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企業のイノベーション・アウトプットの多面的測定

Multi-Dimensional Measurement of Innovation Outputs by Firms

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第1研究グループ

池内　健太

【執筆者】

池内 健太　　独立行政法人経済産業研究所 研究員
文部科学省科学技術・学術政策研究所 客員研究官
政策研究大学院大学 客員研究員

【Author】

Kenta Ikeuchi　　Fellow, Research Institute of Economy, Trade and Industry
Affiliated Fellow, National Institute of Science and Technology Policy (NISTEP), MEXT
Visiting Scholar, National Graduate Institute for Policy Studies (GRIPS)

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企業のイノベーション・アウトプットの多面的測定

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

本稿では、企業のイノベーション活動のアウトプットに関する様々な指標間の相互依存性について検討する。プレスリリースや特許、商標、意匠登録などの知的財産権といった文献ベースのデータを日本の「全国イノベーション調査」の企業レベルのミクロデータに企業レベルで結びつけたパネルデータを構築し、イノベーション活動の多様性を定量的に捉えることを試みる。さらに、企業のイノベーション活動のアウトプットが企業価値と生産性に及ぼす影響を検証する。本稿の分析結果は、企業のプレスリリースが多面的なイノベーション活動、特に、急進的な（市場にとって新しい）プロダクト・イノベーション、組織イノベーション、研究開発活動の状況を表していることを示唆している。知的財産権については、プロダクト・イノベーションを有する企業がより多くの商標を登録し、その中でも急進的な新製品を有する企業ほど、より多くの商標を登録していることが実証された。また、研究開発支出の多い企業ほど特許出願件数が多く、デザイン活動やマーケティング・イノベーションを実施している企業ほど意匠登録件数が多いことも確認された。さらには、特許出願や商標登録が多い企業や新製品、技術開発、組織変更に関するプレスリリースが多い企業ほど、企業の市場価値や生産性が高いこともわかった。

Multi-Dimensional Measurement of Innovation Outputs by Firms

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

ABSTRACT

This paper examines the interdependence between various measurements of firms’ innovation outputs. Linking firm-level microdata from the Japanese National Innovation Survey to the literature-based microdata on firm innovation from press releases and data on intellectual property rights such as patents, trademarks, and design registrations, I construct a panel dataset that captures the diversity of innovation activities. Additionally, I examine the effects of firms’ innovation outputs on the market value and productivity of the firms. The empirical results suggest that observed firm’s press releases represent the multi-dimensional innovation activities of firms, particularly the radical product (new-to-market) innovations, organizational innovation, and research and development (R&D) activities. With respect to the intellectual property rights, the empirical results show that firms with product innovation registered more trademarks, in particular firms with more radical new products tend to register more trademarks, and patent data reflects the R&D activity of firms while design registrations reflect the design activity and marketing innovation measured in the innovation survey. In addition to patent applications and trademark registrations, press releases on new products, technological developments, and organizational changes of a firm are positively correlated with the market value and productivity of that firm.

本 DISCUSSION PAPER は、文部科学省科学技術・学術政策研究所（NISTEP）と政策研究大学院大学（GRIPS）・科学技術イノベーション政策研究センターとの共同研究プロジェクトの成果の一部である。

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概要

1. はじめに

イノベーションは、経済の発展と成長、豊かさにとって最も重要な源泉の 1 つであり、イノベーションの実態を捉えることは生産性向上の決定要因やプロセスを理解することにつながる。日本では 1990 年代初めに始まった長期的な景気低迷と高齢化による労働力不足に直面しており、イノベーションを促進し、生産性を高めることが重要な政策課題の 1 つとなっている。また、イノベーションは、知識の創造と普及のプロセスと密接に関連しているため、経済政策のみならず科学技術政策にも密接に関連している。

イノベーション・プロセスの現状の正確な理解は政策立案者が適切な政策を実施するための必要条件であり、イノベーション活動の成果を精緻に捉えるためのイノベーション・アウトプットの測定は特に重要である。また、企業のイノベーション活動のアウトプットを適切に測定することは、イノベーション・プロセスを理論的・実証的に研究するためにも重要である。しかしながら、イノベーション自体が多様な側面を持つことに加え、複数のプロセスで構成されているため、イノベーション活動のアウトプットを測定することは最も困難な課題の 1 つとなっている。他方、Andrew *et al.*（2008）の調査によれば、民間企業の役員のほとんどは「自社がイノベーションを測定すべき」だと考えているが、実際に自社のイノベーションの状況を測定しているのは約 4 割にとどまっており、イノベーションのアウトプットの測定は、産業界においても重要かつ困難な課題であると認識されていると考えられる。

既存研究では、イノベーションのアウトプットの測定方法として、「Community Innovation Survey（CIS）」と呼ばれる企業に対する質問票調査が広く使われている。日本においても、科学技術・学術政策研究所（NISTEP）が CIS の質問票と対照可能な「全国イノベーション調査」(J-NIS)を一般統計調査として実施しており、イノベーション・アウトプットを含め、企業のイノベーション活動の状況が定期的に調査されている。J-NIS や CIS の質問票では、直近 3 年間における新しい製品やサービスの市場への導入（プロダクト・イノベーション）や新しい生産工程の自社内での導入（プロセス・イノベーション）といった技術的なイノベーションに加え、新しい組織管理の方法やマーケティング手法の自社内での導入といった非技術的なイノベーションについても調査されている。しかしながら、J-NIS や CIS の質問票に基づく現行のイノベーション・アウトプットの測定にはいくつかの限界がある。特に、新製品・新サービスの数といったイノベーション活動のアウトプットの量的な側面が調査されていないことや自社が行った製品・サービスの質の改善が質問票に記載されたイノベーションの定義に該当するのかの判断を回答企業が行う必要があり、その回答負担が大きいといった点がある。

一方、企業への質問票調査やインタビューではなく、業界誌などの文献から得られた情報に基づいて企業のイノベーション活動のアウトプットを測定する方法も提案されており、このように測定された指標は「文献ベースのイノベーション・アウトプット（LBIO）」指標

として呼ばれている（Coombs *et al*. 1996）。イノベーションの量的な側面は標準的な CIS の質問票には含まれていないが、LBIO を用いることでプレスリリースや業界紙に掲載された新製品・新サービスの数を集計することが可能であり、イノベーション活動のアウトプットを量的に捉えることも可能である。しかしながら、LBIO のデータの活用は、1980 年代に米国におけるイノベーション活動の分析として初めて行われたものの（Acs and Audretsch 1987）、その後は CIS の質問票を用いた測定に比べるとあまり発展・普及していない。

そこで本研究では、企業のイノベーション活動のインプット及びアウトプットに関する全国イノベーション調査(J-NIS)の回答結果が LBIO とどのような関係性があるかを統計的に検証する。本研究では、LBIO として、企業が発行したプレスリリースと知的財産権に関するデータを用いる。既に多くの先行研究において、イノベーション活動のアウトプットの代理変数として特許データが用いられている。一方、知的財産権に関する情報には特許に加えて登録商標や登録意匠も利用できるが、商標や意匠とイノベーション活動の関係を分析した既存研究はほとんどない。そこで本研究では、商標と意匠を含めた知的財産に関わる文献情報もイノベーション活動の中間的な成果物と捉え、LBIO の一部として扱う。さらに本研究では、これらの LBIO と企業価値及び生産性との関係性を統計的に検証することにより、LBIO と企業の経営パフォーマンスとの関係性についても明らかにする。

2. 分析方法

図 1 は、本研究におけるイノベーションのアウトプットを測定する枠組みを示している。本研究では、特許、商標、意匠及びプレスリリースといった LBIO に関するデータと J-NIS で調査されるイノベーション活動のインプットやアウトプットの関係性、さらにはイノベーションの成果としての経営パフォーマンスとの関係性を統計的に検証していく。そのため、本研究では、特許、商標、意匠、プレスリリースの 4 つの LBIO に関するデータソースを「全国イノベーション調査」の企業レベルのミクロデータ及び上場企業の財務データ（DBJ）及び生産性データ（EALC）に接続して分析に用いるデータセットを構築した（図 2）。

図 1：本研究におけるイノベーション・アウトプットの測定枠組み

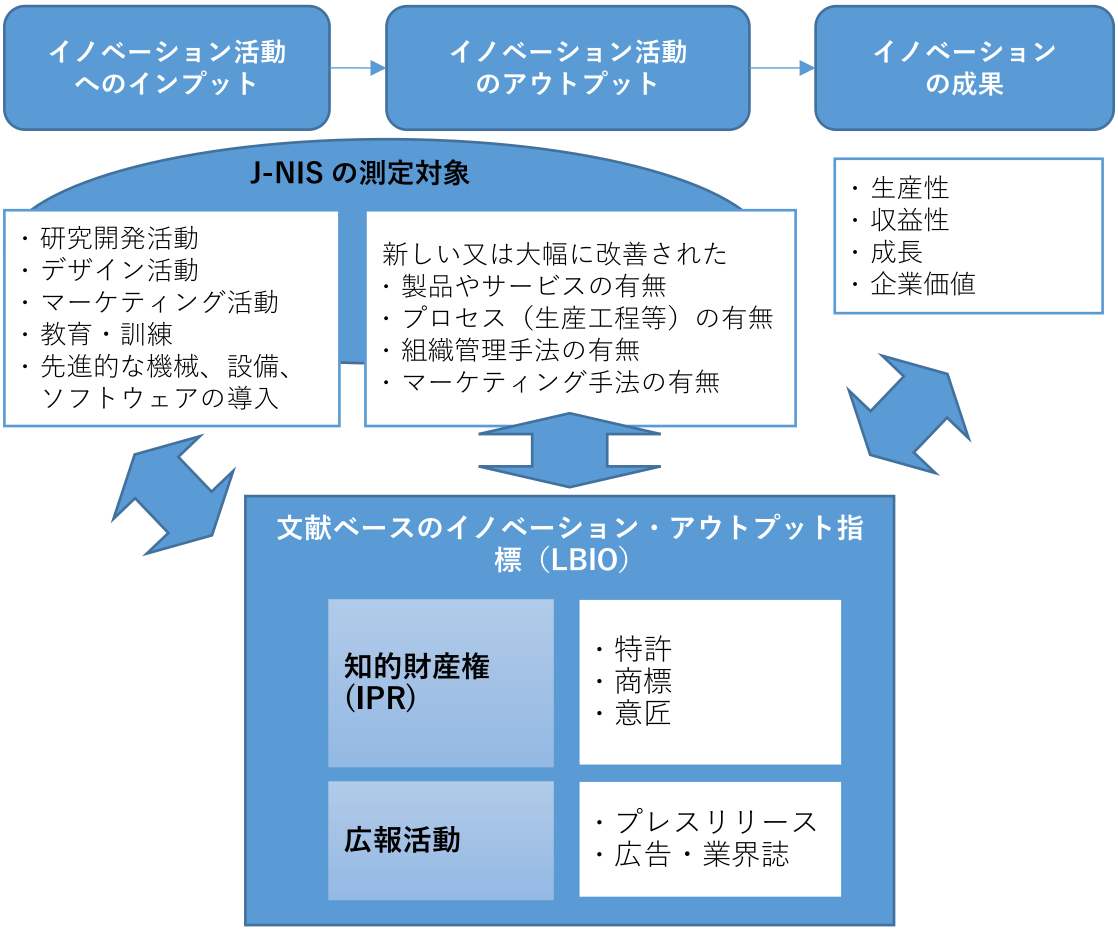
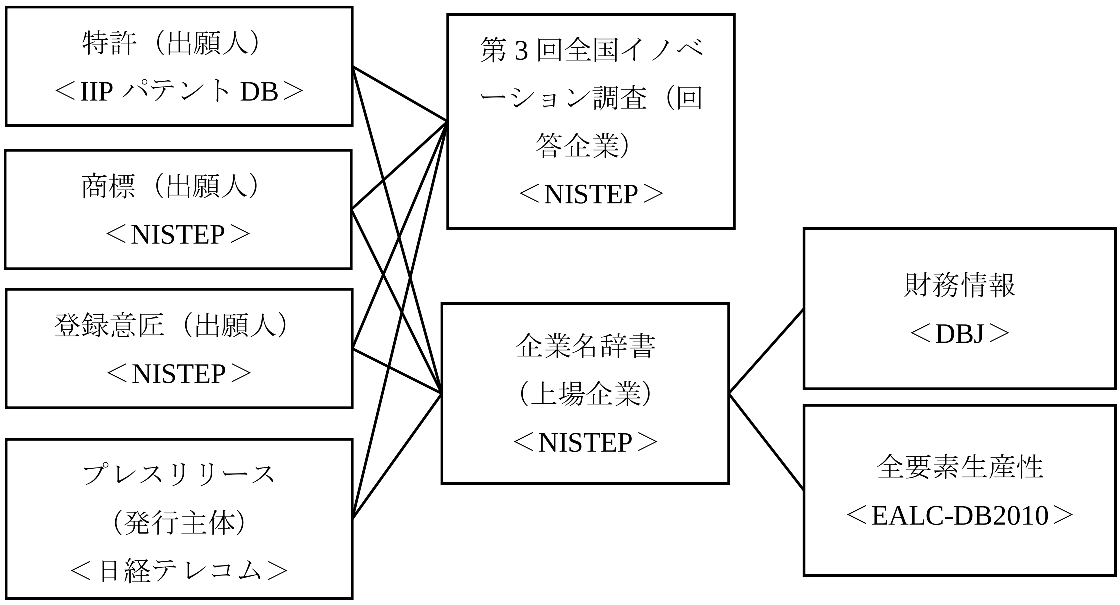


図 2：分析に用いるデータとデータの接続方法



「全国イノベーション調査（J-NIS）」は、科学技術・学術政策研究所（NISTEP）が実施している政府統計であり、その質問票は欧州の EEA 諸国において中核質問票として作成されている CIS の質問票を比較対照して作成されている。J-NIS は日本で 4 回実施されているが、本研究では、利用可能な最新のデータであり、2012 年に実施された第 3 回調査のデータ（J-NIS 2012）を使用する。この調査は、2009 年に日本で活動している常用雇用者数 10 人以上の全ての製造業の企業と、一部の非製造業の企業とから無作為に抽出された 20,405 社を対象とし、有効回答数は 7,034 社である。J-NIS2012 の調査方法に関する詳細は科学技術・学術政策研究所（2014）を参照されたい。

特許データとしては、「IIP パテントデータベース 2015 年版」（知的財産研究所）を用いる。このデータには 1964 年から 2011 年までの特許庁に出願された全ての特許データが含まれている。商標と意匠に関するデータは NISTEP が公表している「意匠権・商標権データベース」（元橋他 2016）を用いる。なお、このデータベースには 1999 年から 2012 年の間に登録された商標及び意匠が含まれている（出願されたものの登録されなかった商標及び意匠は含まれない）。特許・商標・意匠の出願人の名称に基づいて、J-NIS2012 の回答企業及び上場企業の名称と照合し、各企業の特許出願件数、商標及び意匠の登録件数を企業のイノベーション活動のアウトプットの指標として用いた。

プレスリリースのデータは、2003 年から 2014 年の「日経プレスリリース」のウェブサイトに掲載されている全ての記事を含む「日経テレコム」から提供されたデータを用いた。なお、各プレスリリース記事のタイトルのテキスト情報からプレスリリースの種類を区別した。このデータには合計で約 35 万件の記事が含まれおり、全記事の約 6 割は新製品・新サ

ービスに関する記事と分類され、全記事の 8%及び 6%がそれぞれ組織変革及び技術開発に関する記事と分類された。なお、プレスリリース記事のタイトルの先頭にはリリースを発行した企業の名称が記載されており、J-NIS2012 の回答企業や上場企業の企業名と照合して、企業レベルでデータベースの接続を行った。

これらのデータを使用して、2 つの企業レベルのデータセットを構築し、イノベーション・アウトプット指標間の相互依存性を検証する。1 つ目のデータセットは、J-NIS 2012 の回答企業に、特許、商標、意匠及びプレスリリースデータを接続したデータである。J-NIS 2012 の回答企業 7,034 社のうち、何らかのプレスリリースを発行した企業は 4.1%、特許を出願した企業は 12%、商標登録を行った企業は 17.4%、意匠登録を行った企業は 6.2%であった（いずれも単純集計値であり、母集団推計値ではない）。この 1 つ目のデータセットを用いて、J-NIS 2012 で調査されている各企業の「プロダクト・イノベーション（新しい又は大幅に改善した製品・サービスの市場への導入）」、「組織イノベーション（組織に関する新しい又は大幅に改善された手法の自社内における導入）」及び「マーケティング・イノベーション（マーケティング手法に関する大幅に改善された手法の自社内における導入）」の有無といったイノベーション活動のアウトプット、「研究開発支出」や「デザイン活動」の有無といったイノベーション活動のインプットが、それぞれ関連する LBIO 指標とどのような関係性にあるかを統計的に検証する。

分析に用いる 2 つ目のデータセットは、特許、商標、意匠及びプレスリリースを上場企業に接続したデータである。LBIO 指標群と企業業績との関係性を分析するため、設備投資銀行（DBJ）の「企業財務データ」と日本経済研究センター・一橋大学経済制度研究センター・日本大学中国・アジア研究センター・ソウル大学企業競争力研究センターが公表している「東アジア上場企業データベース（EALC-DB）2010」も接続した。なお、これら特許、商標及び意匠の出願人、プレスリリースの発行主体と上場企業の名寄せには「NISTEP 企業名辞書」を活用した。上場企業のうち、プレスリリースを発行した企業は 63%、特許出願企業は 73%、商標登録企業は 93%、意匠登録企業は 45%であった（いずれも単純集計値であり、母集団推計値ではない）。このデータセットを用いて、特許出願件数や商標及び意匠の登録件数及びタイプ別のプレスリリースの件数が上場企業の企業価値や生産性とどのような関係性にあるかを統計的に検証する。そのため、企業価値の指標としては「トービンの q」（時価総額と負債の合計の総資産に対する比率で定義され、企業の株式市場からの評価の高さを示す）を用い、生産性の指標としては「全要素生産性（TFP）」を用いた。

3. 分析結果

本研究では、主に２つの側面から分析を行う。まず、（１）全国イノベーション調査（J-NIS 2012）の企業が自己申告で回答したイノベーション活動のインプット及びアウトプットがプレスリリースや特許、商標、意匠といった LBIO 指標群とどのような関係性があるかを統計的に検証する。次に、（２）上場企業に関して LBIO 指標群と企業の経営パフォーマン

ス（企業価値及び TFP）との関係性を統計的に検証する。

図 3 は分析結果の概要を示している。まず、上記（1）の分析の結果、以下のように企業の自己申告で測定されたイノベーションと LBIO 指標群が整合的であることが明らかとなった。なお、いずれも企業規模の効果をコントロールした結果である。

① 「市場にとって新しいプロダクト・イノベーション」を導入したと回答した企業はそうでない企業よりも、「新製品・新サービスに関するプレスリリース件数」と「商標登録件数」が統計的有意に多い。

② 「企業にとってのみ新しいプロダクト・イノベーション」を導入したと回答した企業はそうでない企業よりも、「商標登録件数」が統計的有意に多いが、「新製品・新サービスに関するプレスリリース件数」との関係性は統計的に有意ではない。

③ 「組織イノベーション」を導入したと回答した企業はそうでない企業よりも、「組織変革に関するプレスリリース件数」が統計的有意に多い。

④ 「研究開発支出額」が大きい企業ほど、「技術開発に関するプレスリリース件数」と「特許出願件数」が統計的有意に多い。

⑤ 「デザイン活動」や「マーケティング・イノベーション」を実施している企業はそうでない企業よりも「意匠登録件数」が統計的に多い。

⑥ 「研究開発支出額」が大きい企業や「デザイン活動」を実施している企業ほど、「市場にとって新しいプロダクト・イノベーション」「企業にとってのみ新しいプロダクト・イノベーション」「マーケティング・イノベーション」を行う確率が統計的有意に高い。

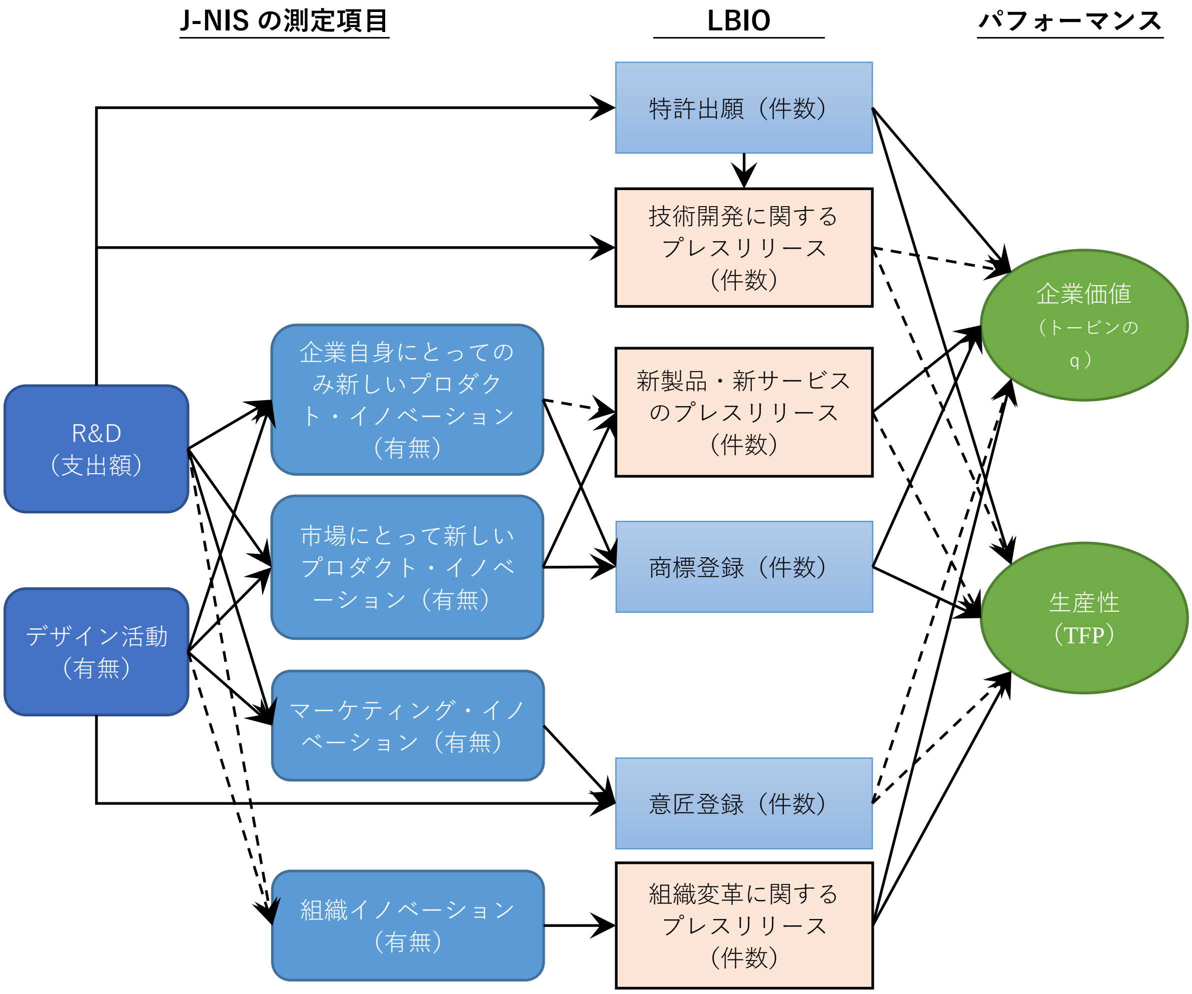
次に、上記（2）の LBIO 指標群と企業の経営パフォーマンスとの関係性を分析した結果、以下のように LBIO 指標群は経営パフォーマンスに関係していることがわかった。なお、いずれも企業規模の効果をコントロールした結果である。

① 「新製品・新サービスに関するプレスリリース件数」と「組織変革に関するプレスリリース件数」が多い企業ほど、企業価値（トービンのｑ）が統計的有意に高い。

② 「組織変革に関するプレスリリース件数」が多い企業ほど、TFP が統計的有意に高いが、「新製品・新サービスに関するプレスリリース件数」と TFP の間には統計的に有意な関係性は見られない。

③ 「商標登録件数」や「特許出願件数」の多い企業ほど、企業価値（トービンのｑ）と TFP が統計的有意に高い。一方、「意匠登録件数」の多い企業ほど、企業価値（トービンのｑ）と TFP が統計的有意に高いとは言えない。

図 3：分析結果の概要



注）実線は統計的に有意な正の関係（5%水準）、破線は統計的に有意な正の関係（5%水準）が検出されなかった関係性を示す。分析結果の詳細は、本文の Table 4、Table 5、Table 6 を参照されたい。

4. 結論と含意

本稿では、複数のイノベーション・アウトプット指標間の関係を検討した。知的財産権とプレスリリースを「全国イノベーション調査」の企業レベルのイノベーションにいくつかのマイクロデータセットをリンクさせて、質問票調査に基づくイノベーション活動のインプット及びアウトプット指標群と LBIO 指標群との関係を分析した。また、上場企業の財務データに知的財産権とプレスリリースに関するデータをリンクすることで、LBIO 指標群と企業業績の関係性についても分析した。

分析結果は、全国イノベーション調査に基づくイノベーション・アウトプットの測定値と

LBIO 指標群との間に論理的に整合性のある関係が統計的に検証された。商標データと新製品・新サービスに関するプレスリリースのデータには企業のプロダクト・イノベーションの測定に寄与する情報が含まれていることを確認し、これらの LBIO 指標群が、プロダクト・イノベーションに加え、組織イノベーションも表していることも確認された。一方、意匠の登録件数と企業のデザイン活動やマーケティング・イノベーションとの相関関係、組織変革に関するプレスリリースと組織イノベーションとの相関関係も確認された。また、これら LBIO 指標群が企業価値や生産性（TFP）といった企業の経営パフォーマンスと正の相関関係にあることも統計的に検証された。

これらの結果は、企業レベルでイノベーション・アウトプットの多次元特性を測定するためには、全国イノベーション調査などの企業への直接的なアンケート調査に加えて、商標、意匠、特許といった知的財産権やプレスリリースなどの文献データに基づくイノベーション・アウトプット指標を活用することの可能性を示している。

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本文（英語）

1. Introduction

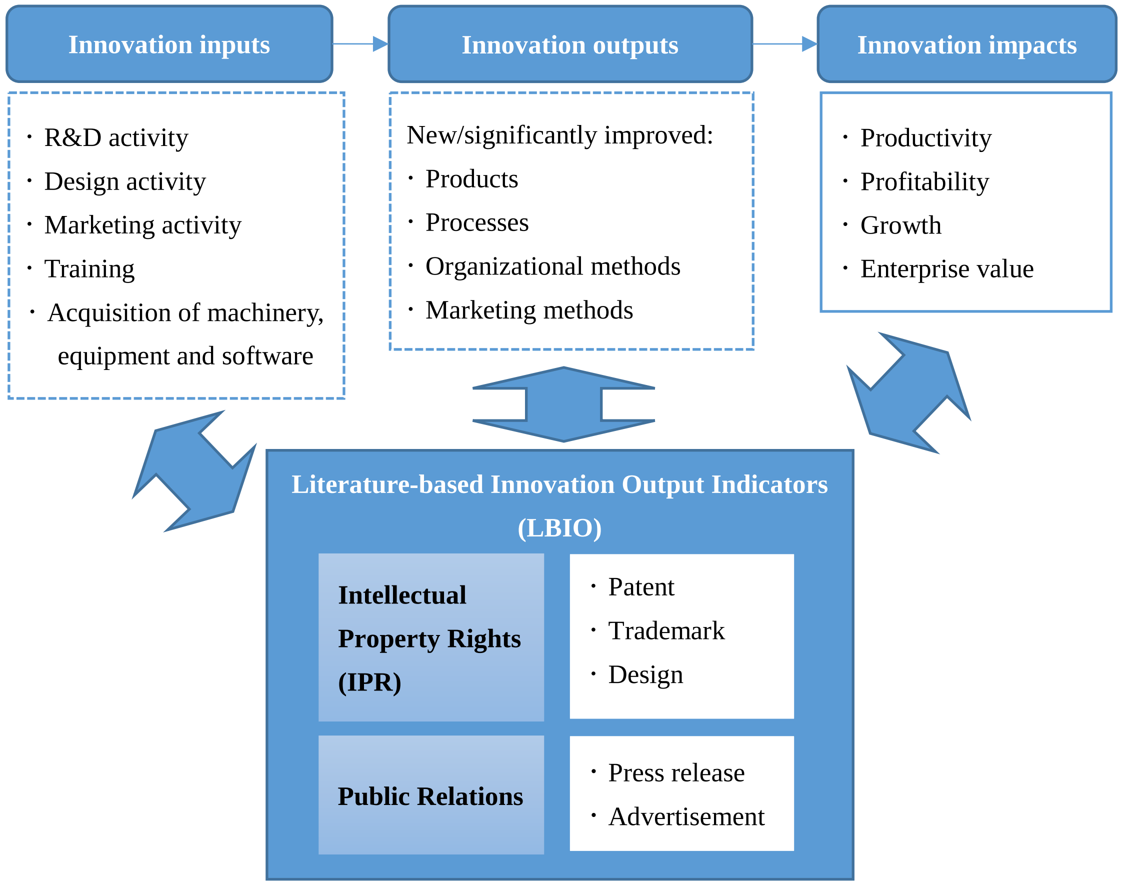
Innovation is one of the most important concepts for economic development, growth, and the wealth of nations. To capture innovation is to understand the determinants or process of productivity improvements. Japan has faced long-term economic stagnation that began in the early 1990s and labor shortages from an aging population; therefore, policy makers need ways to enhance productivity and encourage innovation. This subject has received attention from economic and science and technology policy makers because it is widely believed that the knowledge creation and diffusion process is closely related to innovation.

The definition of innovation is provided by the *Oslo Manual* (OECD and European Communities, 2005). According to the *Oslo Manual*, "an innovation is the implementation of a new or significantly improved product (goods or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization, or external relations." Edison *et al*. (2013) examined 41 definitions by conducting a questionnaire survey and interviews with academics and practitioners, and the authors recommended a definition by Crossan and Apaydin (2010): "Innovation is: production or adoption, assimilation, and exploitation of a value-added novelty in economic and social spheres; renewal and enlargement of products, services, and markets; development of new methods of production, and the establishment of new management systems. It is both a process and an outcome." Both definitions indicate that innovation has a broad meaning. Innovation includes the discovery of new ideas or knowledge but also the commercialization or implementation of these discoveries into production processes, business practices, or marketing activities. Additionally, Edison *et al*. (2013) argued that "the perception of innovation differs across the departments of the same organization."

An innovation activity in a firm is a function that changes innovation inputs to innovation outputs and generates some positive economic value. Because innovation inputs are multi-dimensional, innovation outputs also have several dimensions. Four types of innovation outputs are recognized (OECD and European Communities, 2005):

(1) Product innovations, which is the introduction of new or significantly improved goods or services to markets.
(2) Process innovations, which is the implementation of new or significantly improved production or delivery methods including a significant change in techniques, equipment, and/or software.
(3) Organizational innovations, which is the implementation of a new organizational method in a firm's business practices, workplace organization, or external relations.
(4) Marketing innovation, which is the implementation of a new marketing method involving significant changes in product design or packaging, product placement, product promotion, or pricing.

Fig. 1. Framework for measuring innovation outputs in firms



Source: Modification of Edison *et al.* (2013) by the author.

This paper examines the interdependence between various measurements of innovation outputs of firms. Fig. 1 illustrates a framework to measure innovation outputs in this paper. Linking firm-level microdata from the Japanese National Innovation Survey to other microdata sources related to innovation in firms such as patents, trademarks, design rights, and press releases on new products and services, which are called as literature-based innovation output (LBIO) indicators, I summarize the innovation indicators and explore the best treatment of the indicators to explain observed diversity in firms' innovation.

This paper is organized as follows. In the next section, several approaches to measuring innovation outputs are introduced. Then, in Section 3, data sources and the methodology for dataset construction is explained. In Section 4, several variables to measure innovation outputs are defined. Section 5 shows the empirical results and examines the relationship between innovation output indicators. Finally, Section 6 concludes this paper.

2. How to Measure Innovation

A reliable measure of innovation is particularly important for policy makers who must assess policy intervention and evaluate the impacts of their policies on innovation. Understanding the current state of innovation and innovation processes correctly is a necessary condition for policy makers to enforce appropriate policies. Relevant measurement of innovation outputs is also important for researchers who are constructing models or empirically examining innovation processes. Measuring innovation, however, is one of the most challenging and difficult tasks. Innovation itself has diverse aspects and consists of several processes. Measuring innovation is also a demanding and challenging task for industry. According to Andrew *et al.* (2008), most executives believe that their company should track innovation, but only 43 percent of companies measure innovation.

A major development in innovation output measurements has been the direct innovation survey. This survey involves surveying firms to ascertain product, process, organizational, and marketing innovations introduced or implemented during a period. The Community Innovation Survey (CIS) organized by Eurostat (the statistical office of the European Union) is the most standard questionnaire worldwide. According to the *Oslo Manual* guideline, all four types of innovation outputs are surveyed in the CIS: product innovation, process innovation, organizational innovation, and marketing innovation. According to Coombs *et al*. (1996), however, "the CIS-type surveys suffer from their own unique problems, the main problem being the burden they place on responding firms to provide data". Additionally, even for firm respondents, it may be difficult to determine whether their firm innovates.

The measure of firm innovation outputs obtained from literature such as trade journals, rather than firm surveys or interviews, is known as the Literature-based Innovation Output (LBIO) indicator (Coombs *et al*., 1996). In the 1980s, LBIO data was used to analyze innovation activity in the US (Acs and Audretsch, 1987). However, measuring the quantity and quality of outputs of a firm's innovation activity is also important. The number of new products introduced and the number of new processes or methods implemented should be different across firms, and the impact of innovations should differ. While the quantity of innovation is not supported in the standard CIS questionnaire, the quality or novelty of (product) innovation is partly included. A count measure is available in the case of the LBIO; patents applied or granted, registered trademarks and designs, and published press releases are countable. In a large body of literature, patent data is used as a proxy for innovation (Griliches, 1984, 1990; Nagaoka e*t al*., 2010). Empirical research using trademarks and design registrations has been scarce. Recently, several studies, however, examine the relationship between trademarks and design activity (Livesey and Moultrie, 2008). Mendonça *et al*. (2004) showed that trademark data capture the non-technological innovation of firms. For example, Walsh (1996) and Verganti (2003) emphasized the importance of design activity in innovation firm processes, and Rubera and Droge (2013) empirically examined the effects of design activity on sales and the market value of firms. D'Ippolito (2014) provided a literature review of research on firms' design activity. These LBIO data contain rich text information of the description of the features that deserve to be published, at least for the firm itself. The rich information may contain data on the quality or novelty of the innovation outputs.

Inputs in innovation activities are also important to measure. Research and development

(R&D) investment is the main inputs measure. Recently, the importance of capturing comprehensive inputs other than R&D, such as design, marketing training, and copyright, has been emphasized by intangible assets scholars (Corrado *et al*., 2009). The absorption of external knowledge and collaborations is also considered an important source of innovation. In the following chapters, the determinants of innovations are discussed in detail.

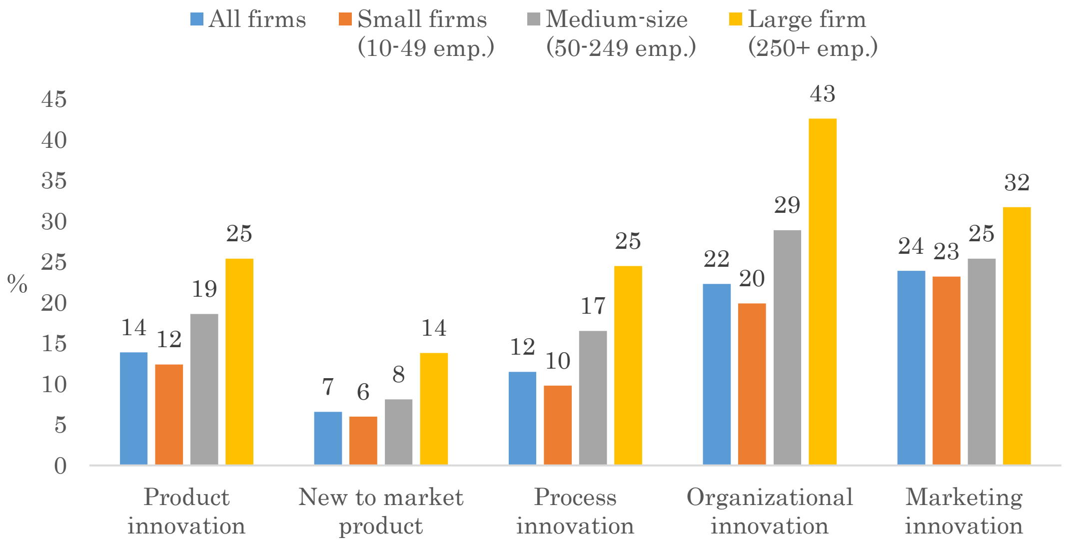
3. Data

This paper uses five data sources to measure innovation output at the firm-level: the Japanese National Innovation Survey (J-NIS), patents, trademarks, design registration, and press releases.

The J-NIS is an official government survey conducted by the National Institute of Science and Technology Policy (NISTEP). The questionnaire used in the J-NIS is harmonized with the CIS, which is developed by Eurostat and is the most standard innovation survey worldwide. The J-NIS has been conducted four times in Japan. Data from the third wave (J-NIS 2012) are used in this paper because they are the latest available data. The survey represents a sample derived from all enterprises with 10 or more employees active in Japan in 2009 in all manufacturing industries and some selected non-manufacturing industries from the core and non-core coverage of the CIS 2010. The sample size of J-NIS 2012 is 20,405 firms, and the number of valid responses is 7,034 firms. The J-NIS 2012 surveys innovation outputs as well as innovation inputs or innovation activities of firms. As the same as in the CIS, all four types of innovation output are surveyed in the J-NIS according to the *Oslo Manual* guideline: product innovation, process innovation, organizational innovation, and marketing innovation. Innovation outputs introduced or implemented during the period 2009 to 2011 are surveyed in the J-NIS 2012. Innovation outputs are defined as new-to-firm innovations. For product innovation, new-to-firm innovation and new-to-market innovation are also differentiated.

Although the definitions of each type of innovation are included in the questionnaire, the answers to the questionnaire are based on the self-judgement of the respondents. For innovation activities, R&D activity and expenditures and design, marketing, and training activity are captured. Most questions required a yes or no answer. Therefore, I could only capture whether a firm has innovation output. The amount or count of innovation outputs could not be captured in this survey. This is a common limitation of the CIS-type questionnaire. Fig. 2 shows the results of J-NIS 2012 for each type of innovation output for three firm sizes.

Fig. 2. Percentages of firms with innovations (J-NIS 2012)



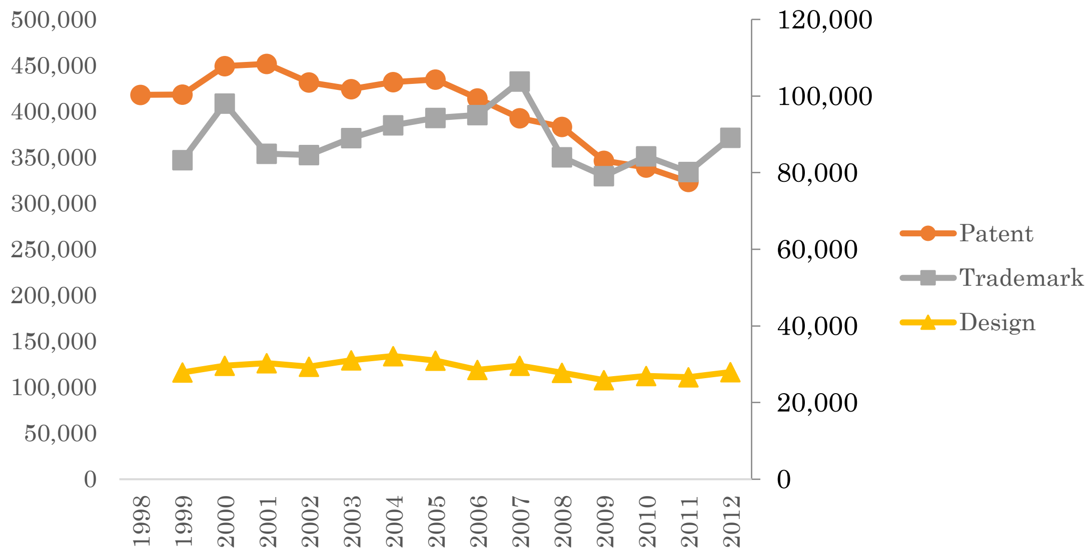
Data source: NISTEP (2014). A report on the Japanese National Innovation Survey 2012, NISTEP REPORT No. 156.

Patent data are obtained from the Institute of Intellectual Property (IIP) patent database, which is a normalized relational database compiled from more complex data in the SGML (Standard Generalized Markup Language) format from the Japan Patent Office (JPO) by IIP. The latest version of the IIP patent database (version 2015) contains the data for all patent applications to the JPO from 1964 to 2011. Applicant information (names) is used to match data with the other databases. The number of patent applications is used as an indicator of innovation outputs. Additionally, to consider the difference in quality among patents, the number of claims (Okada *et al*., 2016) and citations from other patents are also calculated.

Databases for trademarks and design registrations are also relational and are compiled from SGML format data from the JPO by NISTEP (Motohashi *et al.* 2016). These databases contain only registered trademarks and designs applied on or after 1999 to 2012. The number of registered trademarks and designs by firm by application year is calculated and used as a proxy for firms' innovation outputs. The names of applicants are used for database matching.

Fig. 3 shows that although the number of patent applications is greater than the trends for trademarks and design registrations, patent applications exhibit a downward trend from 2005. From 1998 to 2011, there were 5.66 million patent applications in total and 404 thousand applications for each year, on average. The number of trademarks and design registrations has been stable compared to patent applications. From 1999 to 2012, there were 1.24 million trademark applications and 405,000 design registration applications in total and 88,700 trademark applications and 28,900 design registration applications for each year, on average.

Fig. 3. The number of patent application, trademarks, and design registrations

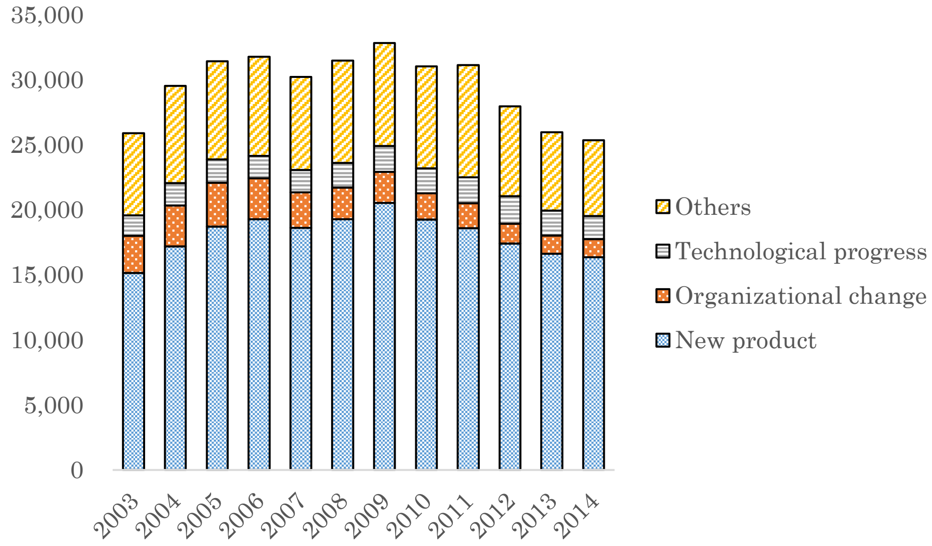


Data sources: Author's calculation based on the IIP patent database and the NISTEP's database of design and trademark rights (Motohashi *et al.* 2016).

Press release data are derived from Nikkei Telecom, which contains all articles published on the Nikkei Press Release website[1] from 2003 to 2014. The number of articles is calculated for each subject. The types of articles are also differentiated. Fig. 4 shows the number of articles by type for each year. There are 355,000 articles in total. Table 1 indicates that 61 percent of articles are classified as new product announcements and 8 percent and 6 percent are classified as organizational changes and technological progress announcements, respectively. The subject and type of each article are extracted from the header of each article. The header of release documents contains information on who did what. The beginning of the release header indicates the subject of the release, and the latter part of the header indicates the object of the release. Because there are abbreviations for subjects, the subject names are manually checked and changed to the correct format for the NISTEP Dictionary of Corporate Names (DCN).

[1] http://release.nikkei.co.jp/

Fig. 4. Number of press releases



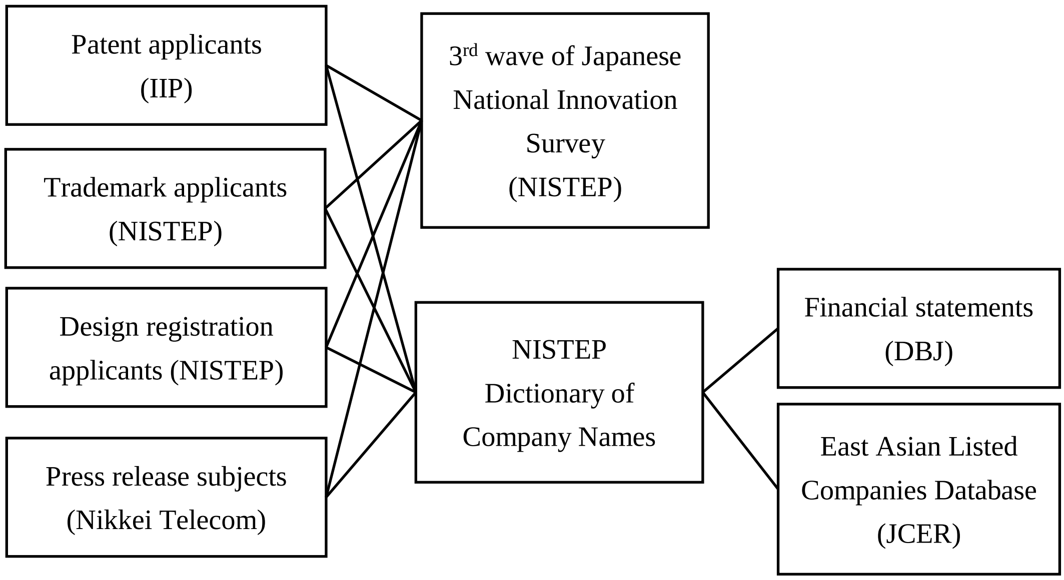
Data sources: Author’s calculation based on the Nikkei Telecom database.

Table 1. Types of press release

	Total	%
Total	354,689	100%
New product	217,059	61%
Organizational change	28,363	8%
Technological progress	22,190	6%
Others	87,077	25%

Using these data, two firm-level datasets are constructed to examine the interdependencies among innovative outputs. Fig. 5 shows the structure of the matched datasets.

Fig. 5. Matching between databases



The first dataset is a cross section, and the respondent firms of the third wave of the J-NIS (J-NIS 2012) are matched with the applicants of patents, trademarks, design registrations, and the subjects of press releases. The J-NIS 2012 contains 7,036 respondents. Matching across databases is based on firm name using the NISTEP Company Name Dictionary. Table 2 shows the matching results of the dataset. Out of 7,034 J-NIS 2012 respondent firms, 4.1 percent of firms issued a press release, 12 percent of firms applied a patent, 17.4 percent of firms had a trademark application, and 6.2 percent of firms applied a design registration. The average number of articles was 30.1 for press releases and 102.7 for patent applications from 2009 to 2011.

Table 2. Matching results of the first dataset

	# of firms	%	# of articles	Avg.
Press release	287	4.1%	8,633	30.1
New product	217	3.1%	4,926	22.7
Technological progress	82	1.2%	590	7.2
Organizational change	124	1.8%	513	4.1
Patent application	843	12.0%	86,536	102.7
Trademark application	1,222	17.4%	11,341	9.3
Design registration	437	6.2%	7,169	16.4
Total	7,034	100.0%		

The second dataset is panel data for which the applicants of patents, trademarks, design registrations, and the subjects of press releases are matched with each other by name and year. As a base for matching, the NISTEP DCN and the concordance table for patent applicant tables developed by NISTEP is used. For each applicant and application year, the number of applications for patents, trademarks, and design registrations is calculated. For listed companies, the financial statements of the firms derived from a company database provided by the Development Bank of Japan and the East Asia Listed Companies (EALC) Database are also merged. Table 3 shows the matching results of the dataset. The matching rates are higher than the first dataset. Among 355 press releases, 59 percent of articles could be matched with the NISTEP DCN. Seventy percent of patents and design registrations are also matched, but the matching rate for trademarks is slightly lower (36 percent). Among the 6,292 firms filed in NISTEP DCN, 49 percent of firms with a press release and design registration matched, and 81 percent and 86 percent of firms with patents and trademarks, respectively, matched. Matching rates are higher for listed firms: 63 percent for firms with press releases, 73 percent for firms with patent applications, and 93 percent for firms with trademarks but only 45 percent for firms with design registrations.

Table 3. Matching results for the second dataset

# of documents	Period	Total	%	Matched	%	Listed firms	%
Press release	2003-2014	354,691	100%	209,235	59%	168,698	48%
Patent	1998-2011	5,658,505	100%	3,960,887	70%	3,174,171	56%
Trademark	1999-2012	1,242,272	100%	447,456	36%	346,302	28%
Design	1999-2012	404,645	100%	282,231	70%	203,938	50%
# of firms				Matched	%	Listed firms	%
Total (DCN)				6,292	100%	3,783	100%
Press release				3,080	49%	2,402	63%
Patent				5,091	81%	2,758	73%
Trademark				5,405	86%	3,502	93%
Design				3,076	49%	1,720	45%

4. Variables

4.1. J-NIS 2012

For innovation outputs, the following dummy variables are utilized from J-NIS 2012: (i) a dummy variable taking the value of one if the firm introduced a new or significantly improved good or service to the firm (New-to-Firm Product) during the period from 2009 to 2011, (ii) a dummy variable taking the value of one if the firm introduced a new-to-market product innovation during the period (New-to-Market Product), (iii) a dummy variable taking the value of one if the firm implemented a process innovation (new or significantly improved production process, distribution method, or supporting activity), (iv) a dummy variable for an implementation of a new organizational method (Organizational Innovation), and a dummy variable indicating a significant change to the aesthetic design or packaging of a good or service (Design Innovation). For innovation inputs, the natural logarithms of R&D expenditure (Ln. of R&D Expenditure) in fiscal year 2011 are calculated, and a dummy variable for Design Activity, which takes the value of one if the firm conducted activities to design, improve, or change the shape or appearance of new or significantly improved goods or services, and zero otherwise, is also used.

4.2. Press Release Data

From the press release data, the following variables are defined: (i) the number of new product announcements (N. of PRs on New Products), (ii) the number of press releases related to technological progress (N. of PRs on Technological Development), and (iii) the number of press releases announcing an organizational change, for example, establishments of new departments, mergers and acquisitions of other enterprises, or a company split (N. of PRs on Organizational Changes).

4.3. Intellectual Property Rights

For invention or innovation output variables, (i) the number of patent applications (N. of Patent Applications), (ii) applications of trademarks (N. of Trademark Registration), and (iii) the applications of design registrations (N. of Design Registration) are used as output variables.

4.4. Innovation Outcomes

Using firm financial information, variables for innovation outcomes are also defined. First, innovation can affect market evaluation from investors (Hall, 2000). In this paper, the market value of the firm is measured by the simple approximation of Tobin's q (Chung and Pruitt, 1994):

Simple q = (stock price times the number of stocks issued + total debt) / (total assets)

Second, innovations can enhance firm productivity (OECD, 2009). Using the EALC database, the effects of innovation indicators on total factor productivity (TFP) of the firm are examined.

5. Empirical Results

This section first examines the inter-relationship among the LBIO indicators and innovation outputs measured in the J-NIS 2012. Then, the section examines the effects of these innovation output indicators on the innovation outcome indicators.

5.1. The Inter-relationship among Innovation Output Indicators

Table 4 shows the results of the regression analyses.[2] For all models, I control for firm size (the logarithm of the number of employees) and industry-year dummies. In columns (i) to (iii) in Table 4, the number of each type of press release is regressed on the related innovation indicators measured by the J-NIS and the intellectual property rights. Column (i) shows the estimation result of the Poisson model in which the dependent variable is measured by the number of new product-related press releases. For explanatory variables, the dummy variables for new-to-firm product innovation and new-to-market product innovation are included in the model. The results show

[2] To control for simultaneous bias, standard errors are adjusted with an unrelated estimation method using the Stata command; *suest*.

that new-to-market product innovation had significantly positive effects on the number of new product-related press releases.

The dependent variables of columns (ii) and (iii) are the number of press releases related to technological progress and organizational changes, respectively. For the press releases related to the technological progress model, R&D expenditures and the number of patent applications are included as explanatory variables. For press releases related to the organizational changes model, I test the effect of organizational innovation. The estimation results shown in column (ii) indicate that the effects of R&D expenditure and the number of patent applications on the number of technological progress-related press releases were significantly positive. The estimation results shown in column (iii) indicate that the effects of organizational innovation on the number of organizational change-related press releases were significantly positive.

Next, I examine the relationships between the number of applications for intellectual property rights and the innovation survey. Columns (iv) to (vi) in Table 4 show the estimation results for the Poisson model for the number of applications for (iv) patents, (v) trademarks, and (vi) design registration. The results show that R&D expenditure has significantly positive effects on the number of patent applications. The effects of new-to-firm product innovation and new-to-market product innovation on the number of trademark applications were both positive and significant, and the effects of design innovation and design activity on the number of design registrations were significant and positive.

Finally, to examine the complementarity between the various innovation output indicators including process and marketing innovation, I regress the dummy variables for new-to-market and new-to-firm product innovation, process, organizational and marketing innovation on R&D expenditure and design activity. Column (vii) to (xi) in Table 4 indicate that these innovation input and output indicators were significantly and positively related to both new-to-market and new-to-firm product innovation, process innovation, organizational innovation and marketing innovation. Particularly, the result indicates that to enhance the novelty of product innovation, other types of innovation, such as process innovation, organizational innovation, and marketing innovation, are required in addition to innovation inputs such as R&D and design activity.

In summary, the results in Table 4 indicate that the LBIO indicators are reliable indicators for innovation outputs, at least related to products, and particularly for novel products, innovations, organizational innovations, and design innovations measured in the CIS-type questionnaire survey.

Table 4. Relationship between LBIO indicators and indicators of the innovation survey

	(i) N. of PRs on New Products	(ii) N. of PRs on Tech. Develop.	(iii) N. of PRs on Org. Changes	(iv) N. of Patent Applic.	(v) N. of Trademark Registr.	(vi) N. of Design Registr.
	Poisson	Poisson	Poisson	Poisson	Poisson	Poisson
Ln. N. of Employees	0.806***	0.419***	1.122***	0.987***	0.636***	0.647***
	(0.081)	(0.136)	(0.064)	(0.104)	(0.049)	(0.096)
New-to-Firm Product (0/1)	0.614				0.428**	
	(0.571)				(0.203)	
New-to-Market Product (0/1)	1.390***				1.135***	
	(0.333)				(0.219)	
Process Innovation (0/1)						
Organizational Innovation (0/1)			0.738***			
			(0.248)			
Marketing Innovation (0/1)						0.527**
						[0.229]
Ln. N. of Patent Applications		0.558***				
		(0.110)				
Ln. of R&D Expenditure		0.119**		0.213***		
		(0.050)		(0.053)		
Design Activity (0/1)						1.108***
						(0.211)
Constant	-4.747***	-6.231***	-9.315***	-4.175***	-2.321***	-3.697***
	(0.687)	(0.672)	(0.577)	(0.540)	(0.320)	(0.707)
Industry-year dummies	Yes	Yes	Yes	Yes	Yes	Yes
N	6,565	6,565	6,565	6,565	6,565	6,565
Pseudo R squared	0.458	0.769	0.601	0.861	0.384	0.383

Notes: Standard errors in parentheses. *p<0.10, **p<0.05, ***p<0.01.

Table 4. (Continued)

	(vii) Only New-to-Firm Product Innovation	(viii) New-to-Market Product Innovation	(ix) Process Innovation	(x) Organizational Innovation	(xi) Marketing Innovation
	Probit	Probit	Probit	Probit	Probit
Ln. N. of Employees	0.056***	0.005	0.057***	0.082***	-0.036**
	[0.018]	[0.020]	[0.016]	[0.014]	[0.016]
New-to-Firm Product (0/1)			0.778***	0.310***	0.452***
			[0.065]	[0.066]	[0.068]
New-to-Market Product (0/1)			0.725***	0.217***	0.580***
			[0.072]	[0.072]	[0.072]
Process Innovation (0/1)	0.542***	0.485***		0.747***	0.138**
	[0.060]	[0.063]		[0.049]	[0.054]
Organizational Innovation (0/1)	0.250***	0.160***	0.705***		0.869***
	[0.056]	[0.060]	[0.045]		[0.042]
Marketing Innovation (0/1)	0.268***	0.413***	0.145***	0.912***	
	[0.062]	[0.063]	[0.053]	[0.045]	
Ln. N. of Patent Applications					
Ln. of R&D Expenditure	0.036**	0.185***	0.084***	0.016	0.041***
	[0.016]	[0.016]	[0.015]	[0.015]	[0.015]
Design Activity (0/1)	0.376***	0.806***	0.485***	0.107	0.852***
	[0.077]	[0.072]	[0.072]	[0.071]	[0.068]
Constant	-1.999***	-1.950***	-1.640***	-1.420***	-1.062***
	[0.091]	[0.099]	[0.078]	[0.072]	[0.075]
Industry-year dummies	Yes	Yes	Yes	Yes	Yes
N	6,565	6,565	6,565	6,565	6,565
Pseudo R squared	0.14	0.332	0.267	0.19	0.251

Notes: Standard errors in parentheses. *p<0.10, **p<0.05, ***p<0.01.

5.2. Relationship between LBIO Indicators and Innovation Outcomes

Table 5 shows the relationship between LBIO indicators and the market value of the firm using the data of listed firms in the second dataset. The simple q index is regressed on the LBIO indicators. Table 5 shows the effects of the number of press releases on firm market value. Columns (i) to (iii) show the statistically significant and positive effects of the number of new product-related press releases, technological development, and organizational changes on the market value of the firm. Column (iv) shows that the coefficient on the number of technological development-related press releases is no longer significant if these three variables are simultaneously included in the model. Column (v) shows the effects of patent applications, trademarks, and design registrations on firm market value. The numbers of patent applications and trademark applications have significant and positive effects on market value. Column (vi) shows that if all the LBIO indicators are included in the model, new product and organizational change-related press releases, patent applications, and trademark registrations have significant positive effects on the simple q index. These results indicate that the stock market positively evaluated the firms' innovation outputs examined in the paper.

Table 5. Relationship between LBIO indicators and market value of the firm

Dependent variable: Ln. simple Q index	(i)	(ii)	(iii)	(iv)	(v)	(vi)
Ln. N. of Employees	0.043***	0.108***	0.079***	0.096***	0.010*	0.064***
	(0.007)	(0.013)	(0.014)	(0.017)	(0.006)	(0.017)
Ln. N. of PRs on New Product per Emp.	0.078***			0.064***		0.048***
	(0.007)			(0.008)		(0.008)
Ln. N, of PRs on Org. Change per Emp.		0.138***		0.065***		0.060***
		(0.014)		(0.015)		(0.015)
Ln. N. of PRs on Tech. Develop. per Emp.			0.106***	0.003		-0.028*
			(0.015)	(0.017)		(0.017)
Ln. N. of Patent Applications per Emp.					0.036***	0.034***
					(0.005)	(0.005)
Ln. N. of Trademark Registrations per Emp.					0.037***	0.022***
					(0.005)	(0.005)
Ln. N. of Design Registrations per Emp.					-0.009	-0.014**
					(0.006)	(0.006)
Constant	0.278***	0.272***	0.244***	0.298***	0.355***	0.385***
	(0.094)	(0.084)	(0.092)	(0.093)	(0.096)	(0.098)
Industry-year dummies	Yes	Yes	Yes	Yes	Yes	Yes
N	20,468	20,468	20,468	20,468	20,468	20,468
R squared	0.242	0.233	0.227	0.244	0.247	0.257

Notes: Standard errors in parentheses. *p<0.10, **p<0.05, ***p<0.01.

Finally, Table 6 shows the relationship between the LBIO indicators and the TFP of firms using the data for listed firms from the second dataset. Columns (i) to (iii) in Table 6 show the effects of the number of firm market value-related press releases. I found statistically significant and positive effects of the number of new product-related announcements, organizational changes, and technological developments on firm TFP. Column (v) shows the effects of patents, trademarks, and design registrations on firm market value. The numbers of patent applications and trademark applications have significant and positive effects on TFP. If all the LBIO indicators are included in the model (Column (vi)), while the coefficients on design registration, new product announcements, and press releases concerning technological development become insignificant, the coefficients on the press releases related to organizational changes, patent applications, and trademark registrations remain significant and positive.

Table 6. Relationship between LBIO indicators and TFP

Dependent variable: Ln. TFP	(i)	(ii)	(iii)	(iv)	(v)	(vi)
Ln. N. of Employees	0.003	0.021***	0.018***	0.024***	0.002	0.015**
	(0.002)	(0.006)	(0.004)	(0.006)	(0.002)	(0.006)
Ln. N. of PRs on New Product per Emp.	0.011***			0.005**		-0.002
	(0.002)			(0.002)		(0.003)
Ln. N, of PRs on Org. Change per Emp.		0.028***		0.019***		0.018***
		(0.006)		(0.007)		(0.007)
Ln. N. of PRs on Tech. Develop. per Emp.			0.025***	0.008		-0.001
			(0.005)	(0.006)		(0.005)
Ln. N. of Patent Applications per Emp.					0.011***	0.010***
					(0.002)	(0.002)
Ln. N. of Trademark Registrations per Emp.					0.011***	0.011***
					(0.002)	(0.002)
Ln. N. of Design Registrations per Emp.					-0.004**	-0.003**
					(0.002)	(0.002)
Constant	0.060***	0.060***	0.059***	0.066***	0.091***	0.094***
	(0.012)	(0.012)	(0.012)	(0.013)	(0.012)	(0.012)
Industry-year dummies	Yes	Yes	Yes	Yes	Yes	Yes
N	14,072	14,072	14,072	14,072	14,072	14,072
R squared	0.223	0.224	0.222	0.225	0.238	0.240

Notes: Standard errors in parentheses. *p<0.10, **p<0.05, ***p<0.01.

5.3. Relationship between LBIO Indicators

Some LBIO indicators are not independent and are conceptually dependent on each other. First, trademark registrations and new product-related press releases should be related because both indicators measure product innovation. Fig. 6 shows the form of the relationship between the number of trademark registrations and the number of new product-related press releases. The relationship between the two indicators is positive and almost linear. On the other hand, patent applications and press releases on technological development are also conceptually related. Fig. 7 shows a positive but non-linear relationship between the number of patent applications and the number of technological development-related press releases. A positive relationship between the two indicators is stronger at low and high levels and weaker at the mid-level.

Fig. 6. Trademark Registration vs. New Product Press Releases

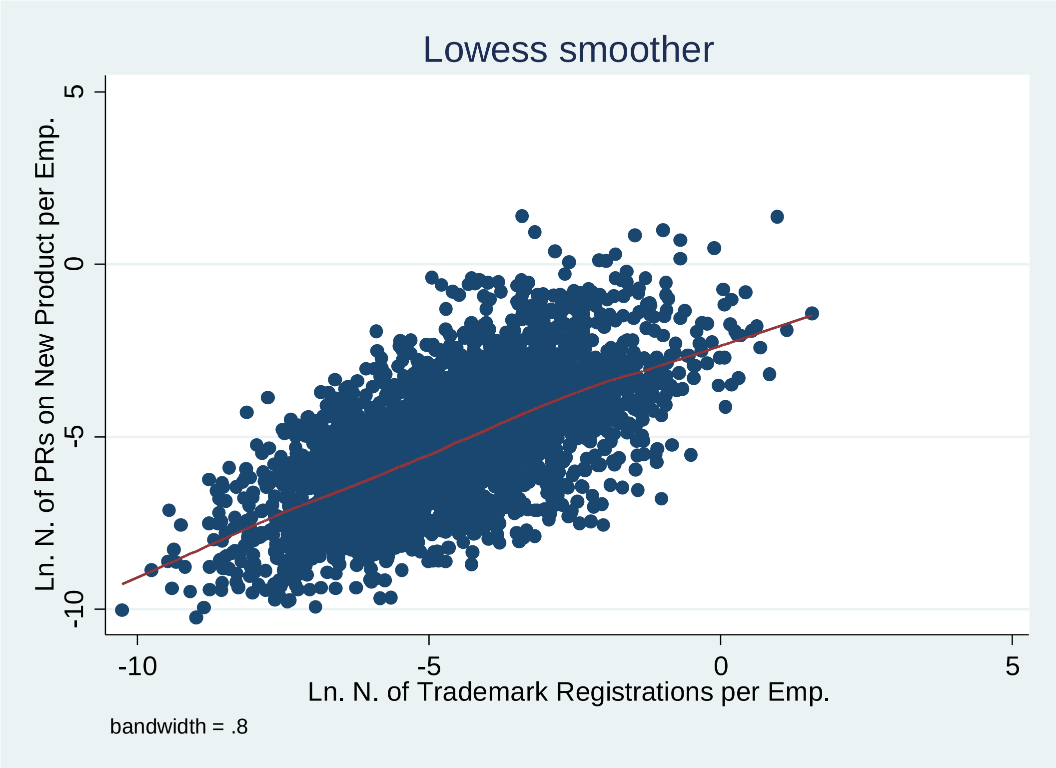
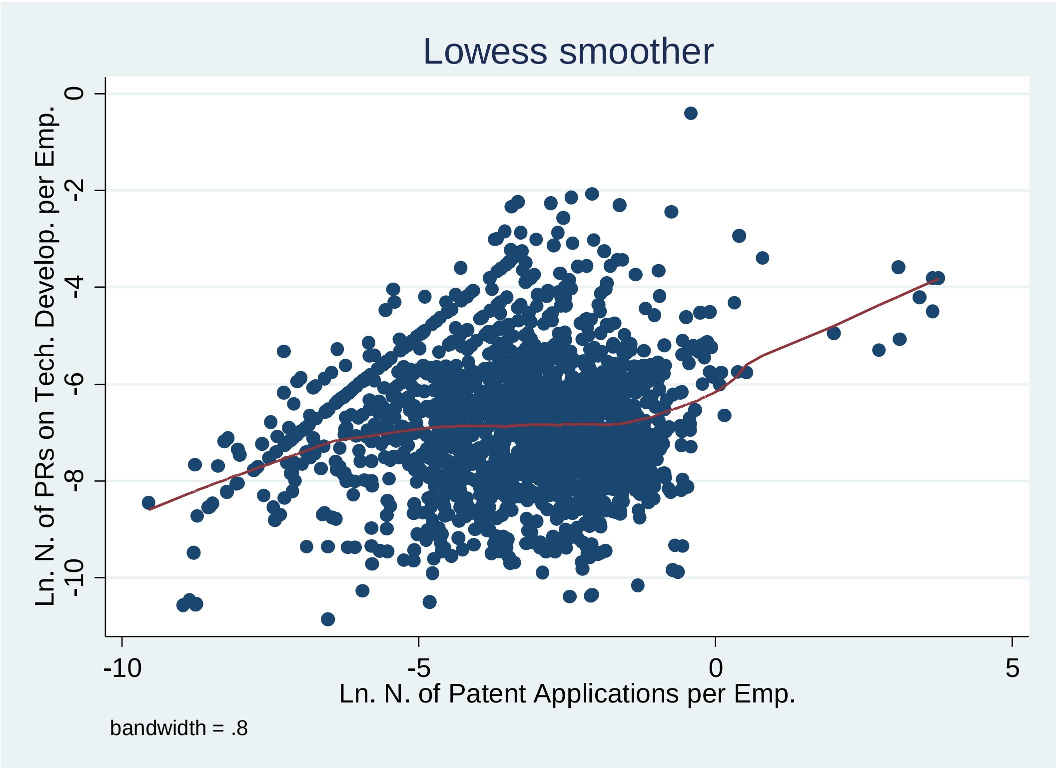


Fig. 7. Patent Applications vs. Technological Development Press Releases



6. Conclusions

This paper examined the relationship between various innovation output indicators. Linking several micro datasets on firm-level innovations, such as the J-NIS databases of intellectual property rights and press releases, I examined the relationship between questionnaire-based innovation output indicators and LBIO indicators. The empirical results indicate that there are consistent and statistically significant relationships between innovation output measurements based on the innovation survey and the LBIO indicators. I confirmed that the patent data, trademark data, and press release data contain the information that contributes to the measurement of firms' product innovation. The empirical results show that these LBIO indicators represent technological innovation such as product innovation and non-technological innovations such as marketing and organizational innovation. On the one hand, I confirmed that design registration data represent the firms' design activity and marketing innovation. On the other hand, organizational change-related press releases have a significant relationship with organizational innovation. Moreover, this paper confirms significant relationships between LBIO indicators and firm performance. I found a significant positive effect of LBIO indicators on firm market value and firm TFP. These results indicate that, in addition to direct firm questionnaires, using the LBIO data including trademarks, design registrations, and press releases as well as patent data is important to measure the multi-dimensional characteristics of innovation outputs at the firm level.

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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
池内健太

〒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

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Kenta IKEUCHI

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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