Promoting universities' patenting and firms' publication: An empirical evaluation of MEXT cluster programs in Japan

Abstract

In several countries, public support has been provided to local university-industry R&D collaboration through cluster policies. However, most empirical studies on the effects of such cluster policies focus on participant firms' performance, paying less attention to comparable performance of universities and public research institutes (PRIs). This study targets the unique university-centered cluster programs of the Japanese science and technology ministry (MEXT), in which only academic researchers become project leaders and receive public subsidy and compares the policy effects on scientific publications and patent applications between the universities / PRIs and firms. Moreover, using the scheme change during the cluster programs as a natural experiment, we examine the effects of support balance between industry and academia. Using comprehensive micro data from public statistics and fixed effect panel estimation, this paper finds that after cluster participation, 1) both academic institutions and firms significantly increased internal and external research expenditures, 2) academic institutions significantly increased patent applications and patent citations, 3) private firms significantly increased scientific publications and citations, and 4) these effects are particularly evident in the second phase of the cluster programs.

Keywords: R&D, innovation, university-industry collaboration, cluster, policy evaluation

JEL classification: L24, O32, O38, R58

1. Introduction

University-industry R&D collaboration has been attracting much attention as an effective means to promote innovation. In several countries, public support including subsidy has been provided to such local R&D collaboration, especially through cluster policies since the 1990s. Regional clusters are regarded as the agglomeration and networks of universities, public research institutes (PRIs) and firms collaborating in R&D for creating innovation. Because such regional clusters are difficult to be created, central and regional governments of several countries have made efforts to create and develop such clusters with various public support.

To date, several empirical studies have examined the effects of these cluster policies, especially in Germany, France and Japan. However, although the cores of these clusters are universities and PRIs, most empirical studies on the effects of such cluster policies focus on the participant firms' performance, paying less attention to comparable performance of universities and PRIs. This study targets the unique university-centered cluster programs of the Japanese science and technology ministry (MEXT), implemented from fiscal years (FY) 2002 to 2009, in which only academic researchers become project leaders and receive public subsidy and compares the policy effects on scientific publications and patent applications between the universities / PRIs and firms. Moreover, using the scheme change during the cluster programs as a natural experiment, we examine the effects of support balance between industry and academia.

Thus, using comprehensive micro data from public statistics and fixed-effect panel estimation, this paper empirically examines the direct effects of MEXT cluster policies on scientific publications and patent applications of cluster universities, PRIs and private firms. This paper finds that after cluster participation, 1) both academic institutions and firms significantly increased internal and external research expenditures, 2) academic institutions significantly increased patent applications and patent citations, 3) private firms significantly increased scientific publications and citations, and 4) these effects are particularly evident in the second phase of the cluster programs.

The remainder of this paper is organized as follows. Section 2 reviews relevant literature to clarify original contributions of this paper. Section 3 describes the development of cluster policies in Japan, focusing on the MEXT cluster programs. Section 4 explains empirical strategy including estimation models, hypotheses and data. Section 5 presents and discusses the estimation results. Section 6 summarizes this paper and provides some limitations, policy implications and future research agenda.

2. Literature review

Effects of university-industry R&D collaboration on firms' performance such as productivity has been analyzed in various studies. For example, analyzing the Japanese biotechnology firms, Zucker and Darby (2001) found that innovation outputs (patent applications, new product development, etc.) increase substantially by collaborative research with star scientists at universities, but knowledge spillover effects from such star scientists to local firms are small. George et al. (2002) showed that collaborations with universities enhance bio-ventures' innovation outputs (new product development, etc.) but do not affect its financial performances.

Knowledge spillover effects from universities or public research institutes (PRIs) to private firms in regional clusters have been analyzed in various studies as well (Anselin et al. 1997, Baptista and Swann 1998, Fritsch and Franke 2003, Dahl and Pedersen 2004, Bonander et al. 2016, Nishimura and Okamuro 2016). Among them, Nishimura and Okamuro (2016), targeting the "Consortium R&D

Project for Regional Revitalization" in Japan, examined knowledge spillover effect from universities to participating SMEs as well as rent spillover effect from these SMEs to their large customer firms.

Cluster policies were launched in European countries such as Germany and France in the 1990s, in order to promote regional innovation, and some empirical studies on the effects of these policies have been conducted using micro data since around 2010. There are several studies for German cluster policies such as Falck et al. (2010) on bio-cluster policies in the State of Bavaria, Engel et al. (2013) on bio-cluster policies, Cantner et al. (2019), Rothgang et al. (2019) and Töpfer et al. (2019) on the more recent Leading-Edge Cluster Competition program. Focusing on this cluster program, Audretsch et al. (2019) confirms negative spillover effects in the cluster areas on the industries and firms that are not the targets of the regional cluster projects. Martin et al. (2011), Fontagné et al. (2013), Abdesslem and Chiappini (2019) and Mar and Messard (2021) investigate the effects of French cluster policies on the participating firms' performance such as R&D expenditures, productivity and employment. However, these studies focus on the firm level or project level analysis, and do not compare the policy effects between research institutes (including universities) and private firms.

In Japan, as we explain in the following section in detail, cluster policies started in 2001 with METI (Ministry of Economy, Trade and Industry)'s Industrial Cluster Project, and in 2002 with MEXT (Ministry of Education, Culture, Sport, Science and Technology)'s two cluster programs. There are some empirical studies on METI's "Industrial Cluster Project" (Nishimura and Okamuro 2011a, 2011b, 2016; Okubo et al. 2022).[1] While each of METI's clusters covered a broad area and so may not directly comparable with cluster policies in other countries, few empirical evaluations have been conducted for MEXT's cluster programs. Horaguchi (2016) examined the MEXT programs' effects on patent application and new product development through the creation of academic spinoffs, but at the cluster level. Okamuro and Nishimura (2018) compared the effects of METI's and MEXT's policies on the project performance and found 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 programs, while the firms' higher commitment leads to higher project performance.

Okamuro and Nishimura (2015) compare the cluster policies and the management of biotech clusters in Germany, France and Japan based on on-site interviews and conclude that Japanese (MEXT) cluster policies are most university-centered and top-down among these countries. It suggests the importance of balancing the public support for universities / PRIs and private firms and of comparing the policy effects between these players.

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[1] Nishimura and Okamuro (2011a) found that participating in the "Industrial Cluster Project" has no effect 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.

This research is the first empirical evaluation of MEXT's cluster programs using comprehensive micro data on cluster participants and comparing those from academia and industry. Moreover, using the significant change in the support scheme in these cluster programs between the first and the second phase as a natural experiment, we identify and compare the impact of different support schemes on academia and private business. In this way, we expect to provide important implications for public support to promote regional R&D and innovation.

3. Development of cluster policies in Japan[2]

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

According to the website of MEXT, 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 of the region, to be created under the local initiatives". In the KCI, 12 local projects were selected from 30 applications in FY 2002, and three projects were added in FY 2003 and 2004, respectively, and eventually 18 projects were selected in the first phase. Each local cluster project received a subsidy for five years. In the second phase starting in FY 2007, the majority of the cluster areas in the first phase continued to be subsidized, partially integrated with the cluster in adjacent areas. The total budget for the eight years until FY 2009 is 63 billion yen (average of 8 billion yen annually).

CAP, MEXT's another cluster program, also started in FY 2002 as a minor version of KCI, aiming to promote local collaborative R&D highlighting local specificity. 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

[2] The description of the Japanese cluster policies in this section is mainly based on the MEXT website information and Okamuro and Nishimura (2015, 2018).

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 FY 2007. The total budget for the first phase (five years) is approximately 20 billion yen (average of 4 billion yen per year).

As mentioned above, since the cluster organization receives a subsidy from MEXT (later also from local governments) and entrusts research to universities and PRIs, the project leaders (principal researchers) are limited to university researchers. Indeed, the collaborative research projects in each cluster were decided by the principal researchers under the coordination by the cluster organization before applying for the MEXT cluster programs. In the MEXT programs, private firms in and outside the cluster areas are expected to provide research funds and efforts to R&D projects without playing a leading role and receiving public subsidies. Thus, direct benefits of cluster participation under the MEXT programs are not considered to be significant for private firms (Okamuro and Nishimura 2018). Therefore, it is an important research topic to evaluate the effects of MEXT cluster programs comparing universities, PRIs and private firms. Moreover, in this regard, the policy scheme of the MEXT programs significantly differ from the German and French cluster policies where local firms play more important roles (Okamuro and Nishimura 2015).

It is noteworthy that a unique matching fund scheme with local governments was introduced in the MEXT programs 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. We will use this policy change as a natural experiment to examine the changes in the policy effects on industry and academia.

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 Ministry of Internal Affairs and Communications (MIC) from FY 2001 to 2009. This is one of the most important Japanese public surveys conducted every year since 1983. 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 (partially sampling survey), around 1,000 to 1,200 PRIs (population survey), and around 3,000 to 3,500 university departments (population survey) every year.

Table 1 shows the number of universities, PRIs and firms participating in MEXT clusters from 2001 to 2009. University data are available 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). 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 FY 2000, there is no address information about the respondents before FY 2000. Thus, we cannot precisely identify their location before FY 2000 due to possible relocations. Therefore, our estimation period starts in FY 2001 and ends in FY 2009 when the MEXT cluster programs were abolished unexpectedly. There were no MEXT cluster participants in FY 2001 because MEXT's programs began in FY 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 FY 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 (FE) estimations, which we explain later in more detail.

Although universities and PRIs are the population survey 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 as a sample survey and also 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 by MEXT programs 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 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.

As mentioned in Section 3, the unique rules of the MEXT's cluster programs are that 1) the leader (principal researcher) of each local cluster project should be an academic researcher at a core university or PRI in the cluster area and that 2) public subsidy cannot be allocated to project member firms (Okamuro and Nishimura 2018). Rather, the MEXT expected the participant firms to provide research funds to university and PRI partners. Moreover, core universities and PRIs of each cluster do not only increase internal research expenditures, but also external research expenditures due to R&D outsourcing to member firms. Thus, we present the following hypotheses regarding research expenditures of cluster participants (input additionality).

Hypothesis 1a: After cluster participation, *universities and PRIs* increase *both* internal and external research expenditures.

Hypothesis 1b: After cluster participation, *private firms* increase *both* internal and external research expenditures.

Next, 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 science and technology (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. Moreover, we expect that, based on joint research with industry partners, joint invention and joint application of patents increase more than scientific publications (behavioral additionality). Thus, we propose the following hypotheses.

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

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

Hypothesis 2c: 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 science and technology (S&T) output (paper publications and patent applications) 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 (behavioral additionality). Thus, we postulate the following final hypotheses.

Hypothesis 3a: After cluster participation, *scientific publications* of participating firms increase both quantitatively and qualitatively.

Hypothesis 3b: After cluster participation, *patent applications* of participating firms increase both quantitatively and qualitatively.

Hypothesis 3c: After cluster participation, *scientific publications* of participating firms increase more than patent applications both quantitatively and qualitatively.

Later, we also examine and compare the effects of cluster participation between the first and second phase. Due to the introduction of the unique matching fund system with municipalities' funding, the academic-business balance of public support may have significantly changed in favor of private firms. We will explain the estimation results comparing the cluster effects between the first and second phase of the cluster programs.

4.3 Estimation models

Panel fixed effect model is used to estimate the effects of MEXT cluster programs. Units of the fixed effect estimations are universities, PRIs, and firms. As mentioned above, cluster participants are selected by the core organization of each cluster, and the regional cluster projects to be subsidized are competitively selected by MEXT. Therefore, 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 (1) internal and external research expenditures as well as obtained research funds of universities, PRIs and firms as the measures for research input (Hypotheses 1a and 1b) and (2) the number of scientific publications and forward citations (from papers) as well as the number of patent applications and forward citations of universities, PRIs and firms as the measures for research output (Hypotheses 2a, 2b, 2c, 3a, 3b, 3c). For the research input variables (1), in addition to the natural logarithm of research expenditures and funds, we use dummy variables indicating the presence or absence of research expenditures or funds.

Hypotheses 1a and 1b are tested by linear probability models to enable comparisons between the models with continuous and discrete (dummy) variables as the dependent variables. Hypotheses 2a, 2b, 2c, 3a, 3b and 3c are tested by Poisson models because dependent variables comprise count data including zeros.

The main independent variable of each model is the cluster participation dummy. In additional analyses comparing the first and the second phase of cluster programs, we use Phase 1 and Phase 2 participation dummies instead of 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 for each year-industry/research field combination to control for any idiosyncratic factors for specific years, locations and fields.

The basic statistics (number of observations, mean and standard deviation) of the dependent and independent variables for universities/PRIs and firms are summarized in Table 2.

5. Estimation results and discussion

We present and discuss the estimation results in the order of the above hypotheses: (1) the effects on research inputs (internal and external research expenditures and obtained research funds) of (Hypothesis 1a and 1b), (2) the effects on S&T output of universities and PRIs (Hypotheses 2a, 2b, and 2c), (3) the effects on S&T output of private firms (Hypothesis 3a, 3b and 3c).

Table 3 shows the estimation results on the internal and external research expenditures as well as obtained research funds (from private firms) of universities and PRIs. The cluster participation dummy has a positive and significant effect on internal research expenditures (in natural logarithm), external research expenditures (dummy), and research funds obtained from private firms (in natural logarithm). These estimation results support Hypothesis 1a, though not for all research input measures. According to the estimation results, as a result of participating in the cluster projects, the internal research expenditures increased by 6.2% and the research funds obtained from firms increased by 19.4%, on average. Moreover, universities and PRIs with external research expenditures (including those to partner firms) increased by 7.2% after cluster participation. These effects are statistically significant and substantial.

Next, Table 4 shows the estimation results on the effect of cluster programs on research input of private firms. The coefficients of the cluster participation dummy are positive and significant on internal and external research expenditures (in natural logarithm) and on the probability of internal research expenditures. It can be seen that the proportion of firms engaged in external expenditures and contract research also increased significantly after participating in clusters, as for internal research expenditures of cluster firms. After participating in a cluster project, the proportion of firms with internal research expenditures increased by 2.2% and internal research expenditures of participating firms increased by 5.5% on average. The proportion of firms with external research expenditures increased by 4.6%. Thus, these results support Hypothesis 1b. However, the amount of obtained research funds significantly decreased by 27.0% after cluster participation, which is puzzling.

The cluster programs had the purpose of promoting regional university-industry collaboration through public subsidies to joint R&D projects, and the above estimation results demonstrate that both internal and external research expenditures of participating universities, PRIs and firms (or the proportion of the participants with these research expenditures) increased after starting the cluster projects, which suggests that their collaborative R&D may also have increased significantly. It is obvious that internal research expenditures of participating universities and PRIs increased after cluster participation due to public subsidies of cluster programs, but an important finding is that, after starting the cluster programs, the proportion of firms with internal and external research expenditures significantly increased.

Table 5 presents the estimation results on S&T output of universities and PRIs. The coefficients of cluster participation dummy on publications and 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 joint patenting with partner firms after cluster participation. These results support Hypotheses 2b and 2c, but not 2a.

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 3a and 3c but not 3b, suggesting that firms (business researchers) increased joint papers with academic researchers 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 (1,244) and on business researchers' publication in Table 6 (1,785). It suggests that patenting academic researchers (institutes) and paper-publishing business researchers (firms) are only a small portion of the entire sample.

We find evidence for input additionality, output additionality and behavioral additionality of public support through MEXT cluster programs. Input and output additionality mean an increase in research input and output by receiving public subsidy, respectively, which were often examined with regard to R&D subsidy programs. Behavioral additionality means changes in the behavior or strategy of the recipients by public subsidy. The results in Tables 5 and 6 suggest that academic researchers were encouraged to more patenting than publishing, whereas business researchers were encouraged to more publishing than patenting, after participating in cluster projects. We can interpret these results as behavioral changes of academic and business researchers through collaborative R&D projects with public subsidies. In this regard, it is noteworthy that such behavioral changes resulted in higher-quality publications or patents measured as the number of citations.

We stressed that the MEXT cluster programs are regarded as university-centered policies, in which project leaders should be academic researchers of core universities and PRIs and public subsidy can be allocated only to academic researchers. It is in a clear contrast to the major cluster policies in Germany and France (Okamuro and Nishimura 2015) and also 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).

Nevertheless, we found that cluster firms significantly increased internal and external research expenditures and scientific works both quantitatively and qualitatively after cluster participation. Thus, the question is why cluster firms as a whole increased their research expenditures and scientific output even under the university-centered scheme. We may suggest some answers to this puzzle. One is that firms could enjoy various soft support from MEXT including networking and consultation (Okamuro and Nishimura 2015), which may have been more valuable for participating firms than the direct subsidy (Nishimura and Okamuro 2011b).

Another possibility is the effect of the change in policy scheme in 2006 (CAP) and 2007 (KCI), in which local authorities of cluster areas were obliged to offer a half of the public subsidy to the regional cluster project. After this program revision, local cluster firms could directly obtain local authority's subsidy for their project. It means that in the second phase of MEXT programs the balance of direct support changed in favor of local cluster firms, which may have encouraged local cluster firms for more research expenditures (internal and external) and research output (especially joint publications). In order to check the effects of this possibility, we changed the estimation models by including Phase 1 and Phase 2 cluster participation dummies instead of the cluster participation dummy that include both the first and the second phase).

The estimation results are shown in Appendix Tables A1 to A4. Regarding the research input, we find no significant differences between the effects of universities' and PRIs' cluster participation in the first and second phase (Table A1), while the effects on firm's internal research expenditures and external research expenditures (dummy) are significant only in the second phase (Table A2). Regarding the S&T output of universities and PRIs, we find similar results to those in Table 5 (positive and significant effects on patent applications and citations) only in the second phase, while we observe *negative* and significant effects of cluster participation on scientific publications and citations (Table A3). Finally, regarding firms' S&T output, we find positive and large effects of cluster participation on publications and citations (similar to Table 6) especially in the second phase, while we see *negative* and significant effects on patent applications and citations also in the second phase (Table A4). In sum, we confirm significant effects of cluster participation particularly in the second phase and a clear shift in S&T output from publication to patenting for academic researchers and from patenting to publication for business researchers in the second phase of the cluster programs.

6. Conclusion

This paper empirically examined the causal effects of MEXT cluster programs in Japan, using the comprehensive micro data of public statistics (SRD) for nine years from 2001 to 2009. Cluster policies have been implemented in several countries including Japan since the 1990s to promote regional innovation by encouraging university-industry R&D collaboration. Several studies have examined the effects of cluster policies on business and project performance, yet few studies have compared the policy effects between academic and business research so far. Therefore, this paper aims to fill the gap by targeting and comparing universities, PRIs and firms in Japan.

Japanese cluster programs implemented by MEXT from 2002 to 2009 had unique characteristics that only academic researchers at core universities or PRIs could become project leaders and that public subsidy could only be allocated to universities and PRIs (but not to firms) (Okamuro and Nishimura 2018). However, the subsidy rule changed in 2006 and 2007 so that local authorities (municipalities) had to offer a half of public subsidy, which then could be allocated to local participants including firms. That may have significantly affected the policy effects and participants' behavior, but to date no empirical studies addressed the effects of changing rules in the same cluster programs.

We found that (1) internal and external research expenditures of universities, PRIs and firms participating in the cluster project (or the proportion of cluster participants with internal and external research expenditures) significantly increased, (2) universities and PRIs significantly increased patent applications and citations rather than scientific publications after cluster participation, and (3) firms significantly increased scientific publications and citations rather than patenting after cluster participation. Moreover, there changes got particularly evident in the second phase in which the subsidy rule changed in favor of local firms. These results suggest that MEXT cluster programs promoted university-industry research collaboration and regional innovation.

We may derive some policy implications from our estimation results. First, regional innovation, especially universities' and PRIs' patenting and firms' publication, can be promoted by cluster programs. Second, commitment by local governments and incentive for local firms are important to activate regional innovation activities, as shown in the policy effects in the second phase.

The empirical analyses in this paper have some shortcomings. First, we could not match all cluster firms with statistical micro data and the data of scholarly works and patents. Especially small local firms may be underrepresented in the sample. Second, MEXT cluster program and some other support policies for business R&D and university-industry collaboration were implemented at the same time with MEXT programs, 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 citations for each cluster participant every year, but we could not distinguish joint papers and applications of research partners from others. Thus, joint papers and applications are double counted as university's and firm's output in our estimation. However, despite these shortcomings, this paper contributes to the innovation policy literature as the empirical evaluation of policy effects comparing universities, PRIs and firms. MEXT cluster programs are interesting policy focus because of the university-centered design and the interim change in the subsidy rule.

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Table 1: Number of cluster participants in the sample 2001-09

	universities and PRIs		firms	
fiscal year	total	participants	total	participants
2001	1,995	0	9,765	0
2002	2,007	100	9,553	76
2003	2,022	143	10,102	137
2004	2,024	180	9,706	178
2005	2,066	174	10,361	176
2006	2,055	185	10,440	178
2007	2,079	170	10,223	165
2008	2,082	185	10,691	189
2009	2,095	186	10,594	219

Table 2: Basic statistics of variables

Subsamples	universities and PRIs			firms		
Variables	N	Mean	S.D.	N	Mean	S.D.
Cluster participation dummy	24,447	0.071	0.257	132,456	0.014	0.117
Cluster participation dummy (Phase 1)	24,447	0.041	0.198	132,456	0.011	0.105
Cluster participation dummy (Phase 2)	24,447	0.042	0.200	132,456	0.003	0.055
Internal research expenditures (dummy)	24,447	1.000	0.016	132,456	0.453	0.498
Log. of internal research expenditures	24,447	12.4	13.9	59,962	9.73	2.09
External research expenditures (dummy)	24,447	0.269	0.443	132,456	0.092	0.289
Log. of external research expenditures	24,447	9.13	11.9	12,195	8.10	2.33
Extramural research funds (dummy)	24,447	0.385	0.487	132,456	0.187	0.390
Log. of extramural research funds	24,447	9.15	11.4	24,708	7.20	2.58
N. of paper publications	24,447	1,148	14,112	132,456	0.609	65.3
N. of forward citations	24,447	37,508	518,389	132,456	50.8	6,012
N. of patent applications	24,447	43.8	539	132,456	14.2	198
N. of forward citaions	24,447	78.4	1,052	132,456	27.8	432
Log. of number of researchers	24,054	3.72	1.45			
Log. of number of employees				132,456	4.74	1.88

Table 3: Estimation results 1: Internal and external research expenditures of universities and PRIs

Inputs	Internal research expenditures (dummy)	Log. of internal research expenditures	External research expenditures (dummy)	Log. of external research expenditures	Extramural research funds from business (dummy)	Log. of extramural research funds from business
Log. of number of researchers	0.00069	0.594***	0.0621***	0.132	0.0586***	0.243***
	[0.000614]	[0.0498]	[0.0118]	[0.105]	[0.0126]	[0.0879]
Cluster participation dummy	0.000166	0.0624***	0.0722***	0.261	0.0208	0.194***
	[0.000171]	[0.0226]	[0.0231]	[0.180]	[0.0153]	[0.0577]
Constant	0.999***	8.310***	-0.356***	7.857***	0.200*	3.576***
	[0.00152]	[0.159]	[0.0985]	[0.869]	[0.106]	[0.772]
Field-year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Prefecture-year dummies	Yes	Yes	Yes	Yes	Yes	Yes
N	24,054	24,052	24,054	6,437	24,054	9,303
R squared	0.053	0.279	0.117	0.247	0.057	0.121

Standard errors in brackets

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

Table 4: Estimation results 2: Internal and external research expenditures of firms

Inputs	Internal research expenditures (dummy)	Log. of internal research expenditures	External research expenditures (dummy)	Log. of external research expenditures	Extramural research funds (dummy)	Log. of extramural research funds
Log. of number of employees	0.0630***	0.480***	0.0318***	0.186**	0.0144***	0.121
	[0.00471]	[0.0253]	[0.00383]	[0.0831]	[0.00311]	[0.0977]
Cluster participation dummy	0.0219***	0.0551**	0.0457**	0.119	0.0163	-0.270**
	[0.00729]	[0.0263]	[0.0194]	[0.0858]	[0.0197]	[0.118]
Constant	0.450***	6.749***	-0.133	5.595***	0.11	10.98***
	[0.161]	[0.793]	[0.173]	[1.156]	[0.135]	[1.450]
Year × industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
Year x prefectural dummies	Yes	Yes	Yes	Yes	Yes	Yes
N	132,456	59,962	132,456	24,708	132,456	12,195
R squared	0.042	0.094	0.021	0.089	0.02	0.168

Standard errors in brackets

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

Table 5: Estimation results 3: S&T output of universities and PRIs

Outputs	N. of paper publications	N. of forward citations	N. of patent applications	N. of forward citations
Log. of number of researchers	0.0468	0.0666*	0.0824	0.0564
	[0.0357]	[0.0367]	[0.132]	[0.0800]
Cluster participation dummy	-0.077	-0.0674	0.311*	0.356***
	[0.0663]	[0.0848]	[0.165]	[0.125]
Constant	11.14***	14.70***	7.477***	8.379***
	[0.288]	[0.296]	[1.117]	[0.679]
Field-year dummies	Yes	Yes	Yes	Yes
Prefecture-year dummies	Yes	Yes	Yes	Yes
N	11,891	10,981	1,244	1,142

Standard errors in brackets

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

Table 6: Estimation results 4: S&T output of firms

Outputs	N. of paper publications	N. of forward citations	N. of patent applications	N. of forward citations
Log. of number of employees	0.194*	0.240***	0.357***	0.315**
	[0.101]	[0.0835]	[0.130]	[0.147]
Cluster participation dummy	0.596***	0.895***	-0.0498	-0.0462
	[0.179]	[0.277]	[0.0600]	[0.0510]
Constant	1.153	4.062***	3.592***	4.851***
	[0.878]	[0.694]	[1.134]	[1.295]
Industry-year dummies	Yes	Yes	Yes	Yes
Prefecture-year dummies	Yes	Yes	Yes	Yes
N	1,785	1,243	27,476	25,935

Standard errors in brackets

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

Appendix: Estimation results comparing the first and the second phase of the cluster programs

Table A1: Research expenditures of universities and PRIs in the first and the second phase

Inputs	Internal research expenditures (dummy)	Log. of internal research expenditures	External research expenditures (dummy)	Log. of external research expenditures	Extramural research funds from business (dummy)	Log. of extramural research funds from business
Log. of number of researchers	0.000692	0.594***	0.0621***	0.13	0.0585***	0.245***
	[0.000613]	[0.0498]	[0.0118]	[0.105]	[0.0126]	[0.0880]
Cluster participation dummy (Phase 1)	0.000178	0.0392**	0.0654***	0.209	0.0182	0.195***
	[0.000208]	[0.0177]	[0.0213]	[0.130]	[0.0144]	[0.0512]
Cluster participation dummy (Phase 2)	0.0000564	0.112***	0.0701*	0.321	0.0246	0.139*
	[0.000197]	[0.0392]	[0.0382]	[0.269]	[0.0224]	[0.0795]
Constant	0.999***	8.312***	-0.355***	7.826***	0.200*	3.581***
	[0.00152]	[0.159]	[0.0985]	[0.896]	[0.106]	[0.772]
Field-year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Prefecture-year dummies	Yes	Yes	Yes	Yes	Yes	Yes
N	24,054	24,052	24,054	6,437	24,054	9,303
R squared	0.053	0.279	0.117	0.248	0.057	0.121

Standard errors in brackets

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

Table A2: Research expenditures of firms in the first and the second phase

Inputs	Internal research expenditures (dummy)	Log. of internal research expenditures	External research expenditures (dummy)	Log. of external research expenditures	Extramural research funds (dummy)	Log. of extramural research funds
Log. of number of employees	0.0630***	0.480***	0.0318***	0.186**	0.0144***	0.116
	[0.00471]	[0.0253]	[0.00383]	[0.0831]	[0.00311]	[0.0970]
Cluster participation dummy (Phase 1)	0.0195***	0.0101	0.00654	0.0663	-0.0279	-0.0463
	[0.00621]	[0.0266]	[0.0226]	[0.103]	[0.0236]	[0.135]
Cluster participation dummy (Phase 2)	0.0224**	0.0860***	0.0662***	0.135	0.0363	-0.425***
	[0.00899]	[0.0331]	[0.0233]	[0.114]	[0.0236]	[0.143]
Constant	0.450***	6.749***	-0.133	5.598***	0.11	10.98***
	[0.161]	[0.794]	[0.173]	[1.157]	[0.135]	[1.460]
Year × industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
Year x prefectural dummies	Yes	Yes	Yes	Yes	Yes	Yes
N	132,456	59,962	132,456	24,708	132,456	12,195
R squared	0.042	0.094	0.021	0.089	0.02	0.169

Standard errors in brackets

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

Table A3: S&T output of universities and PRIs in the first and the second phase

Outputs	N. of paper publications	N. of forward citations	N. of patent applications	N. of forward citations
Log. of number of researchers	0.0603*	0.0920**	0.0315	0.0103
	[0.0349]	[0.0461]	[0.132]	[0.0950]
Cluster participation dummy (Phase 1)	-0.0278	-0.0479*	0.0506	-0.105
	[0.0266]	[0.0271]	[0.0703]	[0.0715]
Cluster participation dummy (Phase 2)	-0.207***	-0.273***	0.380***	0.340*
	[0.0253]	[0.0577]	[0.0898]	[0.194]
Constant	11.07***	14.56***	7.957***	8.988***
	[0.291]	[0.390]	[1.121]	[0.795]
Field-year dummies	Yes	Yes	Yes	Yes
Prefecture-year dummies	Yes	Yes	Yes	Yes
N	11,891	10,981	1,244	1,142

Standard errors in brackets

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

Table A4: S&T output of firms in the first and the second phase

Outputs	N. of paper publications	N. of forward citations	N. of patent applications	N. of forward citations
Log. of number of employees	0.195*	0.241***	0.347***	0.312**
	[0.101]	[0.0840]	[0.119]	[0.141]
Cluster participation dummy (Phase 1)	0.397*	0.615	0.135*	0.0972*
	[0.207]	[0.483]	[0.0742]	[0.0553]
Cluster participation dummy (Phase 2)	0.883***	1.017***	-0.216**	-0.224**
	[0.264]	[0.292]	[0.105]	[0.104]
Constant	1.139	4.052***	3.684***	4.874***
	[0.874]	[0.698]	[1.043]	[1.244]
Industry-year dummies	Yes	Yes	Yes	Yes
Prefecture-year dummies	Yes	Yes	Yes	Yes
N	1,785	1,243	27,476	25,935

Standard errors in brackets

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