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Determinants and Impacts of Incorporation of Local Public Technology Transfer Organizations: Evidence from Japan's *Kohsetsushi*

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Determinants and impacts of incorporation of local public technology transfer organizations: Evidence from Japan's *Kohsetsushi*[*]

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Abstract

Legal reforms act as a fundamental shift in incentive systems by creating and redefining incentive tools, such as ownership, discretion, and reward. This study examines the impacts of the *Local Independent Administrative Corporation Law* enacted in 2003 that altered patent ownership and managerial autonomy of *Kohsetsushi*, which are technology transfer organizations established by local governments. Key findings of the panel data analysis are as follows. First, the local governments' decision-making regarding the incorporation was not based on the goal of improving technology transfer performance measured by licensing income. Second, incorporation encouraged *Kohsetsushi* to allocate their resources from diffusion/extension activities to research/inventive activities. Third, incorporation positively affected patent applications, but had no effect on licensing income. Fourth, there was a U-shaped (inverted U-shaped) relationship between licensing income of non-incorporated (incorporated) *Kohsetsushi* and the number of technical problems consulted with them. Fifth, counterfactual analysis showed negative ATT and positive ATU, which suggests an unintended consequence of the policy. Policy implications of the results are discussed.

Keywords: innovation policy, Japan, *Kohsetsushi*, regional innovation systems, patents, technology transfer, unintended consequences

JEL classification: H1; L6; M2; O3; R5

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1. Introduction

Legal reforms fundamentally shift incentive systems by creating and redefining incentive tools, such as ownership, discretion, and reward. In innovation and technology transfer policies, the most prominent example of such a legal reform in the US is the *Bayh-Dole Technology Transfer Act* (BDA) of 1980. BDA shifted the ownership of patents based on federally funded research from the federal government to universities to promote technology transfer from universities to the private sector via licensing. In Japan, the *Industrial Revitalizing Special Law* enacted in 1999 had the same effect as the BDA, except that it did not apply to national universities until they obtained corporate status in 2004. Previous literature that evaluated the BDA (Henderson et al. 1998; Mowery et al. 2001; Sampat et al. 2003; Link and Hasselt 2019a) and the *Industrial Revitalizing Special Law* (Motohashi and Muramatsu 2012; Suzuki et al. 2016) show that legal changes altered the economic incentives of universities through ownership change, which had a positive impact on the number of patents filed by universities.[1]

The *Local Independent Administrative Corporation Law* (*LIACL*) was enacted in 2003 when a series of administrative organizational reforms were underway both at the national and regional levels in Japan. *LIACL* allowed local governments to establish local independent administrative corporations (LIACs) that undertook public works under fewer regulations on ownership, discretion, and reward. *LIACL* has been applied mainly to hospitals and universities established by local governments. From a legal perspective, incorporation activates technology transfer because it grants corporate status to public organizations that used to be a part of a local government, allowing LIACs to own patents, both patents filed by new LIACs and those invented by local government employees before incorporation (*LIACL*, Article 66), and license them to the private sector. Furthermore, *LIACL* offers greater flexibility in resource allocation as LIACs are exempted from legal constraints according to the *Local Autonomy Act* and the *Local Public Service Act* that define the status and obligations of local government employees. Therefore, incorporation brings about a fundamental shift in the incentive system, thus affecting the behavior and performance of LIACs.

This study sheds lights on the impact of *LIACL* on *Kohsetsushi,* technology transfer organizations established by local governments[2]. The first generation of *Kohsetsushi* was established in the agri-food sector (e.g., brewery) in the late nineteenth century, while the second generation steadily expanded in the manufacturing sector throughout the twentieth century.[3] *Kohsetsushi* now cover all the local units of governance of Japan in a broad range of fields, including medical science, environmental science, industrial design, and architecture. The first attempts of incorporation were made in Iwate and Tokyo in 2006, and the latest case was in Kanagawa in 2017, with sixteen percent of the manufacturing *Kohsetsushi* being incorporated as of 2019 (Figure 1). This study focuses on manufacturing *Kohsetsushi* to which *LIACL* has been applied most intensively.

Figure 1 here

Kohsetsushi play three important roles in regional innovation systems (Fukugawa 2008), namely, diffusion/extension activities, research/inventive activities, and networking/intermediary activities. First, they provide small local firms with technical consultation services, normally for free. For example, small

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1 This field of research started with the examination of the impacts of BDA on both quantity and quality of university patents (Sampat 2006). Recent literature places more emphasis on "broad-based impacts resulting from technology transfer program activities" (NIST 2019: 114). This study focuses on a "direct" route through which *Kohsetsushi* contribute to regional economic development. See [*Phase 3*] of a multi-stage technology transfer model in Section 3.

2 Previous studies provide econometric evidence for the impacts of similar technology diffusion programs on small firms. Jarmin (1999) examined the Manufacturing Extension Partnership (MEP) in the US and reported a positive effect on the labor productivity growth of small-sized clients. Ponds et al. (2010) examined the Netherlands Organisation for Applied Scientific Research (TNO) finding its positive effect on innovations of small firms. See Shapira et al. (2011) for examples in other advanced and emerging economies.

3 See Fukugawa and Goto (2016) for historical development of *Kohsetsushi* since the initial phase of modern economic growth of Japan.

local firms can use the equipment of *Kohsetsushi* that they cannot afford, and have inspection services at a rate lower than market price, which includes hands-on technical support, such as on-site training of engineers. In other words, the diffusion/extension activities of *Kohsetsushi* help small local firms upgrade their basic technological skills through hands-on support. Second, they perform their own research, publish papers and manuals, patent inventions, and license the patents mainly to small local firms. Third, in the case of technical problems that are hard to be solved immediately, they connect small local firms with other sources of knowledge, such as universities. That is, the research/inventive and networking/intermediary activities of *Kohsetsushi* help small local firms invest in research and development and enhance their absorptive capacity to further exploit the spillover from external sources of knowledge.

These activities are affected by incorporation through changes in the incentive system, in which *Kohsetsushi* are embedded. For instance, a change in patent ownership encourages *Kohsetsushi* to license their patents and obtain royalty,[4] thus affecting their technology transfer performance. However, little has been known about whether and how incorporation affects the roles of *Kohsetsushi* in regional innovation systems and their contributions to regional economies due to data limitations. Based on comprehensive data of technology transfer activities by *Kohsetsushi*, this study examines the determinants and impacts of incorporation of *Kohsetsushi* to provide quantitative evidence for future regional innovation policies.

The remainder of this paper is organized as follows. Section 2 reviews the legal background of LIACs, and proposes hypotheses regarding the determinants and impacts of the incorporation of *Kohsetsushi*. Section 3 develops an economic model of technology transfer and derives empirical specifications for econometric analysis. Section 4 introduces variables and the data used for empirical analysis. Section 5 presents the estimation results and discusses their implications. Section 6 summarizes the conclusions.

2. Background and hypotheses

The purpose of the *LIACL* is to enable LIACs to provide services with a high social rate of return, which may not be undertaken by the private sector due to poor appropriability conditions (*LIACL*, Article 2). It aims at providing such services more efficiently by leveraging changes in the incentive system. A typical example of such services is public health with nine percent of hospitals established by local governments having been incorporated as of 2015 (JMHA 2015). Additionally, the diffusion/extension activities provided by *Kohsetsushi* to small local firms fall under this category of services. Table I lists incorporated *Kohsetsushi* under the *LIACL*.

Table I here

Table II shows differences in key variables between *Kohsetsushi* according to the incorporation status, demonstrating that non-incorporated and incorporated *Kohsetsushi* are inherently different groups. The comparison between columns 2 and 4 reveals that the *Kohsetsushi* to be incorporated are inherently larger in budgetary and employment size than the *Kohsetsushi* that are not incorporated. In addition, the *Kohsetsushi* to be incorporated were inherently more patent-intensive and more successful in the commercialization of patents compared to the *Kohsetsushi* that were not incorporated. However, the *Kohsetsushi* to be incorporated were not inherently science-based or research-intensive in terms of scientific knowledge resources and capabilities for obtaining external research funds. Regarding technical consultation and the use of equipment, the *Kohsetsushi* to be incorporated were not intensively engaged in hands-on technical support for small local firms.

Table II also shows differences between before and after incorporation. The comparison between columns 4 and 5 demonstrates that, among incorporated *Kohsetsushi*, incorporation made *Kohsetsushi* larger in employment and budgetary size, more research-oriented, and more heavily involved in hands-

[4] Incorporated *Kohsetsushi* inherit employee inventions made before the incorporation with the terms of licensing agreements with private companies kept intact. Original licensing agreements between local governments and private companies include a clause indicating the inheritance of rights and obligations in the case of organizational changes.

on technical support for small local firms, except for testing. Moreover, after incorporation, *Kohsetsushi* have become more successful in the commercialization of patents.

Table II here

Overall, the results of Table II imply that what appears to be the impact of incorporation could be an artifact of inherent differences between the *Kohsetsushi* to be incorporated and *Kohsetsushi* that opted out of incorporation. Therefore, incorporation can be a choice variable. In light of this, the present study employs an endogenous treatment model to test the following hypotheses. Table I shows that local governments that exhibit both high and low fiscal stability choose the incorporation of *Kohsetsushi*. Therefore, it is hypothesized that:

H1: Fiscal soundness of local governments is associated with the incorporation of *Kohsetsushi* by a U-shaped relation.

Local governments facing financial difficulties may have *Kohsetsushi* incorporated for the purpose of fiscal reforms. For such a move to be rational, the ratio of *Kohsetsushi* budget to a local government budget needs to be relatively high.

H2: The ratio of *Kohsetsushi* budget to a local government budget positively affects incorporation.

From an administrative perspective, incorporation entails initial costs of clerical resource (e.g., staff, software, and computer systems), which used to be borne by local governments or virtually nonexistent. Examples of new divisions associated with such initial costs encompass employment (e.g., labor contracts under the *LIACL*), finance (e.g., corporate accounting systems) and public relations (e.g., communications with an independent assessment committee). As these investment costs can be spread by scaling, *Kohsetsushi* that prepare for incorporation are considered to be large in size. Therefore, it is hypothesized that:

H3: Organizational size positively affects incorporation.

The principal-agent theory postulates that an incentive system comprises a complementary set of instruments: ownership, discretion, and reward. Previous studies highlight that these incentive tools need to be devised in a consistent manner so that the incentive system can motivate agents to behave as the principals intend (Holmstrom and Milgrom 1994; Taylor and Wiggins 1997). Indeed, strong incentives in the form of reward for technology transfer office staff and inventors' royalty share positively affect the productivity of university technology transfer (Markman et al. 2004; Lach and Schankerman 2008). Similarly, incorporation could affect technology transfer productivity of *Kohsetsushi* through the following shifts in the incentive system. Incorporation changes ownership of intellectual property rights (IPRs). Additionally, it grants corporate status to *Kohsetsushi*, which enables them to own patents, encouraging them to appropriate innovative returns through licensing. Moreover, the commercial success of *Kohsetsushi* patents is more important after incorporation, as new organizations depend less on public funding and have to finance their activities as independently as possible, thus making *Kohsetsushi* patents after incorporation more productive in terms of generation of economic returns. Therefore, it is hypothesized that:

H4: Incorporation positively affects the number of patent applications.

H5: Incorporation positively affects the royalty that *Kohsetsushi* patents yield.

H6: Incorporation positively affects the impact of *Kohsetsushi* patents on royalty.

Incorporation grants *Kohsetsushi* greater freedom in resource allocation, as LIACs are exempted from the constraints of laws that define the status and obligations of local government employees, with directors of LIACs establishing employment standards and appointing their staff (*LIACL*, Article 3). Moreover, incorporation allows *Kohsetsushi* to obtain competitive research funds from broader regions and organizations. This encourages them to independently finance their research activities and promotes them to accumulate scientific knowledge, as research quality is a significant factor in attracting external research funds based on a peer-review system. This affects the human and financial resource management of *Kohsetsushi*. Therefore, it is hypothesized that:

H7: Incorporation positively affects resource allocated to research/inventive activities.

Furthermore, an enhanced research orientation and an increasing reliance on external research funds could lead to decreased efforts allocated to hands-on technical support for small local firms (e.g., consultation and training). Such a trade-off stems from the organizational characteristics of manufacturing *Kohsetsushi*. In the case of agricultural *Kohsetsushi*, research/inventive and diffusion/extension activities are undertaken by different organizations (Fukugawa 2019). However, in manufacturing *Kohsetsushi,* the same researchers undertake both tasks, creating the trade-off in terms of effort allocation. In light of these notions, it is hypothesized that:

H8: Incorporation negatively affects resources allocated to diffusion/extension activities.

3. Conceptual and empirical frame

Previous studies model university-based technology transfer as a multistage process consisting of invention, disclosure, patenting, and licensing, with determinants varying across stages (Shane 2002; Thursby and Thursby 2002; Siegel et al. 2003; Anderson et al. 2007). This study employs a knowledge production function to design a technology transfer process of *Kohsetsushi* comprising: [Phase 1] invention; [Phase 2] patenting; and [Phase 3] royalty. Licensing income constitutes the final output of technology transfer because it represents the commercial success of firms that exploit *Kohsetsushi* patents (mostly small local firms). Therefore, it is suitable for measuring the contribution of *Kohsetsushi* to regional economic development.

As *Kohsetsushi* cannot execute patents by themselves, when their technology transfer performance is measured by royalty, both the supply- and demand-side factors of technology transfer need to be incorporated in the model. Assuming that the technology transfer process at *Kohsetsushi* conforms to a knowledge production function, $Y=AR^{\alpha}N^{\beta}e^{\delta D}$, where Y is the technology transfer output (e.g., royalty), A is constant, R is the technology transfer input in terms of the providers of knowledge (e.g., research resources of *Kohsetsushi*), N is the technology transfer input in terms of the seekers of knowledge (e.g., absorptive capacity of small local firms), and D denotes a binary variable representing incorporation, then the empirical specification of the knowledge production function (the main equation) can be written as:

$$log(Y_{it})=constant+\alpha log(R_{it})+\beta log(N_{rt})+\delta D_{it}+\varepsilon_{it}, \qquad (1)$$

where R represents the number of Ph.D. holders (*Phd*)[5] and the number of technical problems consulted with *Kohsetsushi* (*Tech_consult*). *Phd* represents scientific knowledge resources, while *Tech_consult* represents the researchers' understanding of the technological needs of local industry. N is the regional-level variables including innovation characteristics of small local firms (*LQ*) and the number of patent attorney offices (*Pat_attorney*). The error term, ε, consists of the time-invariant individual effect, individual-invariant time effect, and unobservable factors affecting technology transfer outputs. Suffixes i, r, and t represent individual *Kohsetsushi*, region, and time, respectively.

$\text{Log}(Y^{1}_{it})-\log(Y^{0}_{it})$ represents the average treatment effect (ATE) of incorporation, with superiors *1* and *0* representing D taking a value of one and zero, respectively. ATE can be approximated as $(Y^{1}-Y^{0})/Y^{0}$, which represents the welfare improvement stemming from a specific technology transfer activity of *Kohsetsushi* (e.g., licensing that accrues royalty). Assuming that D takes a value of one when the benefit of

[5] Most of the Ph.D. researchers at *Kohsetsushi* complete their dissertations while studying at graduate schools as working students. This is due to two reasons: first, they enroll in *Kohsetsushi* as local government employees who are not required to obtain a Ph.D.; second, they are allowed to enroll in graduate schools when they select a topic of dissertation that tackles technical problems encountered by the local industry, not out of pure scientific curiosity. This practice makes a Ph.D. indicative of the responsiveness of scientific knowledge resources to the technological needs of local industry. Since there are no constraints regarding human resource management after incorporation, new employees with a Ph.D. are quite common at incorporated *Kohsetsushi*.

incorporation exceeds the cost of incorporation,[6] then the former can be described as $(Y^1\text{-}Y^0)/Y^0$, while the latter can be described as $(C^1\text{-}C^0)/C^0$, where C^0 denotes the running cost of *Kohsetsushi* and C^1 is the sum of the running cost and initial cost of incorporation.

Assuming the ratio of initial cost to running cost to be $C'=a_1X+a_2Z+v$, where X denotes the characteristics of local governments, Z denotes the characteristics of *Kohsetsushi*, and v denotes unobservable factors that affect the cost of incorporation, then the incorporation of *Kohsetsushi* occurs when $(Y^1\text{-}Y^0)/Y^0>\alpha_1X+\alpha_2Z+v$. This can be written in the form of a probit model (the selection equation) as follows:

$$P^*=\gamma_1R_{it}+\gamma_2N_{rt}+\gamma_3X_{rt}+\gamma_4Z_{it}+u_{it}, \qquad (2)$$

where P^* denotes an unobservable latent variable, u denotes unobservable factors that affect the probability of incorporation, D=1 if $P^*>0$, and D=0 if $P^*\leq 0$.[7] X consists of the fiscal soundness index of local governments (*Fiscal_health*)[8], the square term of *Fiscal_health* (*Fiscal_health2*), and the ratio of *Kohsetsushi* budget to local government budget (*Budget_share*). Z is the number of *Kohsetsushi* employees (*Emp*). *Fiscal_health* and *Budget_share* are the exclusion restriction.

Phase 1: Researchers at *Kohsetsushi* seldom perform research out of pure scientific interest. Furthermore, the average *Kohsetsushi* researcher does not have a Ph.D., even though the ratio of Ph.D. holders to researchers has remarkably increased over time (from 12% in 2000 to 28% in 2017), suggesting that their research ideas tend to come from actual problems rather than scientific curiosity. Indeed, the seeds of inventions at *Kohsetsushi* normally build on the technological needs of local firms that are best transferred via interpersonal communication due to their tacit nature. Technical consultation is one of the major routes for *Kohsetsushi* researchers to capture such local needs. Therefore, the present study assumes that both research/inventive and diffusion/extension activities are important inputs of inventions. In particular, the regression model incorporates not only scientific knowledge (*Phd*), but also the understanding of the technological needs of local industry (*Tech_consult*).

Phase 2: Patenting inventions costs. Therefore, a variable representing *Kohsetsushi* budget (*Budget*) is incorporated in the model. Based on the discussions about *Phase 1*, empirical specification to test H4 is described as:

$$log(Pat\_application_{it})=constant+\alpha logR_{it}+\beta logN_{rt}+\delta D_{it}+\varepsilon_{it}, \qquad (3)$$[9]

where *Pat_application* denotes the number of patent applications in year t. Location quotient (*LQ*) is defined as $(x_{ir}/x_r)/(x_i/x)$, where x denotes the number of patents filed in a country and x_{ij} denotes the number of patents in a specific technological field (i) filed in a region, r. (x_{ir}/x_r) represents the technological specialization of the region, while (x_i/x) represents the relative importance of the technology in a country. Thus, *LQ* represents the technological field in which the region specializes.[10]

[6] The discussion draws from Lee (1978) that assumed a union/non-union wage differential to be a key determinant for workers to join a union, making union participation an endogenous variable in the wage equation.

[7] Incorporation has been adopted in sixteen percent of the total number of *Kohsetsushi* with different timings, starting in 2006. Therefore, the generalized treatment effect model with a staggered introduction of the treatment is employed (Wing et al. 2018). This is essentially the same as estimating a coefficient of an interaction term between a treatment dummy and an active treatment dummy, where the former takes a value of one before and after the incorporation and does not vary within a group, while the latter varies over time within the group with a value of one (zero) given after (before) the incorporation.

[8] This index is defined as the fiscal revenue divided by fiscal demand, with a ratio exceeding a value of one indicating the fiscal robustness of local governments.

[9] A binary variable representing zero patents is incorporated in the regression model to control for a no-patent filing status (Czarnitzki et al. 2009; Link and Hasselt 2019b). Similarly, a binary variable representing zero royalty is incorporated in Equation 4.

[10] In generating the regional-level variables, *Kohsetsushi* established by municipal governments are associated with the prefecture, in which the city is located.

Phase 3: *Kohsetsushi* cannot execute patents by themselves. Only firms can. Therefore, one route for the commercialization of *Kohsetsushi* patents is to search for a licensee, and another route is to encourage joint research partners to invest into complementary assets and appropriate innovative returns, with regional characteristics affecting both routes. First, the possibility to find a licensee depends on the availability of providers of knowledge-intensive business services (KIBS) in the region. KIBS providers, such as patent attorneys, promote transactions in the market for technology, thus being conducive to the commercialization of *Kohsetsushi* patents. Therefore, *Phase 3* incorporates a variable representing human resources that promote patenting and licensing (*Pat_attorney*). Second, the innovative activities that small local firms engage in also affect the commercialization of *Kohsetsushi* patents. Fukugawa (2016) shows that licensing is prevailing among *Kohsetsushi* located in regions where small firms are specialized in analytical knowledge-based innovations, typically observed in the field of biotechnology where patents are very effective. Therefore, *Phase 3* incorporates a regional variable representing the types of innovations dominant among small local firms (*LQ*). Empirical specification to test H5 is described as

$$log(Royalty_{it})=constant+\alpha logR_{it}+\beta logN_{rt}+\delta D_{it}+\varepsilon_{it}. \qquad (4)$$

To test H6, this study employs an endogenous switching regression (ESR) model (Maddala 1983: 223-228), which assumes that the main equation switches according to the selection equation regressing P^* (Equation 2). Empirical specification can be written as:

$$log(Y^1_{it})=constant+\alpha^1 log(R^1_{it})+\beta^1 log(N^1_{rt})+\delta^1 T^1_{it}+\varepsilon^1_{it} \qquad \text{if } D=1, \quad (5)$$
$$log(Y^0_{it})=constant+\alpha^0 log(R^0_{it})+\beta^0 log(N^0_{rt})+\delta^0 T^0_{it}+\varepsilon^0_{it} \qquad \text{if } D=0, \quad (6)$$

where Y denotes royalty, T denotes patents granted or filed, and ε denotes unobservable factors influential in Y. If P^* exceeds zero, *Kohsetsushi* are incorporated and exposed to change in the incentive system; otherwise, they are a part of local governments and not associated with changes in the incentive system. The difference between delta1 and delta0 captures the impact of incorporation on the commercialization of *Kohsetsushi* patents, with positive values implying that ownership change motivates *Kohsetsushi* to commercialize their patents more efficiently.

H7 and H8 examine the effect of incorporation that grants *Kohsetsushi* managerial autonomy regarding resource allocation.[11] Several resource variables can be bundled together as one factor representing the tendencies of *Kohsetsushi* to allocate resources in a specific direction. In light of this notion, a factor analysis is performed to extract the latent factors that affect several observable variables in the same direction. The variables used for factor analysis include the ratio of Ph.D. holders to researchers (*r_phd*), the number of scientific publications per researcher (*r_paper*), , the number of patents granted or filed per researcher (*r_pat_all*), revenue from funded research per researcher (*r_funded*), technical problems consulted per researcher (*r_consult*), revenue from testing per researcher (*r_test*), and revenue from rental equipment per researcher (*r_equip*). Based on the scree plot, the number of factors is assumed to be two, with Figure 2 showing factor loadings.[12] *Factor1* exclusively correlates with variables related to research/inventive activities, while *Factor2* exclusively correlates with variables related to diffusion/extension activities. Therefore, *Factor1* is presumed to represent the allocation of resources to scientific research, while *Factor2* is presumed to represent allocation of resources to hands-on support for small local firms. Factor scores based on factor analysis are incorporated into the regression models. Empirical specification to test H8 and H9 is written as:

$$Factor1_{it}=constant+\beta N_{rt}+\delta D_{it}+\varepsilon_{it}, \qquad (7)$$
$$Factor2_{it}=constant+\beta N_{rt}+\delta D_{it}+\varepsilon_{it}. \qquad (8)$$

where R is not incorporated in the model, as the variables comprising R are already considered in the creation of the dependent variables.

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[11] Researchers at manufacturing *Kohsetsushi* allocate efforts to research by 35 %, to technical consultation by 27 %, and to testing and use of equipment by 24 % (Japan Association for the Advancement of Research Cooperation 2001).

[12] See Fukugawa (2008) for older evidence regarding this topic which is consistent with the results of the present study.

Figure 2 here

4. Data and descriptive statistics

The data on technology transfer activities by *Kohsetsushi* were collected from the "Current Status of *Kohsetsushi* 2000-2009" compiled by the National Institute of Advanced Industrial Science and Technology (AIST) and the "Current Status of *Kohsetsushi* 2012-2017" compiled by the Association of Directors of Manufacturing *Kohsetsushi*. This survey had been suspended during 2010 and 2011, making the entire data for this period unavailable. As the incorporation of *Kohsetsushi* took place in this period, the unavailability of the relevant data should have some effect on the results. This study measures technology transfer performance using royalty, for which data were less available than other variables, thus making the missing value problem serious. Moreover, a small number of observations makes the estimation impossible or difficult to converge. Therefore, this study employs information between 2010 and 2011 obtained from linear interpolation. Appendix Figure 1 shows the time-series variations in royalty for which information became available after 2005. Royalty sharply declined in 2009, and then has grown steadily since 2012 when the survey was resumed. This study shows the estimation results using data obtained from linear interpolation, as well as those using original data. Appendix Figure 1 shows that it is difficult to fit a specific time trend to the interpolated data. Therefore, dummy variables are used to control for the time effect in both data analyses. Some *Kohsetsushi* were dropped from the data due to organizational reform and integration, while other newly established or reorganized *Kohsetsushi* appeared in the mid of the empirical period. Therefore, an unbalanced panel was used for estimation.

The data on patents were collected from the Institute of Intellectual Property Patent Database (IIPPD), released in 2017. IIPPD was matched with the National Institute of Science and Technology Policy (NISTEP) Corporate Database (NCD). Then, NCD was used to identify patents by small and medium-sized enterprises (SMEs). NCD follows the numerical definition of SMEs provided by the *Basic Law on SMEs* amended in 1999.[13] A concordance table between international patent classification (IPC) and technology compiled by the World Intellectual Property Organization (WIPO) was used to match IPC with six technological fields, namely, biotechnology, chemicals, electrical engineering, instruments, mechanical engineering, and others.

Data on the financial status of local governments were collected from the "Survey on Financial Status of Local Governments" compiled by the Ministry of Internal Affairs and Communications (MIC) and "Social Indicators by Prefecture" compiled by the Statistics Bureau of Japan, MIC. Data on the financial status of *Kohsetsushi* were collected from the "Survey of Research and Development" compiled by the Statistics Bureau of Japan, MIC.

Data on patent attorney offices were collected from the "White Paper on Patent Attorneys" compiled by the Japan Patent Attorneys Association.

Appendix Table 1 provides definitions of variables and descriptive statistics. Appendix Table 2 presents a correlation matrix. Appendix Table 3 shows a WIPO IPC-technology concordance table.

5. Results and discussion

Table III shows the estimation results for the selection equation. The fiscal health index of local governments is associated with the probability of incorporation by a U-shaped curve. Therefore, H1 is

[13] SMEs are firms that employ less than 301 workers or have a capital equal to or less than 300 million yen. Micro-businesses in the manufacturing sector are firms that employ less than 21 workers, and are integrated into SMEs in the empirical analysis. NCD collects information about all firms that filed at least 100 patents and all listed firms for the period (2012-2017) regardless of the number of patent applications. This means that only SMEs that are listed or filed more than 99 patents are identifiable from NCD. Previous studies employ a threshold, as a rule of thumb, of 100 patents to identify small-sized applicants (Motohashi and Muramatsu 2012; Galasso and Schankerman 2014). In light of this, this study assumes that unidentifiable applicants from NCD that filed less than 100 patents are SMEs.

supported. The inflection point of the curve is 0.873 for the fiscal health index, which corresponds to the ninety-fifth percentile of the whole observations, indicating that most of the *Kohsetsushi* fall into the descending domain of the curve. Therefore, the result captures a negative effect of the fiscal health of local governments on incorporation. The ratio of *Kohsetsushi* budget to the local authority budget negatively affects the probability of incorporation. Thus, H2 is not supported, indicating that local authorities allocating fewer fiscal resources to all types (agriculture, medical, etc.) of *Kohsetsushi* tend to adopt the incorporation of manufacturing *Kohsetsushi*. However, the ratio of *Kohsetsushi* budget to the local authority's total budget is, in general, less than one percent (Fukugawa and Goto 2016). Therefore, it is irrational for local governments facing serious fiscal difficulties to have *Kohsetsushi* incorporated for the purpose of fiscal reform. One interpretation is that local authorities might have targeted *Kohsetsushi* with smaller influence in the local assembly to show off their efforts with regard to fiscal reform, even though the effectiveness of incorporation was very limited. *Kohsetsushi* with larger employment size tend to be incorporated. Therefore, H3 is supported, suggesting that economies of scale that enable organizations to spread fixed costs played a role in the decision-making regarding the incorporation of *Kohsetsushi*.

The number of Ph.D. holders and the number of technical problems consulted do not affect the probability of incorporation, suggesting that technology transfer activities did not play an important role in the incorporation of *Kohsetsushi*. All the variables representing characteristics of small firm innovation are negatively associated with the probability of incorporation, whereas the number of patent attorney offices in a region is positively associated with the probability of incorporation in the region.

Table III here

Table IV shows the estimation results of patent applications. The ancillary parameter of the correlation coefficient between the error terms of the selection and main equations (*rho*) is not significant, demonstrating that treatment was exogenous. The discussion here builds on the estimation results of the ordinary least squares (OLS). Incorporation has a positive impact on patent applications. Therefore, H4 is supported. The number of Ph.D. holders positively affects patent applications, which is in consonance with the finding of Fukugawa (2009). Technical consultation does not affect patent applications, while the number of patent attorney offices is negatively associated with the number of patent applications.

Table IV here

Table V shows the estimation results of royalty. The ancillary parameters of *rho* are not significant, implying that the improvement of technology transfer performance was not considered in the decision-making regarding the incorporation of *Kohsetsushi*. The discussion here builds on the estimation results of OLS. Incorporation has no effect on royalty. Therefore, H5 is not supported. The elasticity of royalty to patents is less than one (0.47-0.58), indicating that royalty is not sensitive to patents. Technical consultation has no effect on royalty, which contradicts the finding of Fukugawa (2009) that it has a positive effect, mediated by the *Kohsetsushi* researchers' better understanding of the technological needs of local industry. Contrary to the finding of Fukugawa (2016) that dominant sectoral patterns of innovation in a region affect the technology transfer channels of *Kohsetsushi* of the region, small local firms' innovative activities in biotechnology, where innovations build on analytical knowledge and are disseminated through licensing, are negatively associated with royalty.

Table V here

Table VI shows the estimation results of resource allocation. The ancillary parameter of *rho* is not significant in the model of *factor_r*, while being significant in the model of *factor_s*, indicating that decision-making regarding the incorporation of *Kohsetsushi* is associated with resource allocation to diffusion/extension activities. The discussion concerning research/inventive activities builds on the estimation results of OLS, while that regarding diffusion/extension activities builds on the estimation results of an endogenous treatment model. Incorporation has a positive effect on research/inventive activities. Therefore, H7 is supported. Conversely, incorporation does not affect diffusion/extension activities. Therefore, H8 is not supported. These results show that incorporation acted as an agent of change in resource allocation, promoting *Kohsetsushi* to pursue a strategy of being more research-oriented and science-based. This could have both positive and negative impacts on technology transfer performance. On the one hand, *Kohsetsushi* with a greater number of Ph.D. holders could have inventions built on basic knowledge, thus having a broader social impact. On the other hand, unlike agricultural *Kohsetsushi*, researchers undertake both research/inventive and diffusion/extension activities in manufacturing *Kohsetsushi* (Fukugawa 2019). Consequently, by allocating more resources to research/inventive activities, they will have fewer resources for hands-on support for small local firms that acts as an important route for *Kohsetsushi* researchers to understand the local needs (Fukugawa 2009; Fukugawa and Goto 2016). This change in resource allocation could hamper the development of inventions that are more ready for commercialization by private companies.

Table VI here

Table VII shows the estimation results for the ESR models, while the estimation results using interpolated data are presented in Table VIII. In Table VII, the covariance between the error terms of the selection and main equations (*lambda*) is not significant for both incorporated and non-incorporated *Kohsetsushi*. This means that the choices of either incorporation or opting out of incorporation are not associated with the improvement in technology transfer performance, which is in line with the results of Table III and Table V. The elasticity of royalty of non-incorporated *Kohsetsushi* to their patents is less than one (0.51-0.54), indicating that their royalty is insensitive to patents. In Table VII, the elasticity of royalty to patents is not significant among incorporated *Kohsetsushi*. However, the results of Table VIII show that elasticity of royalty of incorporated *Kohsetsushi* to their patents is greater than one and larger than that of non-incorporated *Kohsetsushi*. This change may have been caused by an increase in the number of observations due to interpolation of the data. Therefore, it is difficult to conclude whether H6 is supported by the data.

In Table VII, the elasticity of royalty of non-incorporated *Kohsetsushi* to their patents is less than one (0.38), demonstrating that their royalty is insensitive to patents. Therefore, the results support that licensing activities at non-incorporated *Kohsetsushi* have much room for improvement. This could be done either by improved search for potential licensees by innovation intermediaries, such as technology licensing offices (TLOs), or greater effort for commercialization made by licensees. As the latter cannot be changed by *Kohsetsushi*, the former is deemed to be the key to the improvement in technology transfer performance. In the case of university technology transfer, after the national innovation system reform of 2004, TLOs were established to help national universities search for licensees and establish licensing agreements. TLOs can pool human resources and know-how across regions to scale licensing activities, thus improving technology transfer productivity (Lach and Schankerman 2008). However, innovation intermediaries are not well connected with licensing *Kohsetsushi* patents, with most of the local governments rarely offering *Kohsetsushi* institutional support for the commercialization of inventions. The results show that simply increasing the number of patents does not help *Kohsetsushi* commercialize their patents successfully. Therefore, it is necessary for them to identify and tap into innovation intermediaries conducive to the commercialization of patents.

The number of technical problems consulted with non-incorporated *Kohsetsushi* is associated with royalty by a U-shaped curve, with the inflection point (2298=exp(7.74)) being approximately the median of the variable (2252). This means that an increase in technical problems consulted increases royalty of approximately half of the non-incorporated *Kohsetsushi*. Under such ascending domain of the U-shaped curve, technical consultation helps *Kohsetsushi* researchers better understand the technological needs of local industry, resulting in inventions more ready for commercialization by private companies. However, no such relation between technical consultation and royalty is observed from the results of incorporated

Kohsetsushi. In this regard, Table VIII shows that the number of technical problems consulted with incorporated *Kohsetsushi* is associated with royalty by an inverted U-shaped curve of which the inflection point (478=exp(6.17)) is located in the tenth percentile of the variable (854). This means that, in general, an increase in technical problems consulted reduces royalty of incorporated *Kohsetsushi*. In such a descending domain, an increase in technical problems, many of which are entry level, may have impeded the research/inventive activities of incorporated *Kohsetsushi*. In other words, the diffusion/extension activities acted as a substitute rather than a supplement to research/inventive activities of incorporated *Kohsetsushi*. One solution to this trade-off problem could be an interorganizational division of labor that the agricultural *Kohsetsushi* adopt (Fukugawa 2019). Researchers at agricultural *Kohsetsushi* are dedicated to knowledge creation (e.g., development of new cultivars), while technology diffusion is undertaken by the extension staff in an independent division.[14] However, this strategy creates another problem, as incorporated *Kohsetsushi* that are research-oriented and science-based would functionally overlap with other economic actors in the regional innovation system, such as universities. Therefore, such incorporated *Kohsetsushi* would need to identify a niche field of research that could differentiate them from other actors.

Table VII here
Table VIII here

Table IV shows the results of the counterfactual analysis. Panel A exhibits the estimation results from original data, while Panel B presents those of the interpolated data. Appendix Figures 2 and 3 show distributions of the expected royalty of incorporated and non-incorporated *Kohsetsushi* under the conditions of being incorporated and non-incorporated, with the results not varying in terms of statistical significance and signs according to the data used. The discussion here builds on Panel A. The average treatment effect on the treated (ATT) is significant and negative, indicating that incorporated *Kohsetsushi* would have increased royalty by twenty-three percent if they had opted out of incorporation, which amounts to 638,976 yen. Assuming the royalty rate local governments apply to small local firms is two percent and the contribution rate of the *Kohsetsushi* patent to a final product is ten percent, this increase in royalty corresponds to 319,488,000 yen of a turnover increase of the small local firm. Although the actual impact of this amount of increase varies according to the company's turnover size, the welfare loss of the incorporation of *Kohsetsushi* appears to be non-negligible. The average treatment effect on the untreated, (ATU) is significant and positive, indicating that royalty of non-incorporated *Kohsetsushi* would have increased nearly by 2.5 times, if they had been incorporated. In this regard, Panel B also shows significant and positive ATU, whose impact appears to be more reasonable due to a greater number of observations. To sum up, the results of ATT and ATU imply that there was an irrational matching between program participation and technology transfer performance. In other words, *Kohsetsushi* that should have participated in the program had chosen to stay out, while *Kohsetsushi* that should not have participated in the program had done so. This failure appears to have been created by an indiscreet decision-making regarding the incorporation of *Kohsetsushi* as discussed above. Lastly, ATE is significant and positive in Panel B, suggesting that policy evaluation without a counterfactual analysis could mislead the redesign of the policy.

Table IV here

Table V summarizes the hypotheses and findings of the present study. The results regarding the determinants of incorporation imply that the incorporation of manufacturing *Kohsetsushi* was determined

[14] Such a division of labor has its roots in the nature of local agricultural production and innovation, which is quite plant-specific and regionally embedded. The extension staff give feedback about the needs of local agricultural producers, on which future research could build. This feedback function renders the extension staff key intermediaries in the regional agricultural innovation systems (Fukugawa 2019).

mainly by the fiscal status of local governments and economies of scale, and was not meant for the improvement in technology transfer performance. Regarding the impacts of incorporation, first, the incorporation positively affected the number of patent applications, but did not affect royalty. Second, it positively affected resource allocation to research/inventive activities, but did not affect diffusion/extension activities. Third, the elasticity of royalty of non-incorporated *Kohsetsushi* to their patents was less than one; thus, technology transfer performance could have been improved by utilizing innovation intermediaries like TLOs. Fourth, there was a U-shaped (inverted U-shaped) relationship between royalty of non-incorporated (incorporated) *Kohsetsushi* and the number of technical problems consulted with them. Fifth, ATT of incorporation was significant and negative. If incorporated *Kohsetsushi* had not been incorporated, their royalty would have increased by 10-23 percent. Sixth, ATU of incorporation was significant and positive. If non-incorporated *Kohsetsushi* had been incorporated, their royalty would have increased. Seventh, ATE of incorporation was significant and positive when the interpolated data were used for the analysis.

With respect to royalty, the present study shows the "unintended consequences" of the legal reform, as the *LIACL* originally aimed to help *Kohsetsushi* contribute more to regional economic development. However, there was a mismatch between the decision-making regarding incorporation and technology transfer performance. The present study employed an endogenous treatment model because an economic model of technology transfer was linked with the decision-making process regarding the incorporation of *Kohsetsushi*. However, a non-economic factor may have made incorporation malfunctioning as an agent of change in the incentive systems. It altered the incentive systems, resulting in changes in resource allocation and patenting activities. However, this change did not contribute to technology transfer performance because it was not the aim of program participation, resulting in welfare loss in regional economies.

The results provide some implications regarding how *Kohsetsushi* could contribute to regional economic development more efficiently. *Kohsetsushi* with an above-median level of engagement in technical consultation should be able to improve their technology transfer performance by engaging in hands-on technical support for small local firms. Technical consultation has no such complementary effect on the commercialization of patents of *Kohsetsushi* that have already been incorporated. In fact, an increase in technical problems consulted with incorporated *Kohsetsushi* generally reduced their royalty, implying that if an independent assessment committee stresses technical consultation too much when evaluating incorporated *Kohsetsushi*, it could damage technology transfer performance.

The *LIACL* requires an independent assessment committee to review LIACs with respect to their organizational structure and performance every three or five years, during which mid-term programs are implemented (Article 11, Article 25). This is because LIACs have to follow a rigorous plan-do-check-act cycle to redesign the program based on the assessment (Article 3). The independent assessment committee has to set numerical targets to be achieved in the next term, of which a typical example is the number of technical problems local firms consult with *Kohsetsushi*. As the numerical targets tend to ratchet assessment by assessment, incorporated *Kohsetsushi* may have faced a serious trade-off in resource allocation.[15]

Incorporated *Kohsetsushi* appear to have chosen a strategy of becoming research-oriented and science-based, which may cause them to overlap with other actors, such as universities and national research institute, in the regional innovation system. To differentiate themselves from other knowledge providers in the regional innovation system, they should identify a niche market they could occupy by utilizing both scientific knowledge and knowledge of local economic contexts, thus avoiding the problem of overlapping investment by local governments.

Table V here

6. Conclusions

[15] The ratchet effect was confirmed by the proceedings of the independent assessment committee of Hokkaido Research Organization.

Legal reforms fundamentally shift incentive systems by creating and redefining incentive tools, such as ownership, discretion, and reward. This study examined the impacts of *the LIACL* on public technology transfer organizations, *Kohsetsushi*. It modeled technology transfer activities and performance of *Kohsetsushi* using a multistage knowledge production function based on the assumption that the incorporation was not randomly assigned, but a choice variable. The panel data analysis revealed that the *LIACL* altered the incentive system through changes in ownership of IPRs, greater freedom in resource allocation, and a merit-based evaluation system. Indeed, incorporation promoted *Kohsetsushi* to allocate more resources to research/inventive activities and to file more patents. However, these changes did not contribute to royalty growth because incorporation was not aimed at the improvement of technology transfer performance, thus creating welfare loss, which was an unintended consequence of the policy.

The key determinants of incorporation were the fiscal status of local governments and economies of scale, both of which aimed at cost reduction, not value creation. In addition, the ATT of incorporation was negative while ATU was positive, implying that there was a mismatch between decision-making regarding incorporation and technology transfer performance. The key for non-incorporated *Kohsetsushi* to contribute to regional economic development appears to be technical consultation which helps researchers understand the needs of local industries. Conversely, for incorporated *Kohsetsushi*, technical consultation did not have a complementary effect on royalty. Since incorporated *Kohsetsushi* have chosen a research-intensive, science-based strategy that overlaps with other actors in the regional innovation systems, such as universities, a more drastic resource allocation is needed for them to contribute to regional economic development. An independent assessment committee under the *LIACL* should understand the situation of incorporated *Kohsetsushi* and need to develop a better assessment system so that such a drastic resource allocation would not be discouraged. For such incorporated *Kohsetsushi*, a new organizational division of labor adopted by agricultural *Kohsetsushi* may be of help to enhance their research/inventive capabilities while keeping diffusion/extension activities intact.

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Table I. Incorporated *Kohsetsushi*

Year	Local government	Fiscal health index 2000-2017 average	Name	Technological field(s)
2006	Iwate Prefecture	0.295	Iwate Industrial Research Institute	Manufacturing
2006	Tokyo	1.097	Tokyo Metropolitan Industrial Technology Research Institute	Manufacturing
2007	Tottori Prefecture	0.247	Tottori Institute of Industrial Technology	Manufacturing
2008	Osaka City	0.912*	Osaka Municipal Technical Research Institute	Manufacturing
2009	Aomori Prefecture	0.297	Aomori Industrial Technology Center	Manufacturing, agriculture, fishery, forestry, food processing
2009	Yamaguchi Prefecture	0.404	Yamaguchi Prefectural Industrial Technology Institute	Manufacturing
2010	Hokkaido	0.381	Hokkaido Research Organization	Manufacturing, agriculture, fishery, forestry, foods, environment, geology, architecture
2012	Osaka Prefecture	0.745	Osaka Research Institute of Industrial Science and Technology	Manufacturing
2012	Osaka Prefecture	0.745	Osaka Research Institute of Industrial Science and Technology	Environment, agriculture, fishery, forestry, foods
2014	Kyoto City	0.736*	Kyoto Municipal Institute of Industrial Technology and Culture	Manufacturing
2017	Kanagawa Prefecture	0.874	Kanagawa Institute of Industrial Science and Technology	Manufacturing

Notes

1. *Fiscal health indices of municipal governments were used.
2. Several non-manufacturing *Kohsetsushi* (e.g., medicine) were incorporated in this period, but they were excluded from analysis of the present study.

Table II. Comparison between incorporated and non-incorporated *Kohsetsushi*

Variables	Non-incorporated *Kohsetsushi*	Incorporated *Kohsetsushi*	Incorporated *Kohsetsushi* before incorporation	Incorporated *Kohsetsushi* after incorporation
Log(budget)	12.7	13.8	13.6	14.1
Log(employment)	3.4	4.2	4.1	4.4
Patent applications per researcher	.096	.149	.134	.170
Royalty per researcher	26.4	41.2	35.6	43.9
Log(royalty)	4.8	6.4	6.2	6.5
Ph.D. researcher ratio	.220	.275	.206	.391
Competitive research fund per researcher	426	965	263	1059
Technical problems consulted per researcher	110	127	88	188
Revenue from testing per researcher	507	569	626	522
Revenue from use of equipment per researcher	276	255	140	346

Table III. Determinants of incorporation: probit estimation

	Coefficient	Standard errors	z	P>z	Significance
Fiscal health index	-10.48	2.305	-4.55	0.000	**
Fiscal health index^2	5.996	1.265	4.74	0.000	**
Kohsetsushi budget share	-0.019	0.004	-4.68	0.000	**
Log of employees	0.868	0.268	3.23	0.001	**
Log of Ph.D. holders	0.349	0.179	1.95	0.051	
Log of technical problems consulted	-0.163	0.085	-1.91	0.056	
LQ biotechnology	-0.373	0.173	-2.15	0.031	*
LQ chemicals	-0.591	0.21	-2.81	0.005	**
LQ electrical engineering	-0.859	0.362	-2.37	0.018	*
LQ instruments	-0.501	0.304	-1.65	0.099	#
LQ mechanical engineering	-0.803	0.387	-2.07	0.038	*
LQ others	-2.099	0.785	-2.67	0.008	**
Log of patent attorney offices	0.24	0.122	1.97	0.049	*
_cons	-238.714	53.295	-4.48	0.000	**
N	1309				

Notes
1. The results of time effect are unreported.
2. (**), (*), and (#) denote the one, five, and ten percent level of statistical significance, respectively.
3. LQ: location quotient

Table IV. Impacts of incorporation on logged patent applications in the survey year

	Model1	Model2
N	948	958
Model	ET	OLS
Zero patent application dummy	-1.148**	-1.147**
	0.052	0.056
Log of budget	0.106*	0.098#
	0.053	0.056
Log of Ph.D. holders	0.120#	0.125#
	0.066	0.070
Log of technical problems consulted	-0.277	-0.309
	0.246	0.266
Log of technical problems consulted^2	0.015	0.017
	0.015	0.016
Lq biotechnology	0.068	0.076#
	0.042	0.046
Lq chemicals	0.047	0.049
	0.046	0.049
Lq electrical engineering	0.211**	0.222**
	0.066	0.071
Lq instruments	0.260**	0.260**
	0.067	0.072
Lq mechanical engineering	0.125#	0.103
	0.074	0.079
Lq others	0.541**	0.524**
	0.137	0.147
Log of patent attorney offices	-0.284**	-0.293**
	0.073	0.078
Incorporation dummy	0.187	0.181*
	0.122	0.090
_cons	0.043	-0.643
	1.226	0.877
athrho	-0.031	
	0.159	
lnsigma	-0.872**	
	0.023	

Notes
1. See Table III for the results of the selection equation.
2. Below coefficients are standard errors.
3. A fixed effects model is estimated. The results of time effect are unreported.
4. (**), (*), and (#) denote the one, five, and ten percent level of statistical significance, respectively.
5. ET: endogenous treatment model; OLS: ordinary least squares
6. LQ: location quotient

Table V. Impacts of incorporation on logged royalty

	Model1	Model2	Model3	Model4
data	original	original	interpolated	interpolated
N	556	563	772	772
Model	ET	OLS	ET	OLS
Zero royalty dummy	-4.011**	-4.019**	-3.657**	-3.659**
	0.223	0.246	0.195	0.210
Log of patents granted or filed	0.574**	0.585**	0.481**	0.479**
	0.137	0.147	0.124	0.134
Log of budget	0.241	0.294#	0.331*	0.332*
	0.167	0.174	0.134	0.144
Log of Ph.D. holders	-0.013	0.074	0.136	0.166
	0.241	0.255	0.218	0.234
Log of technical problems consulted	-0.697	-0.656	0.414	0.483
	0.907	1.009	0.830	0.899
Log of technical problems consulted^2	0.037	0.036	-0.028	-0.032
	0.054	0.061	0.051	0.055
Lq biotechnology	-0.344**	-0.345**	-0.444**	-0.451**
	0.120	0.132	0.116	0.125
Lq chemicals	-0.005	-0.018	-0.137	-0.151
	0.127	0.139	0.124	0.133
Lq electrical engineering	-0.588**	-0.613**	-0.668**	-0.692**
	0.196	0.215	0.191	0.204
Lq instruments	-0.394#	-0.386	-0.228	-0.226
	0.238	0.262	0.231	0.248
Lq mechanical engineering	-0.693**	-0.709**	-0.659**	-0.657**
	0.221	0.239	0.219	0.235
Lq others	-0.172	-0.272	-0.893*	-0.947*
	0.437	0.481	0.405	0.435
Log of patent attorney offices	0.305	0.344	0.197	0.214
	0.291	0.321	0.232	0.250
Incorporation dummy	0.558	0.109	0.635	0.188
	0.374	0.285	0.390	0.261
_cons	4.459	0.155	-0.122	-0.475
	4.259	5.192	3.873	4.180
athrho	-0.376		-0.354	
	0.249		0.259	
lnsigma	-0.105**		-0.053#	
	0.035		0.031	

Notes
1. See Table III for the results of the selection equation.
2. Below coefficients are standard errors.
3. A fixed effects model is estimated. The results of time effect are unreported.
4. (**), (*), and (#) denote the one, five, and ten percent level of statistical significance, respectively.
5. ET: endogenous treatment model. OLS: ordinary least squares.
6. LQ: location quotient

Table VI. Impacts of incorporation on resource allocation

	Model1	Model2	Model3	Model4
depvar	*Factor_r*	*Factor_r*	*Factor_s*	*Factor_s*
N	696	702	696	702
Model	ET	OLS	ET	OLS
Log of employees	-0.052	-0.052	-0.037	-0.074
	0.105	0.114	0.108	0.119
Lq biotechnology	-0.010	-0.008	-0.237**	-0.225**
	0.032	0.035	0.034	0.037
Lq chemicals	-0.049	-0.048	-0.174**	-0.168**
	0.035	0.038	0.037	0.039
Lq electrical engineering	-0.022	-0.018	-0.336**	-0.314**
	0.051	0.056	0.055	0.058
Lq instruments	0.114#	0.117#	-0.183**	-0.189**
	0.058	0.064	0.062	0.067
Lq mechanical engineering	0.030	0.025	-0.244**	-0.268**
	0.061	0.066	0.065	0.069
Lq others	0.136	0.140	-0.527**	-0.490**
	0.112	0.121	0.118	0.126
Log of patent attorney offices	-0.113	-0.112	-0.081	-0.095
	0.075	0.081	0.077	0.085
Incorporation dummy	0.167	0.177*	0.004	0.243**
	0.109	0.069	0.087	0.072
_cons	1.397**	0.185	0.989#	1.938**
	0.506	0.598	0.533	0.625
athrho	0.024		0.681**	
	0.251		0.195	
lnsigma	-1.310**		-1.233**	
	0.027		0.032	

Notes
1. See Table III for the results of the selection equation.
2. *Factor_r*: factor scores representing research/inventive activities
3. *Factor_s*: factor scores representing diffusion/extension activities
4. Below coefficients are standard errors.
5. A fixed effects model is estimated. The results of time effect are unreported.
6. (**), (*), and (#) denote the one, five, and ten percent level of statistical significance, respectively.
7. ET: endogenous treatment model. OLS: ordinary least squares.
8. LQ: location quotient

Table VII. Impacts of incorporation on the impacts of patents on royalty: estimation results using original data

	Model1	Model2	Model3	Model4
depvar	*Log_royalty0*	*Log_royalty0*	*Log_royalty1*	*Log_royalty1*
N	489	496	67	67
Model	ESR	OLS	ESR	OLS
Zero royalty dummy	-4.034**	-4.042**	-11.442	0.000
	0.221	0.247	11.923	.
Log of patents granted or filed	0.519**	0.545**	1.142	0.803
	0.145	0.156	1.611	0.930
Log of budget	0.172	0.240	1.698	1.610#
	0.172	0.179	1.608	0.924
Log of Ph.D. holders	-0.046	0.053	-1.140	-0.522
	0.249	0.262	3.983	2.049
Log of technical problems consulted	-2.072*	-2.075#	3.385	5.470
	1.056	1.189	7.632	4.165
Log of technical problems consulted^2	0.135*	0.134#	-0.325	-0.470#
	0.064	0.072	0.478	0.258
Lq biotechnology	-0.351**	-0.355*	0.553	0.754
	0.129	0.140	1.537	0.817
Lq chemicals	-0.013	-0.026	-4.081#	-3.815**
	0.132	0.144	2.307	1.388
Lq electrical engineering	-0.610**	-0.652**	-2.974	-1.822
	0.208	0.223	2.862	1.614
Lq instruments	-0.559*	-0.559#	-1.700	-0.615
	0.267	0.296	2.856	1.349
Lq mechanical engineering	-0.749**	-0.770**	-0.796	-0.492
	0.228	0.246	3.018	1.500
Lq others	-0.416	-0.620	0.852	1.324
	0.498	0.531	5.089	2.750
Log of patent attorney offices	0.328	0.414	-0.582	-0.858
	0.332	0.365	1.897	1.111
_cons	10.704*	10.277#	-1.182	-18.248
	4.761	5.547	33.790	16.541
/mills				
lambda	0.574		-1.977	
	0.501		1.783	

Notes
1. See Table III for the results of the selection equation.
2. *Log_royalty1*: log of royalty of incorporated *Kohsetsushi*. *Log_royalty0*: log of royalty of non-incorporated *Kohsetsushi*
3. Below coefficients are standard errors.
4. A fixed effects model is estimated. The results of time effect are unreported.
5. (**), (*), and (#) denote the one, five, and ten percent level of statistical significance, respectively.
6. ESR: endogenous switching regression. OLS: ordinary least squares.
7. LQ: location quotient

Table VIII. Impacts of incorporation on the impacts of patents on royalty: estimation results using interpolated data

	Model1	Model2	Model3	Model4
Depvar	*Log_royalty0*	*Log_royalty0*	*Log_royalty1*	*Log_royalty1*
N	683	683	89	89
Model	ESR	OLS	ESR	OLS
Zero royalty dummy	-3.632**	-3.628**	-3.196**	-2.848**
	0.199	0.216	0.732	0.954
Log of patents granted or filed	0.380**	0.387**	2.039**	1.868*
	0.131	0.142	0.557	0.714
Log of budget	0.267#	0.272#	1.450*	1.433
	0.137	0.149	0.705	0.910
Log of Ph.D. holders	0.068	0.089	-0.737	-0.301
	0.226	0.243	1.217	1.511
Log of technical problems consulted	-0.553	-0.530	5.540#	6.759#
	0.937	1.023	3.006	3.653
Log of technical problems consulted^2	0.045	0.043	-0.450*	-0.533*
	0.058	0.063	0.189	0.228
Lq biotechnology	-0.463**	-0.472**	0.425	0.412
	0.124	0.133	0.581	0.747
Lq chemicals	-0.194	-0.205	-1.383#	-1.435
	0.128	0.137	0.833	1.112
Lq electrical engineering	-0.776**	-0.801**	-2.507*	-2.521#
	0.200	0.213	1.039	1.374
Lq instruments	-0.471#	-0.467#	0.188	0.268
	0.256	0.278	0.768	0.955
Lq mechanical engineering	-0.662**	-0.671**	-0.352	-0.541
	0.226	0.244	1.074	1.318
Lq others	-1.372**	-1.464**	1.559	1.168
	0.457	0.480	1.898	2.409
Log of patent attorney offices	0.206	0.243	-0.717	-0.755
	0.261	0.280	0.633	0.853
_cons	6.826	5.168	-26.088#	-31.358*
	4.438	4.813	13.343	15.027
/mills				
Lambda	0.403		-0.585	
	0.493		0.436	

Notes
1. See Table III for the results of the selection equation.
2. *Log_royalty1*: log of royalty of incorporated *Kohsetsushi*. *Log_royalty0*: log of royalty of non-incorporated *Kohsetsushi*
3. Below coefficients are standard errors.
4. A fixed effects model is estimated. The results of time effect are unreported.
5. (**), (*), and (#) denote the one, five, and ten percent level of statistical significance, respectively.
6. ESR: endogenous switching regression. OLS: ordinary least squares.
7. LQ: location quotient

Table IV Counterfactual analysis

Panel A: Estimation results using original data

		To be incorporated		Not to be incorporated		Treatment effect		
	N	Mean	S.D.	Mean	S.D.	ATT	ATU	Ln%
Incorporated	67	4.902	2.434	6.423	3.131	-1.520**		-23.7
Non-incorporated	489	13.206	4.701	5.168	2.368		8.037**	155.5

Notes

1. ATE=-0.265
2. (**), (*), and (#) denote the one, five, and ten percent level of statistical significance, respectively.

Panel B: Estimation results using interpolated data

		To be incorporated		Not to be incorporated		Treatment effect		
	N	Mean	S.D.	Mean	S.D.	ATT	ATU	Ln%
Incorporated	89	5.992	2.068	6.717	2.884	-0.724**		-10.8
Non-incorporated	683	7.272	4.018	4.867	2.444		2.404**	49.4

Notes

1. *ATE*=1.124**
2. (**), (*), and (#) denote the one, five, and ten percent level of statistical significance, respectively.

Table V Summary of the results

Hypotheses	Results	Support
H1: Fiscal soundness of local governments has a U-shape relation with the incorporation of *Kohsetsushi*.	Table III	yes
H2: The share of *Kohsetsushi* budget to local government budget positively affects incorporation.	Table III	no
H3: Organizational size positively affects incorporation.	Table III	yes
H4: Incorporation positively affects the number of patent applications.	Table IV	yes
H5: Incorporation positively affects royalty that *Kohsetsushi* patents yield.	Table V	no
H6: Incorporation positively affects the impact of *Kohsetsushi* patents on royalty.	Table VII, VIII	yes/no
H7: Incorporation positively affects resource allocated to research/inventive activities.	Table VI	yes
H8: Incorporation negatively affects resource allocated to diffusion/extension activities.	Table VI	no

Appendix Table 1 Descriptive statistics

Definition	N	Mean	S.D.	Min	Max
D					
Incorporation dummy	1710	0.054	0.226	0	1
Z					
Fiscal health index of local government	1710	0.475	0.205	0.197	1.406
Kohsetsushi budget/local government budget (%)	1710	67.775	27.037	9.266	250.984
X					
Kohsetsushi employees	1556	50.150	46.113	3	386
Kohsetsushi budget	1521	653974	801238	6308	9825864
R					
Number of Ph.D. holders	1363	10.811	13.682	0	100
Number of technical problems consulted	1485	5205.811	11543	0	139101
N					
Patent attorney offices in a region	1710	201.432	724.582	0	6108
Y					
Number of patent applications in the survey year	1094	5.193	7.714	0	129
Royalty	611	1209.445	2533.087	0	20544
Factor_r	702	-5.44E-11	0.853	-1.342	4.463
Factor_s	702	9.34E-10	0.733	-0.986	3.328

Appendix Table 2 Correlation matrix

	Incorporation dummy	Fiscal health	Budget share	Employment	Budget	Ph.D.	Consultation	Patents	Patent application	Royalty	Factor_r	Factor_s
Incorporation dummy	1											
Fiscal health index of local government	0.079	1										
Kohsetsushi budget/local government budget (%)	-0.356	-0.138	1									
Kohsetsushi employees	0.303	0.561	-0.147	1								
Kohsetsushi budget	0.415	0.531	-0.227	0.883	1							
Number of Ph.D. holders	0.435	0.419	-0.292	0.731	0.749	1						
Number of technical problems consulted	0.404	0.518	-0.280	0.806	0.893	0.768	1					
Patent attorney offices in a region	0.371	0.662	-0.365	0.598	0.752	0.622	0.782	1				
Number of patent applications in the survey year	0.357	0.268	-0.147	0.470	0.515	0.673	0.513	0.449	1			
Royalty	0.161	0.016	-0.030	0.077	0.038	0.210	0.059	0.056	0.350	1		
Factor_r	0.218	-0.051	-0.104	0.011	0.067	0.538	0.114	0.113	0.560	0.375	1	
Factor_s	0.187	0.430	-0.110	0.463	0.509	0.476	0.687	0.431	0.359	0.029	0.121	1

Appendix Table 3 IPC8 -Technology Concordance as of March 2018

Biotechnology	Chemistry excluding biotechnology	Electrical engineering	Instruments	Mechanical engineering	Others
Biotechnology	Basic materials chemistry	Audio-visual technology	Analysis of biological materials	Engines, pumps, turbines	Civil engineering
Environmental technology	Chemical engineering	Basic communication processes	Control	Handling	Furniture, games
Food chemistry	Macromolecular chemistry, polymers	Computer technology	Measurement	Machine tools	Other consumer goods
Pharmaceuticals	Materials, metallurgy	Electrical machinery, apparatus, energy	Medical technology	Mechanical elements	
	Micro-structural and nano-technology	IT methods for management	Optics	Other special machines	
	Organic fine chemistry	Semiconductors		Textile and paper machines	
	Surface technology, coating	Telecommunications		Thermal processes and apparatus	
				Transport	

Note: IPC-Technology Concordance is to link a specific international patent classification (IPC) with a specific technological field.
Source: World Intellectual Property Organization. (2016). IPC concordance table. http://www.wipo.int/export/sites/www/ipstats/en/statistics/patents/xls/ipc_technology.xls. Accessed on 28 February 2019.

Figure 1 Ratio of incorporated manufacturing *Kohsetsushi*

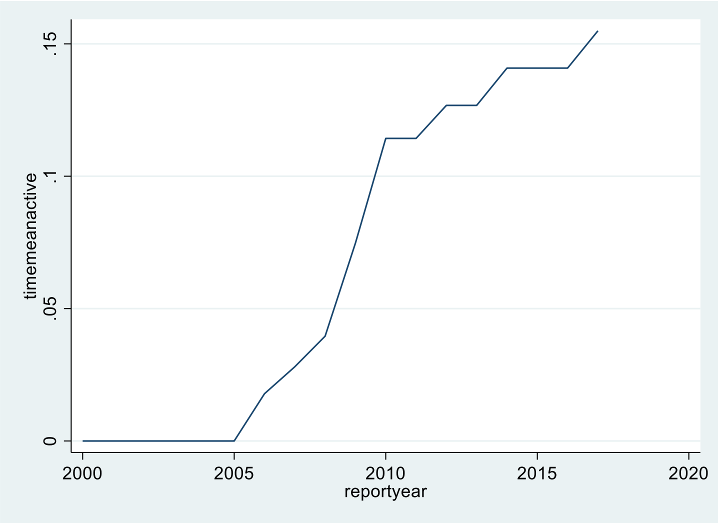
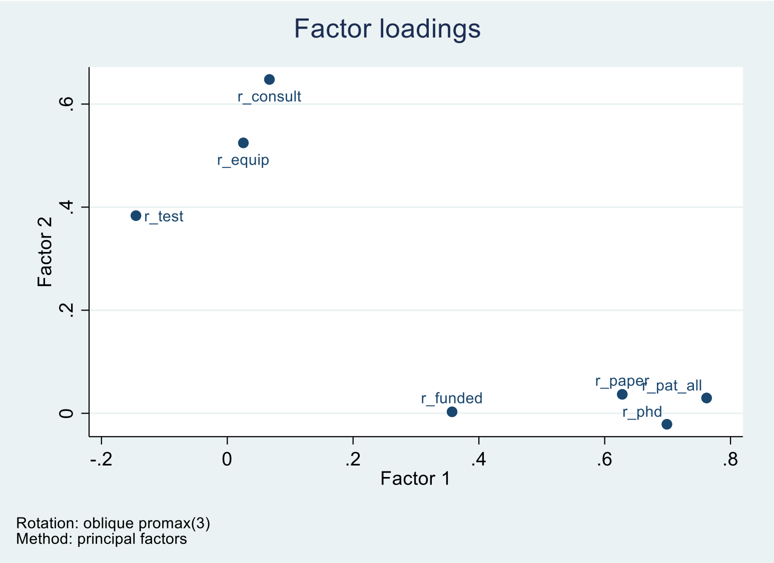


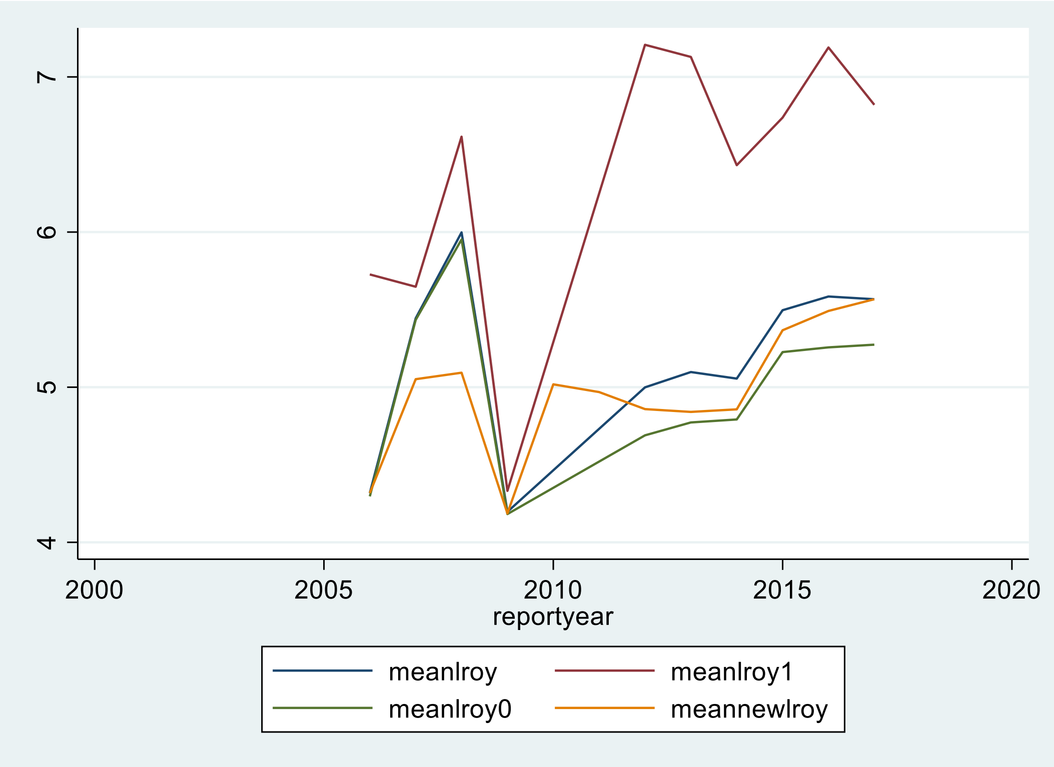
Figure 2 Factor loadings



Notes

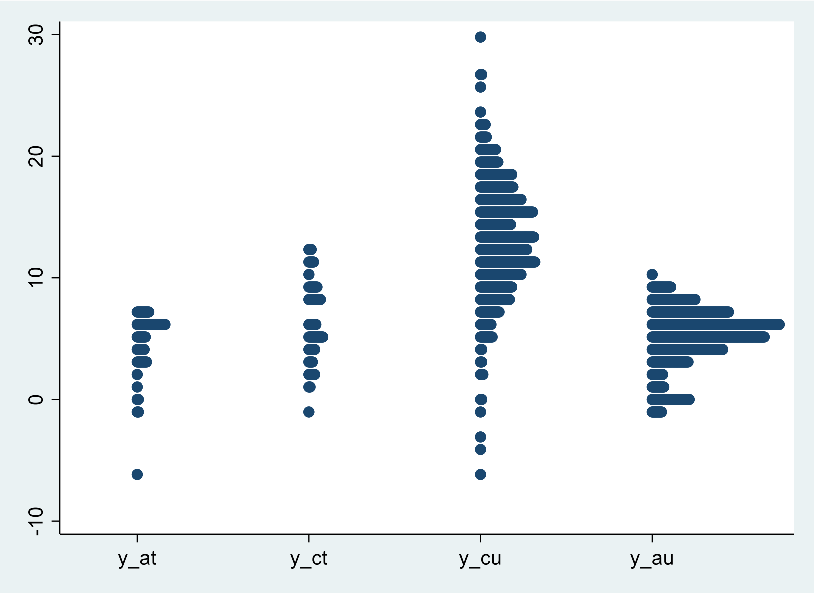
1. *r_phd*: number of Ph.D. holders; *r_funded*: revenue from funded research; *r_paper*: number of scientific publications; *r_pat_all*: number of patents granted or filed; *r_consult*: number of technical problems consulted; *r_test*: revenue from testing; *r_equip*: revenue from use of equipment. All the variables are divided by the number of technical staff to control for size.
2. *Factor1*: research/inventive activities; *Factor2*: diffusion/extension activities.

Appendix Figure 1 Time series variations in logged royalty: original data and interpolated data



Notes
1. *Lroy1* denotes logged royalty of incorporated *Kohsetsushi*.
2. *Lroy0* denotes logged royalty of non-incorporated *Kohsetsushi*.
3. *Newlroy* denotes logged royalty from interpolated data.

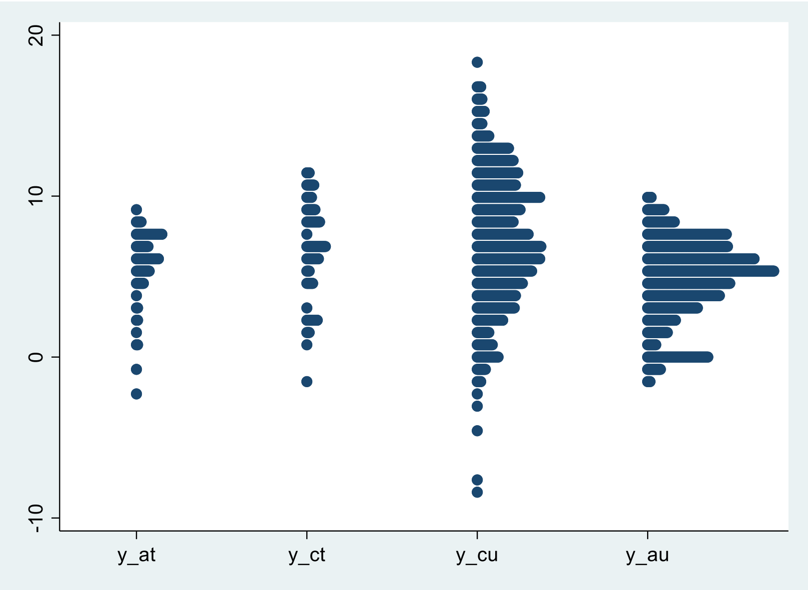
Appendix Figure 2 Distributions of expected royalty of incorporated/non-incorporated *Kohsetsushi* with/without incorporation: original data



Notes

1. y_at: expected value of logged royalty of incorporated *Kohsetsushi* that were actually incorporated
2. y_ct: expected value of logged royalty of incorporated *Kohsetsushi* had they opted out of incorporation
3. y_cu: expected value of logged royalty of non-incorporated *Kohsetsushi* had they been incorporated
4. y_au: expected value of logged royalty of non-incorporated *Kohsetsushi* that actually opted out of incorporation

Appendix Figure 3 Distributions of expected royalty of incorporated/non-incorporated *Kohsetsushi* with/without incorporation: interpolated data



Notes
1. y_at: expected value of logged royalty of incorporated *Kohsetsushi* that were actually incorporated
2. y_ct: expected value of logged royalty of incorporated *Kohsetsushi* had they opted out of incorporation
3. y_cu: expected value of logged royalty of non-incorporated *Kohsetsushi* had they been incorporated
4. y_au: expected value of logged royalty of non-incorporated *Kohsetsushi* that actually opted out of incorporation