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The impact of cluster policy on academic knowledge creation and regional innovation: Geography of university-industry collaboration in Japan

学術的知識創造と地域イノベーションへのクラスター政策の影響: 日本における産学連携の地理

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学術的知識創造と地域イノベーションへのクラスター政策の影響:
日本における産学連携の地理

文部科学省 科学技術・学術政策研究所 第 1 研究グループ
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要旨

本論文は、産学連携における地理的な複雑性を考慮しつつ、クラスター政策の効果を検証する。本研究は、2002 年から 2009 年にかけて実施された日本独自の「大学を中心とする」文部科学省の知的クラスター事業に焦点を当てる。公的統計のミクロデータと学術論文・特許のデータベースからのデータを接合し、大学及び公的研究機関と企業の科学技術成果に対するクラスター政策の効果を比較する。パネル固定効果ポアソンモデルを推定することにより、これらの知的クラスター政策への参加が、特に大学や公的研究機関の（学術論文でなく）特許出願を増やす一方、企業の（特許出願でなく）学術論文を増やすことで地域におけるイノベーションを促進したことが確認された。また、それらの数が増えただけでなく、被引用件数も増えたことから、科学技術成果の質の向上も示唆される。以上の結果は、知的クラスター政策によって大学・公的研究機関と企業の科学技術成果の出し方が変化したという意味で、行動面の付加効果（behavioral additionality）を示している。

The impact of cluster policy on academic knowledge creation and regional innovation: Geography of university-industry collaboration in Japan

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ABSTRACT

This paper evaluates the effects of cluster policy in light of the complexity of geography of university-industry R&D collaboration. The study focuses on the unique 'university-centred' cluster programmes in Japan, implemented between 2002 and 2009. Our analysis compares the effects of cluster policy on universities / public research institutes (PRIs), and those on firms, by utilising micro-data from official statistics combined with data from databases of academic publications and patents. By estimating panel fixed-effect Poisson models, we find that these cluster programmes promoted regional innovation, especially by increasing universities' and PRIs' patenting (but not publication) and firms' publication (but not patenting), indicating behavioural additionality of cluster policies. Moreover, we find that forward citations from academic patenting and firms' scientific papers significantly increased after cluster participation, which suggests enhanced quality of science and technology output.

概要

1995年に科学技術基本法が制定されて以来、日本政府は「科学技術基本計画」の下で、さまざまな形で産学官連携による研究開発を推進してきた。産学官の共同研究開発の拠点を地域に形成するクラスター政策は欧州で1990年代に始まり、日本でも2001年度に始まる第2期科学技術基本計画の下で地域クラスターの創出に対する公的支援が政策の優先課題とされ、2001 年度から経済産業省が「産業クラスター計画」、2002 年度から文部科学省が2つの知的クラスター事業（「知的クラスター創成事業」と「都市エリア産学官連携促進事業」）を開始した。これらの事業は目標とする水準、対象地域の範囲、予算規模と補助期間が異なるが、基本的な制度設計はほぼ同じである。経済産業省の事業が広域的で参加も自由であり、地域企業が共同研究のリーダーになり、補助金を受給できる一方、文部科学省の事業では地域間の競争的選抜に基づいて補助対象のクラスターが選定され、共同研究のリーダーは大学・公的研究機関の研究者に限定され、参加企業が補助金の配分を受けることはできない。本稿は、このような特徴を持つ文部科学省のクラスター事業の効果を、大学・公的研究機関と企業で定量的に比較することを目的とする。

これまで、データの制約の問題もあって、クラスター政策の効果に関する実証研究の蓄積は限定されているが、日本に先行して大規模なクラスター政策が開始されたドイツとフランスについて、また経済産業省のクラスター事業については比較的多くの先行研究がある。文部科学省のクラスター政策は、特定の科学技術分野に強みを持つ地域クラスターの競争的選抜という点でドイツやフランスのクラスター政策と共通点を持つが、研究費（補助金）の配分やプロジェクト運営において地域の中核大学・研究機関が中心になるという点でそれらと大きく異なる。しかし、これまでの実証研究は主に参加企業あるいはプロジェクト全体への効果を検証するものであり、大学・公的研究機関と企業の成果を比較する研究はほとんど見られない。

そこで本論文は、大学・公的研究機関・企業の 2001 年度から 2009 年度までの 9 年間のパネルデータを用いて、パネル固定効果ポワソン回帰分析により、文部科学省による知的クラスター政策の効果を検証し、大学・公的研究機関と企業について比較する。研究開発成果（従属変数）は出版された学術論文数とその前方引用（被引用）件数（それらの論文が他の論文にどれだけ引用されたか）および特許出願件数と特許の前方引用（被引用）件数（それらの特許が他の特許にどれだけ引用されたか）で測定される。前方引用（被引用）件数はしばしば研究開発成果の質の指標として用いられるが、本稿でも同様に質の指標とする。従属変数がゼロを含むカウントデータであるため、ポアソンモデルによる推定を行う。各モデルの主な独立変数は、クラスターに参加している年度は1，それ以外は0をとる参加ダミーである。また、特定の年、場所、分野の特異な要因をコントロールするために、各年と都道府県の組み合わせ、各年と産業・研究分野の組み合わせのダミー変数をモデルに含める。

クラスター地域は文部科学省によって競争的に選出され、クラスター参加者は各クラスターの中核組織によって選出される。このようなクラスターに参加する大学、公的研究機関、企業は、非参加者に比べて研究開発やイノベーションの能力が高いのではないかという内生性が懸念される。しかし、パネル固定効果分析を採用することで、研究・イノベーション能力を含む、

時間的に変化しない各参加者に固有のすべての要因をコントロールし、クラスター参加の内生性に対処することができる。このような各参加者の固定効果を排除し、大学や公的研究機関と企業のクラスター事業参加前後の差異を比較することで、クラスター参加の因果効果を特定・比較することができる。なお、因果効果をより明確にするために、クラスター参加終了後は、大学、公的研究機関、企業をサンプルから除外している。

分析の対象となる大学、公的研究機関、企業は総務省「科学技術研究調査」の個票データに含まれるものである。論文・特許とそれらの引用のデータはそれぞれ lens.org と知的財産研究所のデータベースから収集した。クラスター参加の情報は、文部科学省の知的クラスター事業のウェブサイトから入手した。2001 年度から 2009 年度の観測期間中、毎年 100 から 200 の大学/公的研究機関と企業がクラスターに参加しており、これは分析対象の大学・公的研究機関と企業のそれぞれ約 7〜9%と 1〜2%に相当する。

クラスター政策の下で、大学・公的研究機関の研究者はクラスター参加企業の研究資金、ノウハウ、市場情報へのアクセスを得ることができる。したがって、大学や公的研究機関は、クラスター参加後、科学技術成果（論文発表や特許出願）を量的にも質的にも増加させると考えられる（成果面の付加効果）。また、企業との共同研究により、学術論文よりも特許について効果がより大きいと予想する（行動面の付加効果）。同様に参加企業は、共同研究開発プロジェクトを通じて大学等の研究者からの知識スピルオーバーを享受できる。したがって、クラスター参加後、企業は科学技術成果を量的にも質的にも増加させると予想される（成果面の付加効果）。さらに、参加企業には共同研究開発の成果を特許よりもむしろ学術論文として発表する機会が増えると予想される（行動面の付加効果）。

パネル固定効果ポワソン回帰分析の結果、1) 大学や公的研究機関はクラスター参加後に学術論文よりも特許出願とその被引用を有意に増加させ、2）企業はクラスター参加後に特許出願よりも学術論文とその被引用を有意に増加させることがわかった。被引用件数が増えたことから、研究成果の質の向上が示唆される。この結果は、クラスター政策によって大学・公的研究機関と企業の研究成果の現れ方が変化したという意味で、行動面の付加効果を示唆している。

文部科学省のクラスター事業は大学中心の政策であり、プロジェクトリーダーは中核大学や公的研究機関の学術研究者でなければならず、公的助成金は地方公共団体が指定する中核機関を通じて、最終的に学術研究者に配分される。これはドイツやフランスの主要なクラスター政策や経済産業省の産業クラスター事業で中小企業を含む地域企業も主役となり、補助金を参加企業に配分できることと対照的である。そのような政策が、参加大学・研究機関のみならず参加企業にも行動面の付加効果を質量ともにもたらしたことは、本研究の重要な発見である。

The impact of cluster policy on academic knowledge creation and regional innovation: Geography of university-industry collaboration in Japan

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Abstract

This paper evaluates the effects of cluster policy in light of the complexity of geography of university-industry R&D collaboration. The study focuses on the unique 'university-centred' cluster programmes in Japan, implemented between 2002 and 2009. Our analysis compares the effects of cluster policy on universities / public research institutes (PRIs) and those on firms, by utilising micro-data from official statistics combined with data from databases of academic publications and patents. By estimating panel fixed-effect Poisson models, we find that these cluster programmes promoted regional innovation, especially by increasing universities' and PRIs' patenting (but not publication) and firms' publication (but not patenting), indicating behavioural additionality of cluster policies. Moreover, we find that forward citations from academic patenting and firms' scientific papers significantly increased after cluster participation, which suggests enhanced quality of science and technology output.

Keywords

R&D collaboration, regional innovation, cluster, policy evaluation, patent, publication

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1. Introduction

Over the last two decades, place-based innovation policy measures addressing regional competitiveness have substantially grown internationally, drawing on the concepts such as 'local industrial clusters', 'regional innovation systems' and 'smart specialisation'. Behind these public policy measures and economic development strategies, spatial proximity is seen as one of the important determinants of firms' collaborative behaviour for innovation. Under the 'cluster' concept (Porter, 1998), in particular, geographical agglomeration and knowledge spillovers beyond organisational boundaries, including firms, universities and public research institutions (PRIs) are considered to be important for promoting local innovations (Anselin et al., 1997; Audretsch et al., 2019).

It is noted that literature evaluating impacts of cluster policies are still relatively scarce (Nathan, 2022), and that studies on impacts of cluster policies are fragmented due to methodological challenges and the diverse structural characteristics of different cluster policy programmes (Wilson et al., 2022). There is limited empirical evidence for the effect of policy support for regional industry-academia-government collaboration, in particular, the impact of cluster policies on universities and PRIs. This paper aims to fill these gaps in our knowledge, by providing a better understanding on the impact of a cluster policy in light of the complex geography of higher education in cluster development processes. Building on a review of recent empirical investigations and literature evaluating the effects of cluster policies and public R&D subsidy in several countries, we empirically examine publicly supported cluster programmes in Japan. Cluster policies in Japan started in 2001 with the Ministry of Economy, Trade and Industry (METI)'s Industrial Cluster Project, followed by the Ministry of Education, Culture, Sport, Science and Technology (MEXT)'s two cluster programmes in 2002. This paper focuses on the unique 'university-centred' cluster programmes under the MEXT (Okamuro and Nishimura, 2015a), implemented in the fiscal years 2002 to 2009. Geography of higher education particularly matters here because of the unique nature of the MEXT cluster programmes targeting universities and PRIs, whereby academic researchers eventually receive public subsidy and lead the cluster programmes by selecting project members (especially cluster member firms that participate in the programme).

Our analysis compares the cluster policy effects on universities / PRIs and firms by utilising both university and industry micro-data from official statistics combined with data from databases of publications and patents. We match these micro-data sets with cluster and location information for the period between 2001 and 2009, employing fixed-effect panel Poisson regression for empirical estimations. We evaluate the MEXT cluster policy impact by comparing the effects on publication and patenting of universities/PRIs on one hand and private firms on the other. The study contributes to granular understanding of the complexity of geography of higher education (Fitjar and Gjelsvik, 2018) and better theoretical understanding of regional innovation and place-based policy design approaches. Methodologically it sheds light on international comparative perspectives to policy evaluation by adopting quantitative methodology with micro-data panel analysis. Our analysis demonstrates the impacts of specific cluster programmes in terms of both output and behavioural additionality of public R&D support.

The remainder of this paper is organized as follows. Section 2 reviews relevant literature covering the geography of university-industry relationships and cluster policy evaluation approaches, to clarify original contributions of this study. Section 3 describes the development of cluster policies in Japan, focusing on the MEXT cluster programmes and their geographical characteristics. Section 4 explains empirical strategy including estimation models, hypotheses and data. Section 5 presents and discusses the estimation results. Section 6 concludes the paper and provides some limitations, policy implications and future research agenda.

2. Review of Literature

2.1 Geography of university-industry R&D collaboration

University-industry collaboration is often local, and some regions with strong universities manage to benefit from technological spillovers (Mansfield and Lee, 1996). Nevertheless, the presence of strong technical universities and research-intensive universities itself does not lead to strong impacts on their surrounding regions (e.g. Feldman and Desrochers, 2003). The last two decades have witnessed a growing body of literature focused on the university-industry relationships by examining the complex nature of geography of R&D collaboration (e.g. Bonander et al., 2016; D'Este et al., 2013; Fitjar and Gjelsvik, 2018; Laursen and Salter, 2004; Villani et al., 2017).

While local university can be an important element for the local industrial cluster development (Čábelková et al., 2019), most of the studies of geography of university-industry collaboration find that the higher the university's quality, the more firms are willing to accept geographical distance, highlighting the 'trade-offs' (Laursen et al., 2011) between geographical proximity and university quality (e.g. D'Este and Iammarino, 2010; D'Este et al., 2013; Garcia et al., 2015; Johnston and Huggins, 2017; Muscio, 2013). As firms demand knowledge that is economically useful, the 'quality' in this context depends on its value to the recipient (industry) and not necessarily equal to 'scientific excellence' (Fitjar and Gjelsvik, 2018).

Further, the impact of academic quality and geographical proximity is not homogeneous across disciplinary fields (D'Este and Iammarino, 2010). For example, in certain sectors (e.g. pharmaceutical industry), firms tend to cluster in the geographical proximity of excellent universities (Abramovsky and Simpson, 2011). A critical mass of researchers and equipment in specific industry areas may facilitate collaboration, and universities may adjust to local industry's R&D demands by specializing in relevant areas (Čábelková et al., 2019; Fitjar and Gjelsvik, 2018). Overall, findings imply that firms weigh the 'quality of knowledge production' against the 'costs of transferring knowledge across geographical distance' (Fitjar and Gjelsvik, 2018, p.1526).

2.2 Cluster policy and policy evaluation

Cluster policies have been employed by many governments' economic policy strategies over the last three decades (see OECD, 1999; 2007; Uyarra and Ramlogan, 2016 for an overview). Knowledge spillover effects from universities to private firms in regional clusters have been analysed in various studies (Anselin et al., 1997; Baptista and Swann, 1998; Dahl and Pedersen, 2004; Bonander et al., 2016; Nishimura and Okamuro, 2016). The challenges of evaluating the effectiveness of cluster policies have been well noted (Rothgang et al., 2019; Wilson et al., 2022).

Table 1 around here

Nathan (2022) identifies three types of cluster policies (see Table 1). The focus of this paper is the first type of cluster policies, 'top-down, formal partnerships backed by grants or subsidies', usually generated through competitive calls for entry, exemplified by those in France, Germany and Japan (Nathan, 2022). Okamuro and Nishimura (2015a) compare the cluster policies and the management of biotech clusters across Germany, France and Japan based on on-site interviews. They observe that the MEXT cluster programmes in Japan are most 'university-centred' and 'top-down' compared to the German and French counterparts where local firms play more important roles.

In Germany and France, cluster policies were launched in the 1990s, in order to promote regional innovation. Empirical studies on the effects of these policies using micro-data have been growing since around 2010 (see Table 1). In the policy context of Japan, while private firms can play a leading role and obtain a considerable share of public subsidies under the METI cluster programme, they are the 'subcontractors' to their university partners in the MEXT programmes, and thus, cannot receive a direct share of the subsidies (Okamuro and Nishimura, 2018). Most of these studies on cluster evaluation primarily focuses on the firm level or project level analysis, estimating the participating firms' performance such as R&D expenditures, productivity and employment. Although universities and PRIs are considered to be the cores of these programmes, most empirical studies on the effects of such cluster policies focus on the participant firms' performance, paying little attention to comparable performance of universities and PRIs.

Investment in R&D projects, R&D productivity, the quality of R&D personnel, and patenting can also be enhanced through collaborations with universities (Fukugawa, 2013). Effects of public support such as public R&D subsidy to enhance collaboration between university and industry have been analysed (e.g. Tripsas et al., 1995; Hemmert et al., 2014; Okamuro and Nishimura, 2015b; Engel et al., 2019). Previous studies have examined the effects of public R&D subsidy employing the concepts of input, output and behavioural additionality (Clarysse et al., 2009). However, it is noted that few studies investigated 'behavioural change of project members with respect to the relationship with their partners' (Okamuro and Nishimura, 2015b, p. 635).

3. Development of Cluster Policies in Japan

Since the Basic Act on Science and Technology was enacted in 1995, the Japanese government has been promoting university-industry R&D collaboration in various forms under the Basic Plans for Science and Technology. In the second Basic Plan for Science and Technology, which began in 2001 for five years, public support for creating regional clusters was regarded as a policy priority. In 2001 the METI started the "Industrial Cluster Project" and in 2002 the MEXT started the "Knowledge Cluster Initiative" (hereafter KCI) and the "City Area Program for Promoting University-Industry Collaboration" (hereafter CAP). In the third Basic Plan for Science and Technology, public support for cluster development was strengthened. The cluster support programmes of the METI and MEXT entered the second phase in 2006 and 2007, respectively. However, after the government change in 2009 to the Democratic Party, both MEXT's cluster programmes were abolished unexpectedly. In the following year, however, the MEXT integrated both programmes to a new programme. After 2011, due to the completion of METI's Industrial Cluster Project in the second phase in the previous year, the MEXT started a new joint cluster program with the METI and other ministries.

The cluster initiatives in Japan under the METI and MEXT both aimed to create R&D consortia by facilitating collaboration between small and medium enterprises (SMEs), large firms, PRIs, and universities, and by promoting the so-called triple helix interactions between university–industry–government at the subnational level (Horaguchi, 2016; Kitagawa, 2004; Kodama, 2008; Okamuro and Nishimura, 2018).There are eight METI Regional Bureaus which administered and monitored cross-prefectural 'regional' cluster projects (Kitagawa, 2007). The MEXT cluster programmes were administered at much smaller geographical scale at prefecture or municipality levels. There are some empirical evaluation studies on the METI's "Industrial Cluster Project" (Nishimura and Okamuro, 2011a, 2011b, 2016; Okubo et al., 2022).[1] Fewer empirical evaluations have been conducted on the MEXT's cluster programmes, notably Horaguchi (2016) that examines effects on patent application and new product development through the creation of academic spinoffs at the cluster level. Okamuro and Nishimura (2018) compare the effects of METI's and MEXT's policies on the project performance and find that the commitment to the joint R&D project is higher for the participant firms of the METI program than for those of the MEXT programmes. This study is the first empirical attempt to evaluate MEXT's cluster programmes using comprehensive micro-data on cluster participants and comparing effects on both academia and industry.

[1] Nishimura and Okamuro (2011a) found that participating in the "Industrial Cluster Project" has no effects on the productivity of R&D as seen by the number of patent applications, but if the participating firms collaborate with the core universities in the cluster area, its productivity of R&D increases. Nishimura and Okamuro (2011b) show that network support is more effective than subsidy among the support measures. Okubo et al. (2022) focused on the effectiveness of network support and verified that cluster support facilitates business transactions with firms in Tokyo in particular.

According to the website information of the MEXT[2], a Knowledge Cluster is defined as "a technological innovation system, which comprises the local public research institutes with original R&D subjects and potential as core organizations and also private firms both within and outside the region, to be created under the local initiatives". In the KCI, 12 local projects were selected from 30 applications in 2002, and three more projects were added in 2003 and 2004, respectively, and eventually 18 projects were selected in the first phase. Each local cluster project received a subsidy for five years. The second phase started in 2007, where many of the cluster areas in the first phase continued to be subsidized, and some projects were integrated with the cluster in adjacent areas. The total budget for the eight years until 2009 is 63 billion yen (average of eight billion yen annually). CAP, the MEXT's another cluster programme, also started in 2002 with a smaller scale of budget compared to KCI, aiming to promote local collaborative R&D highlighting local specific needs. The support period is three years, and the scale of the project is set at around 100 million yen per year. New selection and adoption of local clusters were carried out every year. 59 projects were adopted in the first phase, and 30 projects were adopted in the second phase starting in 2007. The total budget for the first phase (five years) is approximately 20 billion yen (average of four billion yen per year).

It is noteworthy that a unique matching funding scheme with local governments was introduced in the MEXT programmes in the second phase (in 2006 in CAP and in 2007 in KCI), in which the municipalities in the cluster areas were to offer 50% of the total R&D subsidy. This change may have changed the support balance between industry and academia, since local governments' subsidy could be directly provided to local firms.

As mentioned above, the MEXT cluster programmes' main targets were universities and PRIs. The MEXT allocated subsidies to the cluster organizations (later also with match funding from local governments) to support research at universities and PRIs, where the project leaders (principal researchers) were limited only to university and PRI researchers. The principal researcher as a leader of each of the cluster projects coordinated with the cluster organization and applied for the MEXT cluster programmes. Under the MEXT cluster programmes, the participant firms, both in and outside the cluster areas, were expected to provide research funds to the university and PRI partners located in the cluster. Table 2 presents the number of participating universities/PRIs and firms both inside and outside the MEXT cluster geographical areas. Both under the KCI and CAP programmes, a majority of the participating firms was located outside the cluster areas. Especially, almost all firms participating in the CAP projects with smaller areas were located outside cluster areas. In contrast, a majority of the participating universities and PRIs was located in the cluster areas even under the CAP programme.

[2] The following definition of a knowledge cluster is based on an English translation of the original Japanese brochure by the authors. See also MEXT's Cluster Brochure 2002 (English version): https://www.mext.go.jp/a_menu/kagaku/chiiki/cluster/h14_pamphlet_e.htm. Lase accessed 29/03/23.

Table 2 around here

Table 3 presents further comparisons of participating firms located in and outside cluster areas at the first year of cluster participation. On average, cluster firms outside cluster areas are significantly larger than those in cluster areas. Cluster firms outside cluster areas have significantly more R&D expenditures than those in cluster areas, while no significant differences at the five percent level can be confirmed regarding external research expenditures. These results suggest that universities and PRIs in each cluster project may select their partner firms from outside their cluster areas.

Table 3 around here

Thus, we may expect that core universities and PRIs of each cluster project increased not only internal research expenditures, but also external research expenditures due to R&D outsourcing to cluster member firms. However, for private firms, with no direct access to public subsidies from the cluster programmes and limited roles in the cluster development, direct benefits of cluster participation under the MEXT programmes may be limited (Okamuro and Nishimura, 2018). We can expect that one of the effects of the MEXT cluster programmes is to match local R&D needs with firms located outside the cluster area (e.g. the Tokyo metropolitan area) and to bring in external R&D investment in the so-called 'peripheral' regions. In the following empirical analysis, we will examine the cluster policy effects in terms of science and technology (S&T) outputs – both publications and patents, and compare those of universities/PRIs and firms.

4. Empirical strategy: data, estimation method, hypotheses and models

4.1 Data

Our sample comprises statistical micro data on universities, PRIs and private firms in Japan from the Survey on Research and Development (*Kagaku Gijutsu Kenkyu Chosa*), hereafter SRD, by the Ministry of Internal Affairs and Communications (MIC) from 2001 to 2009. This is one of the most important Japanese official surveys conducted every year. This survey collects detailed data on researchers and research expenditures (internal and external), and their compositions according to expense items, scientific and technological fields, and sources). This survey covers around 12,000 private firms (sampling survey), around 1,000 to 1,200 PRIs (complete enumeration), and around 3,000 to 3,500 university departments (complete enumeration) every year, of which we could match around 10,000 firms and around 2,000 universities and PRIs every year with publication and patent database.

University data are available from the SRD for each department and institute, but we matched the university data with cluster project information and publication / patent data at the university level (not at the department level). We obtained cluster project information including designation period and participants' lists from the MEXT website. Publication and patent data were collected from the lens.org database (https://www.lens.org/lens/) and the Institute of Intellectual Property (IIP) Patent Database (https://www.iip.or.jp/e/index.html), respectively. During the observation period from 2001 to 2009, between 100 and 200 universities / PRIs and firms participated in any cluster program every year, which correspond to ca. 7-9% and 1-2% of sample universities/PRIs and firms, respectively.

Although the micro-data of SRD are also available before 2000, there is no address information about the respondents before 2000. Thus, we cannot precisely identify their location before 2000 due to possible relocations. Therefore, our estimation period starts in 2001 and ends in 2009 when the MEXT cluster programmes were abolished. There were no cluster participants in 2001 because the MEXT's programmes began in 2002. KCI was a five-year program with different starting and ending years; six of the 18 designated cluster projects in the first phase started in 2003 or 2004. CAP was for three years, also with different starting and ending years. Some local cluster projects were designated again after the first three years, sometimes with one or more years of vacancy. Others were never designated again after the first three years. We use this variety in the years of cluster designation and cluster participation of universities, PRIs and firms to estimate the causal effect of cluster policy with panel fixed effect estimations.

Although universities and PRIs are included in the complete enumeration every year, the population of the survey may change every year due to entry, exit or integration. Since the survey for private firms is conducted partially as a sample survey[3], and some firms do not respond, it is not always possible to obtain the data for every firm every year. Moreover, we excluded the universities, PRIs and firms that participated in the cluster projects from the analysis after the end of the cluster period in order to clarify the comparison of cluster participants before and after the start of the cluster participation. For these reasons, we use unbalanced panel data in that sample composition changes every year during the estimation period.

4.2 Estimation method and hypotheses

We evaluate the impacts of the cluster policy with the following procedure. First, we identify the starting and ending years of each regional cluster project designated under the MEXT programmes using the MEXT website information. Then, we identify the universities, PRIs and firms that participated in each cluster project also from the MEXT website information and match them with SRD micro data, using their names and the unique organization codes. Further, we collect data of scholarly journal publications and citations as well as patent applications, grants and citations of universities, PRIs and firms from lens.org online database, and match them with SRD and cluster data. Finally, we

[3] The SRD is composed of complete enumeration and sampling survey. The SRD targets firms that have paid-in capital of at least one billion yen, as well as those with paid-in capital between 100 million and one billion yen that reported positive research expenditures in the previous year's round of survey.

estimate the effects of cluster participation using this original panel data set and the fixed effect model. The most important independent variable here is the cluster participation dummy.

Due to intensive R&D collaboration with member firms, academic researchers can obtain access to partner firms' research funds, knowhow and market information. Thus, we expect that universities and PRIs increase S&T output (paper publications and patent applications) both quantitatively and qualitatively after cluster participation (*output additionality*). We measure the quality of S&T output with the number of forward citations of papers and patents (the number of scientific papers or patents that cite the focal scientific papers or patents). Moreover, we expect that, based on joint research with industry partners, joint invention and joint application of patents increase more than scientific publications (*behavioural additionality*). Thus, we propose the following set of hypotheses.

Hypothesis 1a: After cluster participation, *scientific publications* of participating universities and PRIs increase both quantitatively and qualitatively.

Hypothesis 1b: After cluster participation, *patent applications* of participating universities and PRIs increase both quantitatively and qualitatively.

Hypothesis 1c: After cluster participation, *patent applications* of participating universities and PRIs increase more than scientific publications both quantitatively and qualitatively.

Similarly, participating firms can enjoy knowledge spillover from academic researchers through collaborative R&D projects. Thus, we expect that firms increase S&T output both quantitatively and qualitatively after cluster participation (*output additionality*). Moreover, we expect that, based on joint research with academic partners, participating firms have better opportunities to publish the outcomes of joint research projects in scientific journals than to apply for patents (*behavioural additionality*). Thus, we postulate the following hypotheses.

Hypothesis 2a: After cluster participation, *scientific publications* of participating firms increase both quantitatively and qualitatively.

Hypothesis 2b: After cluster participation, *patent applications* of participating firms increase both quantitatively and qualitatively.

Hypothesis 2c: After cluster participation, *scientific publications* of participating firms increase more than patent applications both quantitatively and qualitatively.

4.3 Estimation models

Panel fixed effect model is used to estimate the effects of MEXT cluster programmes. Units of the fixed effect estimations are universities, PRIs and firms. As mentioned above, cluster participants were selected by the core organization of each cluster, and the publicly subsidised regional cluster projects were competitively selected by the MEXT. There is a concern about endogenous bias that universities, PRIs and firms participating in these cluster projects may have higher capability of R&D and innovation than non-participants.

However, by employing panel fixed effect analysis, we can deal with endogenous problems of participation in and selection of the clusters by controlling for all factors unique to each participant, which does not change over time, including the research and innovation capability. By eliminating these fixed effects of each participant and comparing the differences before and after cluster project participation between the universities or PRIs and the firms, we can identify and compare causal effects of cluster participation. In order to clarify the causal effect, universities, PRIs and firms are excluded from the estimation sample after the end of cluster participation.

The estimation models are as follows. As the dependent variables, we use the number of scientific publications and forward citations (in scientific papers) as well as the number of patent applications and forward citations of granted patents of universities, PRIs and firms as the measures for research output. These hypotheses are tested by Poisson models because dependent variables comprise count data including zeros (Wooldridge, 1999). The main independent variable of each model is the cluster participation dummy. Some control variables are included in the estimation models: the number of employees (for firms) or researchers (for universities and PRIs) to control for the effect of the size of institutions or firms, the dummy variables for each year-prefecture combination and for each year-industry/research field combination to control for any idiosyncratic factors for specific years, locations and fields.

The basic statistics (the number of observations, mean, and standard deviation of the variables are summarized in Table 4. It shows that the universities/PRIs and firms have "comparative advantages" in publication and patenting, respectively (in the sense that the former yield more publications than patents and the latter yield more patents than publications), while the former show higher output than the latter in terms of both publication and patents.

Table 4 around here

5. Estimation results and discussion

Table 5 presents the estimation results on S&T output of universities and PRIs. The coefficients of cluster participation dummy on publications and their forward citations are negative but not significant, suggesting that MEXT cluster programs neither encouraged nor discouraged scientific publications of academic researchers. However, the effects on patent applications and citations are positive and significant, suggesting that universities and PRIs significantly increased patenting and the average quality of patents after cluster participation. These results support Hypotheses 1b and 1c, but not 1a.

Table 6 shows the estimation results on S&T output of firms. In contrast to the results in Table 5, cluster firms significantly increased both the number of paper publications and citations, but there were no significant changes in patent applications and citations. These results support Hypotheses 2a and 2c but not 2b, suggesting that firms (business researchers) increased publication and the average quality of papers after cluster participation. It is noteworthy that the number of observations is quite small for the estimation results on academic researchers' patenting in Table 5 (874) and on business researchers' publication in Table 6 (1,073). It suggests that patenting academic researchers (institutes) and paper-publishing business researchers (firms) are only a small portion of the entire sample.

Table 5 and Table 6 around here

We find evidence for both *output additionality* and *behavioural additionality* resulting from public support through the MEXT cluster programmes. Output additionality means an increase in research output by receiving public subsidy, which is often examined with regard to R&D subsidy programmes. Behavioural additionality means changes in the behaviour or strategy of the recipients by public subsidy (Clarysse et al., 2009). The results in Tables 5 and 6 suggest that academic researchers were encouraged for more patenting than publication, whereas business researchers were encouraged to more publication than patenting, after participating in cluster projects. We can interpret these results as behavioural changes of both academic and business researchers through the collaborative R&D projects under public support of the MEXT cluster programmes.

In this regard, it is noteworthy that such behavioural changes resulted in higher-quality publications or patents measured by the number of citations. In this context, we need to be aware of the changes in incentives for universities' patenting due to the new national legal frameworks in 1999 (i.e. the Japanese Bayh-Dole Act), followed by the 'incorporation of national universities' in 2004 with greater institutional autonomy (Kitagawa and Woolgar, 2008). The cluster impacts may reflect these intertwined institutional incentive mechanisms for both academic and industry actors.

We stress that the MEXT cluster programmes are regarded as 'university-centred' policies, in which project leaders should be academic researchers of core universities or PRIs, while public subsidy can be eventually allocated to academic researchers through cluster management organizations. This is in a clear contrast to the major cluster policies in Germany and France (Okamuro and Nishimura, 2015a) and to METI's Industrial Cluster Project, where also local firms including SMEs can play a leading role and public subsidy can be allocated to business firms and SMEs (Okamuro and Nishimura, 2018). One of our key findings is that a part of the MEXT cluster member firms significantly increased scientific works both quantitatively and qualitatively after cluster participation.

There remains a question as to why a part of the cluster firms increased scientific output under the primarily university-centred MEXT cluster scheme. We may suggest some answers to this puzzle. One answer might be that firms could enjoy various soft support from the MEXT programmes including networking and consultation, which might have been more valuable for participating firms than the direct subsidy. Another possibility is the effect of the change in funding structures in the policy scheme in 2006 (CAP) and 2007 (KCI), whereby the local authorities of cluster areas were obliged to offer match funding covering a half of the public subsidy to the regional cluster project. After this programme revision, local cluster firms could directly obtain local authority's subsidy for their project. It means that in the second phase of the MEXT programmes the balance of direct support changed in favour of local cluster firms, which might have encouraged them for more research output (especially joint publications). Further policy analysis is needed to reflect the 'heterogeneous and varied nature' of local governments in terms of their capacity, resources, and decision-making powers (Okamuro et al., 2019, p. 805).

6. Conclusion

Our aim in this paper is to evaluate the effects of a specific cluster policy in light of the complexity of geography of university-industry R&D collaboration. Cluster policies have been implemented in several countries since the 1990s to promote regional innovation by encouraging university-industry R&D collaboration. A majority of studies has examined the effects of cluster policies on business and project performance, yet fewer studies have compared the policy effects between academic and business research outcomes so far. This paper fills this gap by comparing the cluster policy effects across universities, PRIs and private firms in Japan.

In Japan, two ministries (the METI and MEXT) implemented cluster policies in parallel as innovation policies for R&D consortia, both aiming to promote the commercialization of joint R&D outcomes, but with contrasting policy designs: the MEXT cluster programmes implemented from 2002 to 2009 had unique characteristics of being 'university-centred': a) only academic researchers at core universities or PRIs could become project leaders and b) public subsidy could eventually be allocated to universities and PRIs (but not to firms) through cluster organizations (Okamuro and Nishimura, 2018). Geographically, while the METI cluster projects encompass wider inter-prefectural 'regions', the MEXT cluster programmes were implemented at much smaller spatial units (intra-prefecture and municipality).

Methodologically this paper has provided a framework on international comparative perspectives to policy evaluation by adopting quantitative methodology with micro-data panel analysis. This study has empirically examined the causal effects of the MEXT cluster programmes in Japan, using the comprehensive micro-data of official statistics (SRD) combined with publication and patent data for nine years from 2001 to 2009. We found that (1) universities and PRIs significantly increased patent applications and forward citations rather than scientific publications after cluster participation, and (2) firms significantly increased scientific publications and forward citations rather than patenting after cluster participation. In short, the MEXT cluster programmes encouraged universities' and PRIs' patenting on one hand, and firms' publication on the other, measured by the number of forward citations of both patents and papers. These results suggest not only *output additionality*, but also *behavioural additionality* of the cluster programmes: both parties significantly increased S&T output for which they had relatively few incentives before cluster participation.

We may derive some policy implications from our findings and discussions. Above all, this study highlights a model of cluster programmes primarily focused on promoting research at universities and PRIs, which may directly contribute to regional innovation by encouraging patenting by regional universities and PRIs. Regional innovation, especially measured by technological impacts (universities' and PRIs' patenting) and scientific impacts (firms' publication), can be promoted by this type of cluster programmes, indicating behavioural additionalities. Therefore, we argue that policy evaluation should consider the impact of such behavioural additionalities. Another key policy implication of this study is the importance for regional clusters to promote interregional university-industry collaboration.

The empirical analyses in this paper have some shortcomings and limitations. First, we could not match all cluster firms with statistical micro-data and the data of publications and patents. Especially small local firms may be underrepresented in the sample. Second, the METI cluster programme and some other support policies for business R&D and university-industry collaboration were implemented at the same time with the MEXT cluster programmes, but we could not explicitly consider the effects of these complementary or competing policies. Third, we counted the number of scientific publications, patent applications and their forward citations for each cluster participant every year, but we could not distinguish joint papers and applications with research partners from other outputs. Thus, joint papers and applications are double counted under universities' and firms' output in our estimation. Despite these shortcomings, we believe that this paper contributes to the empirical evaluation of a regional cluster policy comparing its effects on universities, PRIs and firms respectively.

These estimation results need to be set against the complexity of the geography of university-industry R&D collaborative relationships as part of the cluster development. As mentioned earlier, the geography and policy designs of the MEXT cluster policy contrasts with those of the METI. Due to the unique nature of university-centred design of the MEXT cluster programmes, universities and PRIs were expected to build links with organisations outside their local areas, and with the smaller geographical scale of the MEXT cluster programmes, many of the linkages forged under the MEXT programmes were outside the local cluster boundaries (see Table 2). On the contrary, the METI cluster programme had the 'regional' (intra-prefectural) governance structure, aiming to promote local network for innovation within each cluster. A study on the METI cluster effects suggests that firms that participated in the METI cluster projects with national universities in the same cluster region significantly improved the R&D productivity, while local firms collaborating with partners outside the cluster showed higher productivity in general (Nishimura and Okamuro, 2011a).

The policy impacts on the behavioural dimension of cluster may be intrinsically linked to wide-ranging collaborative networks within and beyond local clusters. In the future study, we need to further unpack the complexity of geography of cluster development through university-industry collaborative relationships, particularly from local universities' point of views (cf. Fitjar and Gjelsvik, 2018). Universities' perceptions of the 'quality' and 'proximity' may differ from those of firms in the cluster R&D consortia, with different dimensions of proximity (Boschma, 2005) at play.

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Table 1: Cluster policy types and evaluation

	Examples of 'cluster' policies	Literature	Evaluation of cluster programmes e.g. Nature of data and level of analysis, key findings
Type 1 **Top-down , public subsidies**	**France:** **Local Productive Systems;** **Pôles de Compétitivité**	Martin et al. 2011; Fontagné et al. 2013; Abdesslem and Chiappini 2019; Hassine and Mathieu 2020; Lucena-Piquero and Vicente 2019; Mar and Massard 2021	- firms' performance such as R&D expenditures, productivity and employment - Increase in business R&D spending, particularly SMEs
	Germany: **BioRegio** and **<u>BioProfile;</u>** **The Bavarian High-Tech Offensive;** **Leading-Edge Cluster Competition**	Engel et al. 2012; Graf and Broekel 2020 Falck et al. 2010 Audretsch et al. 2019; Cantner et al. 2019; Engel et al. 2019	- increase in collaboration with PRIs, and improved access to suitable R&D personnel, but decrease in R&D expenditure - positive impact of clustering on knowledge spillovers, innovation and growth; - significant leverage effect of funding, especially on SMEs - negative spillover effects in the cluster areas on the industries and firms that unsupported by the regional cluster projects
	Japan: **METI Industrial Cluster Project;** **MEXT cluster programmes**	Nishimura and Okamuro 2011a; 2011b; Okubo et al. 2022 Okamuro and Nishimura 2018	- No direct effects on participant firms in terms of the productivity of R&D. - Commitment to the joint R&D project is higher for the participant firms of the METI program than for those of the MEXT programmes.
Type 2 Physical redevelopment of ex-industrial areas	**Spain:** **22@Barcelona cluster** **US: 'Innovation Districts'**	Viladecans-Marsal and Arauzo-Carod 2012 Katz and Wagner 2014	- cluster amenities have played a part in attracting knowledge-based firms, small shifts in firm composition.
Type 3 Light-touch, market-oriented interventions	**US: Regional Innovation Cluster (RIC) programme;** **UK: City Growth Strategies** e.g. the UK Tech City programme	Yu and Jackson 2011 McDonald et al. 2007; Nathan 2022	- limited empirics in the US in support of the positive impact or advisability of RICs on regional economic development and prosperity - Cross-sectional analysis on UK clusters shows that deep clusters are not associated with employment growth or international competitiveness.

Sources: Nathan (2022) and authors' compilation.

Table 2: Participating universities/PRIs and firms in and outside cluster areas

	Number of universities/PRIs						Number of firms					
	KCI		CAP		MEXT		KCI		CAP		MEXT	
year	total	in	total	in	total	in	total	in	total	in	total	in
2002	55	32	53	38	108	70	64	35	15	4	79	39
2003	71	44	85	60	156	104	114	63	26	10	140	73
2004	93	55	108	75	201	130	150	75	32	11	182	86
2005	96	57	101	65	197	122	155	69	24	5	179	74
2006	96	56	120	67	216	123	156	69	26	6	182	75
2007	86	44	121	67	207	111	143	52	28	8	171	60
2008	87	47	140	62	227	109	135	50	64	5	199	55
2009	103	50	131	61	234	111	149	48	81	4	230	52
total	687	385	859	495	1546	880	1066	461	296	53	1362	514

Table 3: Comparison of participating firms in and outside cluster areas
(at the first year of cluster participation)

	Sample size		Mean			
measures of firm size	Outside	Inside	Outside	Inside	Diff.	p-value
Log. of number of employees	272	106	6.86	6.19	0.673	0.001
Log. of sales	271	106	10.8	9.64	1.19	0.000
Log. of internal research expenditure	253	104	12.3	10.7	1.524	0.000
Log. of external research expenditure	118	40	9.15	8.41	0.737	0.054

Table 4: Descriptive statistics

	Universities / PRIs			Firms		
Variables	N	Mean	S.D.	N	Mean	S.D.
Cluster participation dummy	17,091	0.077	0.267	90,935	0.014	0.120
N. of paper publications	17,091	1,115	13,239	90,935	0.632	63.2
N. of forward citations of papers	17,091	39,551	536,789	90,935	57.8	6,437
N. of patent applications	17,091	41.2	500	90,935	15.8	214
N. of forward citations of patents	17,091	87.3	1,144	90,935	35.2	507
ln. N. of researchers	17,091	3.75	1.46			
ln. N. of employees				90,935	4.76	1.87

Table 5: Estimation results on S&T output of universities and PRIs (panel FE Poisson regression)

Variables	N. of paper publications	N. of forward citations of papers	N. of patent applications	N. of forward citations of patents
ln. N. of researchers	0.0253	0.0383	-0.0164	0.0224
	[0.0297]	[0.0338]	[0.131]	[0.0962]
Cluster participation dummy	-0.0173	-0.0493	0.323**	0.387***
	[0.0560]	[0.0860]	[0.128]	[0.0989]
Constant	11.17***	14.92***	8.158***	8.682***
	[0.237]	[0.273]	[1.098]	[0.810]
Field-year dummies	Yes	Yes	Yes	Yes
Prefecture-year dummies	Yes	Yes	Yes	Yes
N	7,510	6,952	874	797

Standard errors in brackets

* p<0.1, ** p<0.05, *** p<0.01

Table 6: Estimation results on S&T output of firms (panel FE Poisson regression)

Variables	N. of paper publications	N. of forward citations of papers	N. of patent applications	N. of forward citations of patents
ln. N. of employees	0.146*	0.238***	0.335**	0.296*
	[0.0781]	[0.0826]	[0.153]	[0.163]
Cluster participation dummy	0.726***	0.728**	-0.0223	-0.027
	[0.223]	[0.343]	[0.0578]	[0.0506]
Constant	1.587**	4.162***	3.868***	5.158***
	[0.681]	[0.685]	[1.345]	[1.443]
Industry-year dummies	Yes	Yes	Yes	Yes
Prefecture-year dummies	Yes	Yes	Yes	Yes
N	1,073	805	18,030	17,300

Standard errors in brackets

* p<0.1, ** p<0.05, *** p<0.01

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学術的知識創造と地域イノベーションへのクラスター政策の影響：
日本における産学連携の地理

2023 年 6 月

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The impact of cluster policy on academic knowledge creation and regional innovation:
Geography of university-industry collaboration in Japan

June 2023

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