						0.55 ***						0.52 ***					

Table 5. The effect of milestone on product innovations: Logit regressions

This table presents the logit estimation results on the effect of milestone ($DUM\_MILESTONE$, $MILESTONE\_INI$, $MILESTONE\_LATE$) on product innovations (DUM_INNOV). ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. The column labeled "dy/dx" reports the average marginal effect.

Estimation method: Logit						
Dependent variables:	DUM_INNOV			DUM_INNOV		
	Coef.	S.E.	dy/dx	Coef.	S.E.	dy/dx
DUM_MILESTONE	0.452	0.315	0.091			
MILESTONE_INI				-0.108	0.205	-0.022
MILESTONE_LATE				0.244	0.190	0.049
lnEMPLOYEE	-0.165	0.158	-0.033	-0.185	0.159	-0.037
RD EXPENSE-SALES RATIO	-0.027	0.020	-0.005	-0.029	0.020	-0.006
RESEARCHER-EMPLOYEE RATIO	0.017	0.017	0.003	0.016	0.017	0.003
RESEARCH EXPENSE RATIO	-0.860	1.280	-0.174	-0.841	1.295	-0.169
DEVELOPMENT EXPENSE RATIO	0.379	0.471	0.077	0.395	0.474	0.079
NUM_RD PROJECT	0.010 **	0.005	0.002	0.010 **	0.005	0.002
DUM_INTERNATIONAL EXCHANGE	0.458	0.325	0.093	0.433	0.326	0.087
DUM_DECENTRALIZED	0.147	0.303	0.030	0.121	0.305	0.024
DUM_HYBRID	0.513	0.400	0.104	0.495	0.402	0.100
Industry Dummy		YES			YES	
Constant	0.755	1.284		0.760	1.285	
Number of observations	295			295		
LR test	24.16 *			25.72 *		
Pseudo R^2	0.07			0.07		
Log likelihood	-173.30			-172.51		

Table 6. The effect of milestone on new-to-firm and new-to-market product innovations: Bivariate probit regressions

This table presents the bivariate probit estimation results on the effect of milestone ($DUM\_MILESTONE$, $MILESTONE\_INI$, $MILESTONE\_LATE$) on new-to-firm innovations (DUM_NTF) and new-to-market innovations (DUM_NTM). ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. The column labeled "dy/dx" reports the average marginal effect. The row labeled "LR test: rho=0" reports the correlation coefficient of the error terms and the result of a likelihood-ratio test for the null that the correlation coefficient is zero.

Estimation method: Bivariate probit												
Dependent variables:	DUM_NTM			DUM_NTF			DUM_NTM			DUM_NTF		
	Coef.	S.E.	dy/dx	Coef.	S.E.	dy/dx	Coef.	S.E.	dy/dx	Coef.	S.E.	dy/dx
DUM_MILESTONE	0.233	0.189	0.089	0.191	0.190	0.069						
MILESTONE_INI							-0.050	0.117	-0.019	0.044	0.119	0.016
MILESTONE_LATE							0.120	0.108	0.046	0.033	0.110	0.012
lnEMPLOYEE	-0.047	0.088	-0.018	0.089	0.093	0.032	-0.057	0.089	-0.022	0.082	0.094	0.029
RD EXPENSE-SALES RATIO	-0.006	0.012	-0.002	-0.028 **	0.013	-0.010	-0.006	0.012	-0.002	-0.028 **	0.013	-0.010
RESEARCHER-EMPLOYEE RATIO	0.001	0.009	0.000	0.025 **	0.011	0.009	0.000	0.009	0.000	0.025 **	0.011	0.009
RESEARCH EXPENSE RATIO	-0.347	0.727	-0.132	-0.865	0.772	-0.311	-0.324	0.730	-0.123	-0.848	0.777	-0.304
DEVELOPMENT EXPENSE RATIO	-0.174	0.274	-0.066	0.180	0.276	0.065	-0.170	0.274	-0.064	0.176	0.277	0.063
NUM_RD PROJECT	0.003 **	0.001	0.001	0.003	0.002	0.001	0.003 **	0.001	0.001	0.003	0.002	0.001
DUM_INTERNATIONAL EXCHANGE	0.002	0.182	0.001	0.163	0.186	0.059	-0.012	0.183	-0.004	0.157	0.186	0.056
DUM_DECENTRALIZED	0.167	0.179	0.063	0.346 *	0.180	0.125	0.156	0.179	0.059	0.339 *	0.181	0.122
DUM_HYBRID	-0.169	0.216	-0.064	0.332	0.225	0.120	-0.174	0.216	-0.066	0.333	0.225	0.120
Industy Dummy	YES			YES			YES			YES		
Constant	-0.321	0.764		-0.433	0.770		-0.323	0.767		-0.428	0.769	
Number of observations	295						295					
Wald	35.66						37.32					
Log likelihood	-366.16						-365.20					
LR test: rho=0	0.51 ***						0.51 ***					

Table 7. The effect of feedback on product innovations: Logit regressions

This table presents the logit estimation results on the effect of feedback ($DUM\_FEEDBACK$, $FEEDBACK\_INI\_RD$, $FEEDBACK\_INI\_NONRD$, $FEEDBACK\_INI\_EXP$, $FEEDBACK\_LATE\_RD$, $FEEDBACK\_LATE\_NONRD$, $FEEDBACK\_LATE\_EXP$) on product innovations (DUM_INNOV). ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. The column labeled "dy/dx" reports the average marginal effect.

Estimation method: Logit								
Dependent variables:	DUM_INNOV				DUM_INNOV			
	Coef.		S.E.	dy/dx	Coef.		S.E.	dy/dx
DUM_FEEDBACK	0.844	**	0.360	0.167				
FEEDBACK_INI_RD					-0.022		0.350	-0.004
FEEDBACK_INI_NONRD					0.681	**	0.311	0.133
FEEDBACK_INI_EXP					0.376		0.380	0.074
FEEDBACK_LATE_RD					0.095		0.355	0.019
FEEDBACK_LATE_NONRD					-0.031		0.349	-0.006
FEEDBACK_LATE_EXP					-0.204		0.410	-0.040
lnEMPLOYEE	-0.141		0.158	-0.028	-0.152		0.161	-0.030
RD EXPENSE-SALES RATIO	-0.037	*	0.021	-0.007	-0.034		0.022	-0.007
RESEARCHER-EMPLOYEE RATIO	0.028		0.019	0.005	0.025		0.020	0.005
RESEARCH EXPENSE RATIO	-0.491		1.271	-0.097	-0.529		1.318	-0.103
DEVELOPMENT EXPENSE RATIO	0.358		0.475	0.071	0.262		0.479	0.051
NUM_RD PROJECT	0.009	*	0.005	0.002	0.009	*	0.005	0.002
DUM_INTERNATIONAL EXCHANGE	0.412		0.329	0.081	0.457		0.335	0.089
DUM_DECENTRALIZED	0.223		0.309	0.044	0.124		0.313	0.024
DUM_HYBRID	0.502		0.402	0.099	0.495		0.407	0.097
Industy Dummy		YES				YES		
Constant	0.257		1.334		0.287		1.351	
Number of observations	294				291			
LR test	28.99	**			31.25	*		
Pseudo R^2	0.08				0.09			
Log likelihood	-169.74				-166.70			

Table 8. The effect of milestone on new-to-firm and new-to-market product innovations: Bivariate probit regressions

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

Estimation method: Bivariate probit												
Dependent variables:	DUM_NTM			DUM_NTF			DUM_NTM			DUM_NTF		
	Coef.	S.E.	dy/dx	Coef.	S.E.	dy/dx	Coef.	S.E.	dy/dx	Coef.	S.E.	dy/dx
DUM_FEEDBACK	0.745 ***	0.236	0.276	0.408 *	0.220	0.145						
FEEDBACK_INI_RD							0.068	0.201	0.025	-0.142	0.204	-0.050
FEEDBACK_INI_NONRD							0.361 **	0.181	0.133	0.206	0.185	0.072
FEEDBACK_INI_EXP							0.340	0.211	0.125	0.248	0.220	0.087
FEEDBACK_LATE_RD							0.161	0.204	0.059	0.318	0.208	0.112
FEEDBACK_LATE_NONRD							-0.023	0.204	-0.008	-0.028	0.205	-0.010
FEEDBACK_LATE_EXP							-0.163	0.230	-0.060	-0.482 **	0.233	-0.169
lnEMPLOYEE	-0.033	0.087	-0.012	0.099	0.093	0.035	-0.040	0.088	-0.015	0.093	0.093	0.033
RD EXPENSE-SALES RATIO	-0.010	0.012	-0.004	-0.035 **	0.014	-0.013	-0.008	0.013	-0.003	-0.033 **	0.015	-0.011
RESEARCHER-EMPLOYEE RATIO	0.004	0.010	0.002	0.033 ***	0.012	0.012	0.002	0.010	0.001	0.033 ***	0.013	0.012
RESEARCH EXPENSE RATIO	-0.128	0.721	-0.047	-0.740	0.781	-0.263	-0.302	0.740	-0.111	-0.805	0.790	-0.283
DEVELOPMENT EXPENSE RATIO	-0.224	0.277	-0.083	0.153	0.278	0.054	-0.288	0.278	-0.106	0.111	0.281	0.039
NUM_RD PROJECT	0.003 **	0.001	0.001	0.003	0.002	0.001	0.003 **	0.001	0.001	0.003	0.002	0.001
DUM_INTERNATIONAL EXCHANGE	-0.023	0.183	-0.009	0.138	0.187	0.049	-0.019	0.186	-0.007	0.146	0.190	0.051
DUM_DECENTRALIZED	0.214	0.181	0.079	0.388 **	0.182	0.138	0.159	0.183	0.058	0.340 *	0.184	0.120
DUM_HYBRID	-0.176	0.217	-0.065	0.328	0.226	0.116	-0.165	0.220	-0.060	0.310	0.229	0.109
Industy Dummy		YES			YES			YES			YES	
Constant	-0.834	0.794		-0.689	0.792		-0.996	0.856		-0.627	0.811	
Number of observations	294						291					
Wald	45.22 *						50.49					
Log likelihood	-359.20						-352.86					
LR test: rho=0	0.49 ***						0.50 ***					

Table 9. The determinants of staged project management: Logit regressions

This table presents the logit estimation results on the determinants of staged project management (DUM_STAGE). ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. The column labeled "dy/dx" reports the average marginal effect.

Estimation method: Logit				
Dependent variable:	DUM_STAGE			
	Coef.		S.E.	dy/dx
lnEMPLOYEE	0.246	***	0.081	0.056
NUM_RD PROJECT	0.007	**	0.003	0.001
DUM_HYBRID	0.749	**	0.311	0.169
DUM_EXTERNAL FUND	0.372	**	0.181	0.084
IND_MB RATIO	-0.021		0.064	-0.005
IND_RD EXPENSE-SALES RATIO	0.064	*	0.034	0.014
Constant	-1.893	***	0.462	
Number of observations	576			
LR test	59.51	***		
Pseudo R^2	0.07			
Log likelihood	-368.82			

Table 10. The effect of staged project management on product innovations: Propensity score matching regressions

This table presents the propensity score matching estimation results on the effect of staged project management (DUM_STAGE) on product innovations (DUM_INNOV), new-to-firm innovations (DUM_NTF) and new-to-market innovations (DUM_NTM). ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. The row labeled "ATET" reports the average treatment effect on the treated.

Estimation method: Propensity score matching			
Outcome variables:	DUM_INNOV	DUM_NTM	DUM_NTF
ATET	0.219 ***	0.185 ***	0.205 ***
S.E.	0.052	0.054	0.045
Number of observations	575	575	575

Appendix. Construction of key variables from the R&D management survey

This appendix presents how we constructed our key variables, which we explained in Section 3.2 in the main text, from the R&D management survey. The original survey questionnaire is presented in the Appendix of Haneda and Ono (2022).

Dependent variables for product innovations: The R&D management survey asked respondent firms whether they introduced new or improved products in the market during the past 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 product innovations, namely "new-to-market" products and "new-to-firm" products. We construct DUM_NTM and DUM_NTF using these questions. In the survey, new-to-market product innovation are new or significantly improved goods or services that no competitor offered in the market, while new-to-firm product are new or significantly improved goods or services that were almost the same as or very similar to ones already offered by competitors in the market. The definition of product innovation and its novelty in our survey is based on the Oslo Manual 2018 by the Organization for Economic Cooperation and Development, which provides international guidelines on innovation statistics.

Dependent variables for stage project management: For each firm, the R&D management survey identifies whether respondent firms implemented staged project management of their R&D projects in FY2018. Using this information, we construct DUM_STAGE. For firms that implemented staged project management, the survey then asked the average number of stages (NUM_STAGE), and the duration of each stage ($DURATION\_STAGE$).

The survey also asked whether a firm set milestones for the interim evaluation of a project ($DUM\_MILESTONE$) and whether a firm provided feedback on the interim evaluation results to the

R&D employee in charge of an R&D project ($DUM\_FEEDBACK$). In addition, for firms that set milestones, the survey asked the importance of intermediate goals (milestones) in assessing whether to terminate/suspend or continue the R&D project in "initial stages" (e.g., idea/basic research) and "late stages" (e.g., preparation for launching new goods/services). To be more precise, the survey asked to what extent firms took into account whether milestones were achieved on a four-point scale (4: "fully" take into account, 3: to some extent, 2: not very much taken into account, 1: not at all). Using this question, we construct the index variables $MILESTONE\_INI$ and $MILESTONE\_LATE$.

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

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

This table presents the summary statistics for the variables used in the estimations (Tables 3–10). Definitions of the variables are provided in Table 1. The bloc of columns labeled "DUM_STAGE=1" reports summary statistics for firms that employed staged project management and those labeled "DUM_STAGE=0" reports summary statistics for firms that did not employ staged project management.

					DUM_STAGE = 1				DUM_STAGE = 0			
	N	Mean	SD	p50	N	Mean	SD	p50	N	Mean	SD	p50
Dependent variables for product innovations												
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_STAGE	557	0.530	0.500	1	295	1	0	1	262	0	0	0
NUM_STAGE	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_MILESTONE	295	0.780	0.415	1	295	0.780	0.415	1	------	------	------	------
MILESTONE_INI	295	2.450	1.430	3	295	2.450	1.430	3	------	------	------	------
MILESTONE_LATE	295	2.800	1.570	3	295	2.800	1.570	3	------	------	------	------
DUM_FEEDBACK	294	0.854	0.354	1	294	0.854	0.354	1	------	------	------	------
FEEDBACK_INI_RD	294	0.609	0.489	1	294	0.609	0.489	1	------	------	------	------
FEEDBACK_INI_NONRD	294	0.605	0.490	1	294	0.605	0.490	1	------	------	------	------
FEEDBACK_INI_EXP	291	0.261	0.440	0	291	0.261	0.440	0	------	------	------	------
FEEDBACK_LATE_RD	294	0.473	0.500	0	294	0.473	0.500	0	------	------	------	------
FEEDBACK_LATE_NONRD	294	0.721	0.449	1	294	0.721	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 EXPENSE-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 EXPENSE RATIO	557	0.038	0.102	0	295	0.047	0.117	0	262	0.027	0.081	0
DEVELOPMENT EXPENSE RATIO	557	0.752	0.315	0.922	295	0.732	0.318	0.870	262	0.774	0.310	0.984
NUM_RD PROJECT	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 FUND	576	0.446	0.498	0	302	0.520	0.500	1	274	0.365	0.482	0
IND_MB RATIO	576	2.010	1.740	1.440	302	2.060	1.770	1.460	274	1.960	1.710	1.440
IND_RD EXPENSE-SALES RATIO	576	4.170	3.230	3.840	302	4.480	3.370	3.920	274	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 3–10). 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)
Dependent variables for product innovations																																				
(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_STAGE	0.27	0.22	0.24	1																																
(5) NUM_STAGE	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_MILESTONE	0.24	0.20	0.22	0.79	0.39	-0.44	1																													
(8) MILESTONE_INI	0.23	0.20	0.23	0.76	0.38	-0.42	0.96	1																												
(9) MILESTONE_LATE	0.25	0.20	0.23	0.78	0.39	-0.43	0.98	0.95	1																											
(10) DUM_FEEDBACK	0.28	0.26	0.25	0.85	0.41	-0.49	0.74	0.73	0.73	1																										
(11) FEEDBACK_INI_RD	0.21	0.20	0.17	0.65	0.32	-0.37	0.55	0.56	0.55	0.76	1																									
(12) FEEDBACK_INI_NONRD	0.26	0.24	0.20	0.64	0.33	-0.37	0.51	0.53	0.51	0.75	0.61	1																								
(13) FEEDBACK_INI_EXP	0.14	0.15	0.11	0.37	0.15	-0.19	0.35	0.35	0.37	0.44	0.36	0.41	1																							
(14) FEEDBACK_LATE_RD	0.17	0.18	0.17	0.54	0.21	-0.31	0.48	0.47	0.47	0.63	0.73	0.52	0.33	1																						
(15) FEEDBACK_LATE_NONRD	0.23	0.20	0.20	0.74	0.33	-0.41	0.65	0.63	0.65	0.86	0.64	0.66	0.43	0.65	1																					
(16) FEEDBACK_LATE_EXP	0.11	0.12	0.04	0.33	0.18	-0.16	0.29	0.30	0.31	0.38	0.35	0.41	0.57	0.40	0.41	1																				
Control variables																																				
(17) lnEMPLOYEE	0.16	0.07	0.21	0.25	0.16	-0.14	0.29	0.27	0.29	0.21	0.17	0.12	0.09	0.14	0.20	0.07	1																			
(18) RD EXPENSE-SALES RATIO	0.01	0.06	-0.06	0.07	0.02	-0.03	0.09	0.08	0.10	0.08	0.04	0.05	0.09	0.04	0.09	0.12	-0.21	1																		
(19) RESEARCHER-EMPLOYEE RATIO	0.05	0.07	0.03	0.04	0.02	-0.03	0.04	0.04	0.05	0.04	0.03	0.05	0.03	0.01	0.05	0.06	-0.21	0.66	1																	
(20) RESEARCH EXPENSE RATIO	0.04	0.04	-0.02	0.10	0.01	-0.04	0.11	0.08	0.09	0.06	0.08	-0.03	-0.01	0.04	0.07	0.06	0.14	0.01	-0.01	1																
(21) DEVELOPMENT EXPENSE RATIO	-0.01	-0.03	0.01	-0.07	-0.02	-0.01	-0.08	-0.07	-0.09	-0.04	-0.05	0.03	0.03	-0.03	-0.06	-0.04	-0.17	-0.02	0.00	-0.42	1															
(22) NUM_RD PROJECT	0.15	0.12	0.17	0.20	0.15	-0.12	0.22	0.21	0.21	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														
(23) DUM_INTERNATIONAL EXCHANGE	0.15	0.07	0.15	0.19	0.08	-0.07	0.21	0.20	0.22	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													
(24) DUM_CENTRALZED	-0.02	-0.03	-0.05	-0.01	-0.07	0.06	0.00	-0.01	-0.01	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												
(25) DUM_DECENTRALIZED	-0.08	0.02	-0.06	-0.13	-0.09	0.01	-0.14	-0.12	-0.13	-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											
(26) DUM_HYBRID	0.14	0.03	0.16	0.20	0.24	-0.10	0.19	0.18	0.20	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										
(27) IND_FOOD	0.14	0.07	0.07	0.00	-0.02	-0.04	-0.04	-0.02	-0.03	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									
(28) IND_CHEMICAL	-0.06	-0.01	-0.03	0.02	0.03	0.00	0.01	0.01	0.02	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								
(29) IND_IRON	0.01	-0.02	0.02	-0.07	-0.01	0.09	-0.02	-0.03	-0.04	-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							
(30) IND_MACHINERY	-0.03	0.00	-0.02	0.08	0.07	-0.07	0.06	0.06	0.07	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						
(31) IND_OTHER_MANUF	0.03	0.00	0.02	0.05	-0.04	-0.03	0.04	0.05	0.03	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					
(32) IND_INFO	-0.03	0.00	-0.04	-0.14	-0.09	0.08	-0.09	-0.10	-0.10	-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				
(33) IND_WHOLESALES	-0.02	-0.05	-0.01	-0.08	-0.04	0.07	-0.06	-0.08	-0.06	-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																																				
(34) DUM_EXTERNAL FUND	0.06	0.06	0.04	0.14	0.03	0.02	0.19	0.19	0.19	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		
(35) IND_MB RATIO	-0.04	-0.02	-0.09	0.02	0.09	0.03	0.04	0.05	0.06	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	
(36) IND_RD EXPENSE-SALES RATIO	-0.08	0.00	-0.11	0.10	0.15	-0.03	0.10	0.09	0.12	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_STAGE=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)
Dependent variables for product innovations																																				
(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_STAGE	.	.	.	.																																
(5) NUM_STAGE	0.04	0.04	0.00	.	1																															
(6) DURATION_STAGE	-0.08	-0.08	-0.05	.	-0.33	1																														
(7) DUM_MILESTONE	0.06	0.05	0.07	.	0.00	0.08	1																													
(8) MILESTONE_INI	0.06	0.06	0.09	.	0.01	0.09	0.91	1																												
(9) MILESTONE_LATE	0.08	0.07	0.09	.	0.02	0.07	0.95	0.89	1																											
(10) DUM_FEEDBACK	0.14	0.17	0.10	.	-0.02	-0.01	0.19	0.24	0.21	1																										
(11) FEEDBACK_INI_RD	0.06	0.10	0.02	.	-0.01	0.03	0.09	0.14	0.10	0.52	1																									
(12) FEEDBACK_INI_NONRD	0.16	0.17	0.08	.	0.02	-0.01	0.01	0.08	0.02	0.51	0.33	1																								
(13) FEEDBACK_INI_EXP	0.06	0.10	0.03	.	-0.04	0.09	0.10	0.11	0.13	0.24	0.16	0.24	1																							
(14) FEEDBACK_LATE_RD	0.05	0.10	0.07	.	-0.08	0.02	0.09	0.11	0.10	0.39	0.60	0.26	0.17	1																						
(15) FEEDBACK_LATE_NONRD	0.06	0.07	0.03	.	-0.06	0.05	0.15	0.15	0.18	0.67	0.32	0.35	0.24	0.43	1																					
(16) FEEDBACK_LATE_EXP																																				
Control variables	0.03	0.06	-0.1	.	0.02	0.09	0.06	0.08	0.09	0.21	0.2	0.28	0.51	0.28	0.26	1																				
(17) lnEMPLOYEE	0.04	0.02	0.11	.	0.06	0.10	0.21	0.17	0.21	0.00	0.00	-0.08	0.00	0.00	0.03	-0.02	1																			
(18) RD EXPENSE-SALES RATIO	-0.04	-0.01	-0.04	.	-0.02	0.06	0.07	0.06	0.09	0.06	0.00	0.01	0.09	0.01	0.09	0.14	-0.15	1																		
(19) RESEARCHER-EMPLOYEE RATIO	0.06	0.00	0.11	.	0.00	0.00	0.03	0.02	0.06	0.02	0.01	0.04	0.03	-0.01	0.04	0.08	-0.09	0.62	1																	
(20) RESEARCH EXPENSE RATIO	-0.05	-0.02	-0.10	.	-0.06	0.05	0.05	0.00	0.03	-0.06	0.02	-0.15	-0.06	-0.02	-0.02	0.03	0.09	0.04	0.04	1																
(21) DEVELOPMENT EXPENSE RATIO	0.06	-0.02	0.06	.	0.02	-0.10	-0.05	-0.02	-0.06	0.06	0.00	0.14	0.09	0.02	-0.02	-0.02	-0.23	-0.02	0.01	-0.45	1															
(22) NUM_RD PROJECT	0.15	0.12	0.17	.	0.06	0.01	0.10	0.10	0.09	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														
(23) DUM_INTERNATIONAL EXCHANGE	0.10	0.00	0.10	.	-0.01	0.13	0.12	0.11	0.14	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													
(24) DUM_CENTRALZED	-0.06	-0.03	-0.09	.	-0.11	-0.02	0.02	0.00	-0.01	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												
(25) DUM_DECENTRALIZED	-0.02	0.06	0.01	.	-0.04	0.01	-0.08	-0.04	-0.05	-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											
(26) DUM_HYBRID	0.09	-0.04	0.11	.	0.19	0.01	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										
(27) IND_FOOD	0.05	0.05	-0.05	.	-0.03	-0.03	-0.09	-0.05	-0.07	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									
(28) IND_CHEMICAL	-0.07	-0.04	0.01	.	0.02	0.09	-0.03	-0.01	0.00	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								
(29) IND_IRON	0.05	0.05	0.03	.	0.04	-0.01	0.09	0.05	0.04	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							
(30) IND_MACHINERY	-0.04	-0.01	-0.04	.	0.04	-0.08	0.00	-0.01	0.01	-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						
(31) IND_OTHER_MANUF	0.07	0.02	0.05	.	-0.09	0.03	0.02	0.03	0.00	-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					
(32) IND_INFO	0.03	-0.01	0.06	.	-0.04	-0.03	0.07	0.03	0.05	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				
(33) IND_WHOLESALES	-0.02	-0.06	0.01	.	0.01	0.03	0.00	-0.04	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																																				
(34) DUM_EXTERNAL FUND	0.00	0.03	-0.03	.	-0.07	0.17	0.18	0.16	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		
(35) IND_MB RATIO	-0.12	-0.05	-0.16	.	0.12	0.12	0.06	0.06	0.09	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	
(36) IND_RD EXPENSE-SALES RATIO	-0.14	-0.02	-0.19	.	0.15	0.09	0.05	0.03	0.09	-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

DISCUSSION PAPER No.209

ステージ型プロジェクト管理がプロダクト・イノベーションの実現に及ぼす影響：
企業向け設問票調査に基づく定量分析

2022年6月

文部科学省 科学技術・学術政策研究所 第1研究グループ
羽田 尚子　栗原 仰基　小野 有人

〒100-0013　東京都千代田区霞が関3-2-2 中央合同庁舎第7号館 東館16階
TEL: 03-3581-2396　FAX: 03-3503-3996

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

June 2022

HANEDA Shoko, KURIHARA Koki, and ONO Arito

First Theory-Oriented Research Group
National Institute of Science and Technology Policy (NISTEP)
Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan

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