Research article

Effects of incorporating public innovation intermediaries on technology transfer performance: evidence from patent licensing of Japan’s Kohsetsushi

Nobuya Fukugawa*

Tohoku University, Sendai, Japan

**Abstract**

The incorporation of public organizations is meant to improve their efficiency and contribution to national and local economies. In Japan, incorporation has been implemented at the national and local levels since the late 1990s. This process alters the incentive system comprising intellectual property (IP) ownership, managerial freedom, and rent sharing, which promotes IP commercialization. This study assesses the economic consequences of the incentive system reform, taking the example of a public innovation intermediary, Kohsetsushi. Unlike the incorporation of national universities, the incorporation of Kohsetsushi is at the discretion of local governments. Therefore, there should be a comparative advantage for both incorporated and unincorporated Kohsetsushi. A dataset representative of both types of Kohsetsushi was established to estimate the average treatment effects on the treated (ATT), identify the type of selection into incorporation, and discuss the economic consequences of endogenous selection by local governments. The counterfactual analysis of licensing income revealed a negative ATT of incorporation and negative selection into not choosing incorporation. Incorporated Kohsetsushi would have had higher licensing income had they not been incorporated. The evidence does not support comparative advantage. The unintended consequence might have been caused by the lack of harmonization between the incentive and evaluation systems.

1. Introduction

Many countries have implemented the practice of incorporating public organizations since the 1980s, with an early example being the privatization of public organizations in various advanced economies. In Japan, this form of incorporation has been introduced against the backdrop of a series of administrative reforms that aimed to help the country escape its secular stagnation since the 1990s. The incorporation began at the national level in the late 1990s and expanded to the regional level in the early 2000s. The latter was legitimized in 2003 by the Local Independent Administrative Corporation Law (LIACL). It endowed local public organizations (e.g., public universities) with a legal entity status, enabled Local Independent Administrative Corporations (LIACs) to own intellectual property (IP), and promoted commercialization of IP, with greater managerial discretion than when organizations were simply a part of local governments and the possibility of rent sharing. The LIACL applied to technology transfer organizations established by local governments, Kohsetsushi.

The first generation of Kohsetsushi was established in the wake of Japan’s modern economic growth in the late 19th century. Kohsetsushi were initially established in the agricultural sector (Fukugawa, 2019) and expanded to the manufacturing sector throughout the 20th century (Fukugawa, 2016). Currently, there are 67 manufacturing Kohsetsushi branches corresponding to industrial agglomerations across all 47 prefectures. They help local firms upgrade their basic technological skills through technical consultation, education, and training. Moreover, through collaboration and networking, manufacturing Kohsetsushi help firms build long-term technological capabilities to innovate for themselves and exploit spillovers from external sources of knowledge. Manufacturing Kohsetsushi collaborate with firms in research, patent inventions, and license patents to collaborating firms. Furthermore, they connect client firms with other sources of knowledge in regional innovation systems, such as universities. These functions imply that manufacturing Kohsetsushi act as an innovation intermediary to mitigate innovation system failures arising from poor capabilities of and weak interactions among firms (Klerkx et al., 2012; Intarakumnerd and Chaoroenporn, 2013; Fukugawa, 2018).

There have been many attempts to improve the efficiency of innovation intermediaries through incentive system reform. What makes the incorporation of Kohsetsushi intriguing is that the decision was left to the
discretion of local governments, implying self-selection. Given a rational choice, there should be positive selection into incorporation for incorporated Kohsetsushi and positive selection into not choosing incorporation for unincorporated Kohsetsushi. These options imply comparative advantage for both types of Kohsetsushi. In other words, if local governments that could benefit from incorporation actually incorporated Kohsetsushi, while those that could not benefit opted out of incorporation, both types of Kohsetsushi would have been better off by either being incorporated or not.

This study establishes a dataset representative of licensing performance of both incorporated and unincorporated Kohsetsushi, which enables the estimation of the average treatment effects on the treated (ATT) of incorporation. Then, this study identifies the type of selection into incorporation and discusses the economic consequences of self-selection by local governments. The results show that the ATT is negative, there is negative selection into not choosing incorporation, and there is no evidence of comparative advantage for both incorporated and unincorporated Kohsetsushi. The results imply an unintended consequence of the incentive system reform.

The remainder of this paper is organized as follows. Section 2 situates this study in the literature on technology transfer and innovation policy. Section 3 lays out the framework of the incorporation of Kohsetsushi and proposes hypotheses regarding its effect on licensing performance. Section 4 describes the econometric model and data used for the estimation. Section 5 presents the estimation results and Section 6 discusses their implications. Section 7 concludes and refers to directions for future research.

2. Literature review

Small and medium-sized enterprises (SMEs) encounter difficulty in tapping into external sources of knowledge due to lack of search capabilities and absorptive capacity. This makes spillover suboptimal and the local business ecosystem less innovative, which causes innovation system failure (Klerkx et al., 2012). To address this issue, many countries have established innovation intermediaries for SMEs as regional innovation policy. Public technology transfer organizations established by local governments, Kohsetsushi, provide SMEs with various technology extension services, such as technical consultation and engineer training, as their main function. Many also perform their own research; some patent inventions and others license patents chiefly to local SMEs. Furthermore, they connect clients with other sources of knowledge, including public research institutes and universities, which expands clients’ knowledge network. These functions suggest a positive policy effect of Kohsetsushi via spillover to local SMEs.

Empirical studies have evaluated Kohsetsushi from the perspective of resource allocation. Using panel data (2000–2006) of technology transfer activities of Kohsetsushi, Fukugawa (2008) showed that they allocated resources between exploitative tasks, such as consultation, and explorative tasks, such as inventions and patenting. Fukugawa (2016) showed that Kohsetsushi located in regions specialized in analytical knowledge-based innovations (e.g., biotechnology) tended to engage in licensing, since analytical knowledge is encapsulated in documents and thus, diffuses through licensing. Meanwhile, Kohsetsushi located in regions specialized in synthetic knowledge-based innovations (e.g., mechanical engineering) tended to engage in technical consultation, since synthetic knowledge is more tacit in nature and thus, diffuses through personal interactions. These findings suggest that Kohsetsushi allocate resources in line with the characteristics of the regional innovation system in which they are embedded, which should promote localized spillover to SMEs.

Program evaluation conducted in Western countries provides evidence from the perspective of profitability and productivity growth of client firms. Assessing the Industrial Research Assistance Program of Canada, Goss Gilroy Inc (2012) performed a partial cost–benefit analysis, assuming that expenditure was the input of the program while wages and profits of the SME sector were the value-added of the program. They concluded that the partial cost–benefit ratio was 1:11. For the US, Lipscomb et al. (2018) compiled panel data (2002–2007) by matching the establishment-level data of recipients of business assistance provided by the Manufacturing Extension Services (MEP) with the establishment-level data of the Census of Manufacturers. They estimated a difference-in-differences (DID) model and found that the treatment group’s growth of sales per production worker was 2.6% higher than that of the control group. Assessing the Manufacturing Advisory Service (MAS) of the UK, the Department for Business, Innovation and Skills (2016) compiled panel data (2012–2013) by matching the MAS monitoring database maintained by a private consultant with a comprehensive list of UK businesses from all economic sectors used by the government for national statistics. They estimated the DID model with nearest neighbor matching and showed that the treatment group’s gross value-added growth was higher than that of the control group. The cases of the MEP and MAS, which adopt a rigorous matching of treatment and control groups combined with the econometric model to estimate the ATT, demonstrate their genuine positive effects via knowledge spillover.

There have been many attempts worldwide to improve the efficiency of innovation policy to promote technology transfer through incentive system reforms. One of the most notable examples is the Bayh-Dole Technology Transfer Act (BD&A) of 1980 in the US. The BDA was triggered by the rapid expansion of the frontiers in life sciences (Rai and Eisenberg, 2003) and increasing demand for university licensing in the biotechnology field. It shifted the ownership of patents resulting from federally funded university research from the government to universities (Sampat, 2006). In Japan, the Industrial Revitalizing Special Law (IRSL, Sangyo Katsuryoku Saisei Tokubetsu Sochi Hou) 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 (Fukugawa, 2017).

Empirical studies evaluating the BDA (Henderson et al., 1998; Mowery et al., 2001; Sampat et al., 2003; Link and Hasselt, 2019) and the IRSL (Motohashi and Muramatsu, 2012; Suzuki et al., 2015) indicate that change in IP ownership has had positive effects on the number of patents that universities filed. Furthermore, the increase in the number of university patent applications has not lowered patent quality, as measured by forward citations (Sampat et al., 2003). Comparing university-industry (UI) joint patent applications with non-UI joint patent applications, Motohashi and Muramatsu (2012) showed that patent quality measured by forward non-self-citations was higher among the former. They also showed that the effect of these UI joint patents persisted before and after the national innovation system reform represented as the IRSL. Meanwhile, Suzuki et al. (2015) found that the market value of firms’ joint patents with public research institutes, measured by patent family size, declined after the enactment of the IRSL. These findings suggest that the incorporation of Kohsetsushi contributes to enhanced spillover to local SMEs. Moreover, local governments are free to choose whether to incorporate Kohsetsushi, which underpins the theory that only those that regard incorporation as a promising option to promote localized spillover actually incorporate Kohsetsushi. So far, however, no study has assessed the genuine effect of the incorporation of Kohsetsushi. Using data representative of the licensing performance of both incorporated and unincorporated Kohsetsushi, this study fills the research gap, thereby contributing to literature on technology transfer and innovation policy.

3. Hypotheses

Figure 1 illustrates the technology transfer activities of manufacturing Kohsetsushi. The LIACL is depicted as an incentive system reform encompassing IP ownership, managerial freedom, and rent sharing (Holmstrom and Milgrom, 1991). The reform brought about by the LIACL has affected various activities, including technology extension through consultation and training (3 in Figure 1), research and invention (4 and 5 in Figure 1), and patenting and licensing (6, 7, and 8 in Figure 1). For instance, incorporation enables LIACL directors to establish their own
employment standards and appoint their staff (LIACL, Article 3). Moreover, the budget of LIACs whose purpose of use was rigorously specified before the incorporation of Kohsetsushi is consolidated as kofukin (block grant) after the incorporation, which can be used at the discretion of LIACs (LIACL, Article 42). These changes increase the flexibility of resource allocation and encourage incorporated Kohsetsushi to actively seek out competitive research funds from a broader range of regions and organizations. This then motivates incorporated Kohsetsushi to enhance their scientific knowledge base (e.g., increasing PhD holders), since research quality is critical in acquiring research funding based on a peer-review system.

Furthermore, the performance of LIACs is evaluated by a third-party panel every mid-term, lasting 3 or 5 years (LIACL, Articles 11 and 25; 9 and 10 in Figure 1). As Kohsetsushi play multiple roles in the regional innovation systems, it is difficult to measure the effects, which are rather broad, using a single performance indicator. It follows that the assessment committee sets up various numerical goals for incorporated Kohsetsushi to accomplish in the next term. In this performance assessment, technology extension is customarily weighted higher than research and inventive activities. Thereafter, according to the results, the third-party panel provides suggestions to be incorporated by LIACs when reformulating their activities in the next mid-term (LIACL, Article 3). Therefore, resource allocation of incorporated Kohsetsushi is determined by both incentive and evaluation systems.

The incorporated status grants LIACs legal independence from local governments, enabling them to own IP. Incorporated Kohsetsushi inherit employee inventions made before the incorporation, and the terms of the relevant licensing agreements between governments and companies are kept intact (LIACL, Article 66). This occurs because the original licensing agreements between these parties include a clause indicating the inheritance of rights and obligations in case of organizational changes. These arrangements enable incorporated Kohsetsushi to own the patents granted before and after the incorporation, which should encourage incorporated Kohsetsushi to engage in patenting and licensing whose rent is shared between the incorporated Kohsetsushi and inventors. This rent sharing is made possible by the LIACL, which should have a positive effect on licensing efficiency (Lach and Schankerman, 2008).

Figure 1 depicts licensing income as the final output of Kohsetsushi activities. This is because it serves as an index of the commercial success of local SMEs that licensed-in Kohsetsushi patents. In other words, licensing income indicates the direct contribution of Kohsetsushi to the regional economy.2 Despite being IP owners, local governments are not adequately incentivized to commercialize Kohsetsushi patents, nor to retain human resources to commercialize Kohsetsushi patents, which in turn might have reduced licensing efficiency (Thursby and Thursby, 2002). This renders incorporation an agent of change in licensing efficiency for Kohsetsushi. Furthermore, incorporation motivates Kohsetsushi to depend less on public funding and finance their activities independently, which should encourage incorporated Kohsetsushi to enhance the generation of economic return on their patents. Incorporation of Kohsetsushi is essential for change in IP ownership and other incentive instruments that generate behavioral changes. This suggests the additionality of incorporation regarding licensing performance, which can be measured by the ATT (Imbens and Wooldridge, 2009). Therefore, this study hypothesizes as follows.

H1. Incorporation of Kohsetsushi generates a positive ATT in terms of licensing income.

Unlike the BDA and IRSL, which were uniformly and simultaneously applied to all public research institutes, the incorporation of Kohsetsushi is at the discretion of local governments, implying self-selection. The first

---

1 The weights for technology extension and inventive activities are 36% and 21%, respectively, at the Tottori Institute of Industrial Technology (https://www.pref.tottori.lg.jp/secure/997673/H26shyouka.pdf. Date of access: July 26, 2021). They are 40% and 30%, respectively, at the Yamaguchi Prefectural Industrial Technology Institute (https://www.pref.yamaguchi.lg.jp/uploaded/attachment/104847.pdf. Date of access: October 20, 2022).

2 Although licensing is suitable for assessing the direct channel through which Kohsetsushi contribute to regional economies, recent literature emphasizes the significance of the assessment of the indirect, broad effects of technology transfer organizations (National Institute of Standards and Technology, 2019). Consulting Kohsetsushi with technical problems and receiving off-the-job training improve basic technological skills of engineers in client firms, and the effects of such improvements are ultimately reflected in the productivity growth of client firms. This indirect contribution of Kohsetsushi to clients’ labor productivity was examined in Fukugawa (2022).
local governments to decide on this incorporation were those of Iwate and Tokyo in 2006, and the most recent was the government of Kanagawa in 2017. As of 2022, 17% of Kohsetsushi headquarters had been incorporated under the LIACL. Given a rational choice by local governments, there should be comparative advantage for both incorporated and unincorporated Kohsetsushi, stemming from the incorporation process. Examining the wage effect of labor union participation, Lee (1978) showed that unobserved factors affecting union participation were positively correlated with union member wage and negatively correlated with non-union member wage. This means that union members are better off by participating in labor union and non-union members also gain wage premium by opting out of unions, implying comparative advantage. Similarly, if local governments that could benefit from incorporation actually incorporated Kohsetsushi, and those that could not benefit from incorporation opted out of it, both types of Kohsetsushi would have been better off by either being incorporated or not being incorporated. This means positive selection into incorporation for incorporated Kohsetsushi and positive selection into not choosing incorporation for unincorporated Kohsetsushi. Guided by this theoretical insight, this study hypothesizes as follows.

H2. There is comparative advantage for both incorporated and unincorporated Kohsetsushi in terms of licensing income.

4. Method

4.1. Model

In Japan, the public innovation intermediary (Kohsetsushi) and the local government constitute one organization. As a part of the local government, Kohsetsushi undertake functions of innovation intermediaries, such as knowledge transfer and encouraging local SMEs to innovate. Local governments incorporate Kohsetsushi when they regard the incentive system reform as conducive to the more efficient technology transfer of Kohsetsushi. For this reason, this study considers the incorporation of Kohsetsushi as a choice variable of local governments. Moreover, this study aims to clarify how the determinants of licensing performance differ according to incorporation status. Therefore, this study adopts a two-stage endogenous switching regression model (Maddala, 1983, pp. 223–228). The first stage is the selection equation (Equation 1) estimated using a probit model.

\[
P^* = \gamma Z + \mu, \tag{1}
\]

\[
D = 1 \text{ if } P^* > 0, \quad D = 0 \text{ if } P^* < 0
\]

where \(P^*\) is a latent variable representing the local government’s tendency to incorporate Kohsetsushi, \(Z\) is factors affecting incorporation, and \(D\) is an incorporation dummy.

The second stage is the regime equations (Eqs. (2) and (3)) that switch their status according to \(D\).

\[
Y_1 = \beta_1 X_1 + e_1 \text{ if } D = 1, \tag{2}
\]

\[
Y_0 = \beta_0 X_0 + e_0 \text{ if } D = 0, \tag{3}
\]

where \(Y\) is the logged licensing income and \(X\) represents supply- and demand-side factors in Kohsetsushi patent licensing (Fukugawa, 2009). Specifically, supply-side factors are measured by the logged technical staff (technical staff) and logged patent stock (patent stock) of Kohsetsushi. Demand-side factors represent characteristics of the users of Kohsetsushi knowledge. These characteristics are measured by joint patent applications between local SMEs and Kohsetsushi. Patent applications are costly for SMEs. Therefore, when SMEs apply for a patent, they do so for immediate commercialization, not for strategic reasons, such as blocking (Giuri et al., 2005). The higher the local joint patent application ratio (local joint application ratio), the more local SMEs are motivated to commercialize Kohsetsushi patents, which should increase licensing income. Another demand-side indicator, location quotient (LQ), represents sectoral differences in needs for patent licensing. LQ is defined as \((X_p/X)/ (X/Y)\). \(X\) denotes the number of patents filed in a country and \(X_p\) denotes the number of patents in a technological field (biotechnology, chemicals, electronics, instruments, and mechanical engineering), i, filed in a region, r. As stated in Section 2, local specialization in biotechnology innovation increases the demand for licensing as analytical knowledge tends to be codified in the form of patents and innovation based on analytical knowledge tends to be disseminated through licensing (Fukugawa, 2016).

\(Z\) comprises \(X\) and an exclusion constraint. Older Kohsetsushi tend to have well-established reputation and influence in the local assembly, discouraging local governments from making drastic organizational changes, such as incorporation. Meanwhile, the year of establishment should not affect the licensing performance of Kohsetsushi. Sargan’s test (Sargan, 1958) of overidentifying restrictions fails to reject the null hypothesis that Kohsetsushi age is uncorrelated with the error term. Thus, Kohsetsushi age is correctly excluded from the regime equations.

The error terms of the selection and regime equations have a trivariate normal distribution (Equation 4), where \(\rho_{\eta}\) is the correlation coefficient between \(\eta\) and \(e_0\) (\(n=0,1\)), \(e_0\) is the standard deviation of \(e_0\), and the variance of \(\eta\) is assumed to be unity.

\[
\text{Cov}(\eta, e_0, e_1) = \begin{bmatrix}
\sigma_\eta^2 & \rho_{\eta0}\sigma_\eta & \rho_{\eta1}\sigma_\eta \\
\rho_{\eta0}\sigma_\eta & \sigma_0^2 & \rho_{\eta1}\sigma_0 \\
\rho_{\eta1}\sigma_\eta & \rho_{\eta1}\sigma_0 & \sigma_1^2
\end{bmatrix} \tag{4}
\]

The covariance of \(e_0\) and \(e_1\) is not defined, because they are not observed simultaneously, as described in Maddala (1983, p. 224). Full information maximum likelihood estimation is applied to simultaneously measure selection and regime equations. Based on the parameters estimated, following Setboonsang et al. (2008), the conditional expectation of performance of incorporated Kohsetsushi with incorporation is described by Eq. (5):

\[
E(Y_1|D = 1, X_1) = \beta_1 X_1 + \rho_{\eta1}\sigma_\eta f(Z)f(y(Z)). \tag{5}
\]

where \(f(\cdot)\) is the normal density distribution function and \(F(\cdot)\) is the cumulative normal distribution function. The conditional expectation of performance of incorporated Kohsetsushi without incorporation (counterfactual) is described by Eq. (6):

\[
E(Y_0|D = 1, X_1) = \beta_0 X_0 + \rho_{\eta0}\sigma_\eta f(Z)f(y(Z)). \tag{6}
\]

The conditional expectation of performance of unincorporated Kohsetsushi without incorporation is described by Eq. (7):

\[
E(Y_0|D = 0, X_0) = \beta_0 X_0 + \rho_{\eta0}\sigma_\eta f(Z)/(1-F(Z)). \tag{7}
\]

The conditional expectation of performance of unincorporated Kohsetsushi with incorporation (counterfactual) is described by Eq. (8):

\[
E(Y_1|D = 0, X_0) = \beta_1 X_0 + \rho_{\eta1}\sigma_\eta f(Z)/(1-F(Z)). \tag{8}
\]

The ATT is described by Eq. (9):

\[
\text{ATT} = E(Y_1|D = 1) - E(Y_1|D = 1) = E(\beta_1 X_1 + (\rho_{\eta1}\sigma_\eta f(Z)f(y(Z))/F(y(Z))|D = 1). \tag{9}
\]

Regarding the selection equation, controlling for unobserved heterogeneity by fixed-effects is not possible, as it requires local government dummies, reducing the sample and causing the estimation to fail to converge. Previous studies that had difficulty in incorporating fixed-effects into panel analysis have suggested controlling for unobserved...
heterogeneity by using pre-sample information of the outcome variable (Blundell et al., 1995; Bortoni et al., 2010). However, it is not possible to create a variable representing pre-sample history regarding the incorporation of Kohsetsushi. Therefore, this study assumes that the unobserved inclination of local governments to incorporate Kohsetsushi is represented by local governments’ appropriability of economic return on Kohsetsushi innovations prior to the empirical period. This assumption builds on the entrepreneurship theory, which explains how the incentive system affects entrepreneurial outcomes of innovative employees’ serendipitous ideas (not pertaining to standard tasks assigned by employers) (Hellmann, 2007; Hellmann and Thiele, 2011). Specifically, firms provide employees with high-powered incentives for standard tasks, which directly pertain to firms’ most lucrative business when firms cannot appropriate economic return on employee invention (e.g., employee IP ownership). By contrast, if appropriability is high (e.g., corporate IP ownership), firms allow employees to pursue their serendipitous ideas, which may create economic returns for firms to appropriate. Guided by this theoretical insight, this study assumes that the ability of local governments to appropriate innovative return on Kohsetsushi patents is measured by local joint application ratio. The higher the ratio, the more able are local governments to appropriate returns on Kohsetsushi patents, as they are more likely commercialized by local firms, which should increase local tax revenue. For the same reason, controlling for unobserved heterogeneity in the regime equations by fixed-effects is not possible, as it further reduces the degree of freedom in the estimation of the regime equations. Therefore, this study controls for unobserved capability of Kohsetsushi to generate licensing income using royalty stock accumulated prior to the empirical period (royalty stock).

4.2. Data

Information on D. Y. Kohsetsushi age, technical staff, patent stock, and royalty stock was collected from the Current Status of Kohsetsushi compiled by the Association of Directors of Manufacturing Kohsetsushi and the National Institute of Advanced Industrial Science and Technology. This survey was started in 2000 and suspended in 2009 and 2010. Some Kohsetsushi were dropped from the data owing to their organizational reform and integration, whereas other newly established or reorganized Kohsetsushi emerged in the empirical period. Therefore, unbalanced panel data were used for the estimation. Patent statistics from the Institute of Intellectual Property Patent Database (IIPPD), released in 2020, were used to create LQ and local joint application ratio with a 3-year lag. The location of the innovation was identified by the IIPPD inventor file. Furthermore, the data from the IIPPD were matched with those in the National Institute of Science and Technology Policy Corporate Database (NCD). The NCD was used to identify SMEs’ patents. A World Intellectual Property Organization concordance table (WIPO, 2013) was used for matching international patent classification (IPC) to technological fields. The address information of inventors in the IIPPD was used to identify the location of patents at the prefecture level. The application year was used to identify time. See Fukugawa (2016) for details.

5 In estimating a random-effects logistic regression model whose dependent variable is a patent application dummy, the previous studies controlled for unobserved heterogeneity among firms by patent application stock accumulated prior to the empirical period.

6 As local public organizations, Kohsetsushi aim to promote localized spillover. In fact, local governments arrange licensing contracts for local SMEs with the lowest royalty rate applied. For this reason, this study assumes the absence of spatial dependence of the error terms.

7 Previous studies suggest various factors affecting time required for X to generate Y, such as region (Lehrer, 2007), technological readiness (Sternitzke, 2010) and product (Fukugawa, 2019), with the distribution being highly skewed (Nagao and Walsh, 2009). Because of the lack of relevant information, it is difficult to know how long it takes for Kohsetsushi patents to yield economic returns. This study assumed a 3-year lag structure between X and Y.

The unbalanced panel (2000–2009 and 2012–2020) consists of 2821 observations. The dataset includes 19 incorporated Kohsetsushi branches and 266 unincorporated Kohsetsushi branches. Descriptive statistics of the variables are presented in Appendix Table 1. Correlation matrix is presented in Appendix Table 2. Technological fields identified by the WIPO IPC-technology concordance table are summarized in Appendix Table 3.

5. Results

Tables 1 and 2 present the estimation results of the endogenous switching regression model and the average treatment effect, respectively. The likelihood-ratio test rejects the null hypothesis of independent equations, meaning that the selection is real. Younger Kohsetsushi tend to be incorporated, as predicted. The coefficient of local joint application ratio is significantly positive, indicating that local governments incorporated manufacturing Kohsetsushi that relied more on localized knowledge networks. Kohsetsushi with more employees tend to be incorporated.

| Table 1. Estimated endogenous switching regression model. |
|----------------------------------------------------------|
| Dependent variable: log of licensing income of unincorporated Kohsetsushi | Coefficient | S.E. |
| Log of technical staff | 0.020 | 0.152 |
| Log of patent stock | 0.957 | 0.085 *** |
| Local joint application ratio | 3.031 | 0.621 *** |
| Log of royalty stock | 0.569 | 0.062 *** |
| LQ biotechnology | 0.130 | 0.114 |
| LQ chemicals | 0.345 | 0.144 ** |
| LQ electronics | 0.415 | 0.323 |
| LQ instruments | 0.049 | 0.309 |
| LQ mechanical engineering | -0.508 | 0.204 ** |
| Constant | -1.434 | 0.797 * |

Dependent variable: log of licensing income of incorporated Kohsetsushi

Log of technical staff | 0.238 | 0.405 |
Log of patent stock | 1.078 | 0.211 *** |
Local joint application ratio | -5.597 | 1.721 *** |
Log of royalty stock | 0.195 | 0.117 * |
LQ biotechnology | 0.908 | 0.599 |
LQ chemicals | 0.906 | 0.292 *** |
LQ electronics | 1.842 | 1.402 |
LQ instruments | -3.270 | 1.419 ** |
LQ mechanical engineering | -1.246 | 1.570 |
constant | 2.980 | 2.143 |

Dependent variable: Incorporation dummy

Kohsetsushi age | -0.077 | 0.014 *** |
Log of technical staff | 0.991 | 0.216 *** |
Log of patent stock | -0.198 | 0.109 * |
Local joint application ratio | 7.005 | 0.988 *** |
Log of royalty stock | 0.242 | 0.067 *** |
LQ biotechnology | 0.685 | 0.135 *** |
LQ chemicals | -0.018 | 0.143 |
LQ electronics | 0.853 | 0.436 * |
LQ instruments | -0.563 | 0.480 |
LQ mechanical engineering | -1.580 | 0.368 *** |
constant | -6.145 | 1.238 *** |
\sigma_0 | 1.960 | 0.054 *** |
\sigma_1 | 1.381 | 0.095 *** |
\rho_0 | 0.503 | 0.168 ** |
\rho_1 | 0.027 | 0.237 |

Notes: N = 810.
LR test of independent equations: chi2(2) = 6.29**.
Level of significance: *** 1%, ** 5%, * 10%.
Log of patent stock is negatively associated with the probability of incorporation while log of royalty stock is positively correlated with it. Regarding supply-side factors in patent licensing, codified knowledge stock increases licensing income of both types of Kohsetsushi. The elasticity of licensing income of incorporated Kohsetsushi to codified knowledge stock is greater than one while that of incorporated Kohsetsushi is smaller than one. Meanwhile, tacit knowledge embodied into technical staff does not affect licensing performance. The effects of demand-side factors in patent licensing differ by incorporation status. The coefficient of \( \text{local joint application ratio} \) is significantly positive among unincorporated Kohsetsushi. This suggests that appropriability and regional embeddedness work together to increase licensing income of unincorporated Kohsetsushi. Specifically, their licensing performance depends on localized knowledge networks, which start to develop when they consult local SMEs. Meanwhile, regional embeddedness reduces licensing performance of incorporated Kohsetsushi. This suggests that innovation in these technological fields builds on synthetic knowledge, which tends to be tacit and disseminated through interpersonal channels (e.g., consultation) rather than codified media (Fukugawa, 2016).

\( \rho_0 \) being significantly positive suggests negative selection into opting out of incorporation for unincorporated Kohsetsushi. As described in Eq. (7), Kohsetsushi that were not incorporated have below-average licensing income without incorporation. Meanwhile, as described in Eq. (6), if incorporated Kohsetsushi were not incorporated, they would have had licensing income greater than that of unincorporated Kohsetsushi. Table 2 indicates that the ATT is significantly negative while the average treatment effect on the untreated (ATU) is significantly positive. The former implies that incorporation genuinely reduced the contribution of Kohsetsushi to local economies through the enhanced commercialization of their patents. The results provide no evidence of comparative advantage for both types of Kohsetsushi. Therefore, neither H1 nor H2 are supported by the data. Lastly, the average treatment effect (ATE) is significantly positive. This suggests that policy evaluation without taking account of endogenous selection could yield misleading implications for the redesign of the policy.

To test the sensitivity of the results from the endogenous switching regression model, the fully interacted model is estimated, with one equation for all observations in which all regressors are multiplied by a dummy variable representing incorporated and another representing unincorporated Kohsetsushi. The results are presented in Table 3. Logged patent stock has a positive effect on licensing performance for both types of Kohsetsushi. The elasticity of licensing income to patent stock is greater than one among incorporated Kohsetsushi. Meanwhile, it is smaller than one among unincorporated Kohsetsushi, which is consistent with the estimation results of the endogenous switching regression model. The coefficient of \( \text{local joint application ratio} \) is positive and negative among unincorporated Kohsetsushi and incorporated Kohsetsushi, respectively, which is also consistent with the results from Table 1. The results of local specialization into chemicals, instruments, and mechanical engineering are also consistent with those of the endogenous switching regression model. The result of the Chow test shows that the coefficients differ significantly by incorporation status, indicating that the endogenous switching regression model is more efficient.

### 6. Discussion

Although \( \rho_0 \) is not statistically significant, the result that both \( \rho_0 \) and \( \rho_1 \) are positive indicates that incorporated Kohsetsushi have greater licensing income both with and without incorporation. This implies that the negative ATT of incorporation is not a result of the incorporation of networks. This result suggests that their licensing performance depends on inventions created through quality research and broad knowledge networks. The specialization of the innovative activities of local SMEs in chemicals is positively associated with patent licensing of Kohsetsushi in the region because of the aforementioned sectoral characteristics of innovation. Meanwhile, the specialization of the innovative activities of local SMEs in instruments negatively affects licensing performance of incorporated Kohsetsushi. The specialization in mechanical engineering negatively affects licensing performance of unincorporated Kohsetsushi. This suggests that innovation in these technological fields builds on synthetic knowledge, which tends to be tacit and disseminated through interpersonal channels (e.g., consultation) rather than codified media (Fukugawa, 2016).
Kohsetsushi with low licensing income, negating reverse causality. In other words, local governments did incorporate Kohsetsushi with higher licensing performance, ending up with a negative ATT. One possibility of the mechanism through which the incentive system reform generated an unintended consequence is the lack of harmonization between the incentive and evaluation systems.

As mentioned in Section 2, the incentive system reform provides high-powered incentives for research and inventive activities while the assessment committee tends to emphasize technology extension that helps localized knowledge networks develop. However, as shown in Table 1, localized knowledge networks are negatively associated with licensing performance of incorporated Kohsetsushi. In other words, the source of commercially successful inventions of incorporated Kohsetsushi shifted from exploitative tasks based on localized knowledge networks to explorative tasks based on geographically broad knowledge networks. As the numerical targets set by the third-party panel tend to ratchet with every mid-term assessment, technical staff of incorporated Kohsetsushi must have faced a serious trade-off in resource allocation. The misalignment between the two systems seems to have stemmed from difficulties in understanding the economic consequences of the incentive system reform. As Figure 1 indicates, licensing performance is contingent on the outputs in the previous stages, and it is difficult for the assessment committee to foresee the chain reaction and its composite effects. Therefore, the assessment committee should flexibly rearrange the assessment scheme as the incentive system and evaluation system are complementary to organizational performance.

Flexible rearrangement would allow incorporated Kohsetsushi to implement drastic changes in their resource allocation. Specifically, an emphasis on research and inventive activities should be placed in the assessment process of incorporated Kohsetsushi even though it would reduce resources allocated to diffusion and extension activities. Meanwhile, this strategy would have incorporated Kohsetsushi functionally overlap with other innovation system constituencies, such as local universities. To differentiate themselves from other knowledge providers in regional innovation systems, incorporated Kohsetsushi should identify a niche market for technological knowledge by utilizing both scientific knowledge and knowledge of local economic contexts, thereby avoiding overlapping investment.

7. Conclusion

This study is the first to elucidate the economic consequences of incentive system reform applied for public innovation intermediaries for SMEs. The results revealed the unintended consequence of the incentive system reform. First, the ATT of incorporation was negative. Second, there was negative selection into not choosing incorporation. Incorporated Kohsetsushi would have had higher licensing income had they not been incorporated. Third, there was no evidence of comparative advantage as a product of self-selection by local governments. The results of the robustness check corroborated the finding that the determinants of licensing performance significantly differ by incorporation status.

These findings imply that the misalignment of the incentive and evaluation systems might have caused unintended consequences. Enhanced managerial freedom of resource allocation and rent sharing combined with the transfer of IP ownership encouraged incorporated Kohsetsushi to upgrade research quality (e.g., increasing PhD holders), which expanded their knowledge networks. This then caused incorporated Kohsetsushi inventions to be based more on science than local technological needs recognized by Kohsetsushi staff through technical consultation. This would have further affected the position and function of manufacturing Kohsetsushi in regional innovation systems and calls for a new division of labor among other innovation system constituencies, such as local universities. It is difficult for the assessment committee to foresee the composite effects of the incentive system reform on technology transfer activities of Kohsetsushi. Therefore, flexible rearrangement of the assessment scheme is needed to make the reform of incentive system and the reform of the evaluation system complementary.

This study assumed that local SMEs commercialized Kohsetsushi patents. However, research-intensive incorporated Kohsetsushi may patent more, leveraging their scientific knowledge rather than local technological needs, which may increase solo patents. If the commercialization of solo patents relies more on intermediaries that bridge invention and the market, the geographical range of the search for potential licensees may expand. This suggests that the error terms can be spatially correlated because of unobservable factors. Then, spatial dependence of the error terms needs to be corrected from a spatial econometric approach.

Declarations

Author contribution statement

Nobuya Fukugawa: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Funding statement

This study was supported by the Japan Society for the Promotion of Science [21K01458].

Data availability statement

The data that has been used is confidential.

Declaration of interest’s statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

---

8 Such a trade-off does not exist among agricultural Kohsetsushi exclusively engaged in research and inventive activities. Agricultural extension activities are undertaken by a different division of local governments (Fukugawa, 2019).
Acknowledgements

This study was conducted as a part of the project Frontier of Innovation Policy: Evidence from Micro Data at the Research Institute of Economy, Trade and Industry (RIETI). I thank project members and participants in the RIETI Discussion Paper Workshop and the Innovation Economics Workshop for their comments on the earlier draft. I appreciate comments from anonymous referees. The usual caveats apply.

References

Bertoni, F., Croce, A., D’Adda, D., 2010. Venture capital investments and patenting activity of high-tech start-ups: a micro-econometric firm-level analysis. Ventur. Cap. 12 (4), 307–326.
Blundell, R., Griffith, R., Reenen, J., 1995. Dynamic count data models of technological innovation. Econ. J. 105 (429), 333–344.
Department for Business, Innovation and Skills (BIS), 2016. The Manufacturing Advisory Service (MAS) Impact Analysis Methodology Study, BIS Analysis paper number 246.

Fukugawa, N., 2008. Evaluating the strategy of local public technology centers in regional innovation systems: evidence from Japan. Sci. Publ. Pol. 35 (3), 159–170.
Fukugawa, N., 2009. Determinants of licensing activities of local public technology centers in Japan. Technovation 29 (12), 885–892.
Fukugawa, N., 2016. Knowledge creation and dissemination by Kosetsushi in sectoral innovation systems: insights from patent data. Scientometrics 109 (3), 2303–2327.
Fukugawa, N., 2017. University spillover before the national innovation system reform in Japan. Int. J. Technol. Manag. 73 (4), 206–234.
Fukugawa, N., 2018. Division of labor between innovation intermediaries for SMEs: productivity effects of inter-firm organizations in Japan. J. Small Bus. Manag. 56 (S 1), 297–322.
Fukugawa, N., 2019. Determinants and impacts of public agricultural research: product-level evidence from agricultural Kosetsushi in Japan. Scientometrics 120 (3), 1475–1498.
Fukugawa, N., 2022. Productivity Effect of Technology Extension Services: Evidence from Japan’s Kosetsushi.[Unpublished manuscript].
Giuri, P., Marzani, M., et al, 2005. Everything You Always Wanted to Know about Inventors (But Never Asked): Evidence from the PatVal-EU Survey. LEM working paper number 2005/20.
Gox Gilroy Inc, 2012. Evaluation of the NRC Industrial Research Assistance Program (NRC-IRAP).
Hellmann, T., 2007. When do employees become entrepreneurs? Manag. Sci. 53 (6), 919–933.

Appendix Table 1 Descriptive statistics

| Variable                        | N     | Mean | S.D. | Min   | Max   |
|--------------------------------|-------|------|------|-------|-------|
| Log of licensing income        | 814   | 5.136| 2.634| 0     | 9.93  |
| Log of technical staff         | 2,173 | 3.381| 0.871| 0.693 | 5.579 |
| Log of patent stock            | 2,102 | 3.096| 1.721| 0     | 7.188 |
| Local joint application ratio  | 2,821 | 0.43 | 0.142| 0.073 | 0.8   |
| LQ biotechnology               | 2,821 | 1.586| 0.973| 0     | 5.671 |
| LQ chemicals                   | 2,821 | 1.186| 0.548| 0     | 3.793 |
| LQ electronics                 | 2,821 | 0.624| 0.348| 0.001 | 1.554 |
| LQ instruments                 | 2,821 | 0.7118|0.294|0.002  |1.472  |
| LQ mechanical engineering      | 2,821 | 1.265| 0.433| 0     | 2.463 |
| Incorporation dummy            | 2,814 | 0.048| 0.214| 0     | 1     |
| Kohsetsushi age                | 2,821 | 50.081|36.272|0     |149   |

Appendix Table 2 Correlation matrix

|        | 1     | 2     | 3     | 4     | 5     | 6     | 7     |
|--------|-------|-------|-------|-------|-------|-------|-------|
| Log of licensing income        | 1.000 |       |       |       |       |       |       |
| Log of technical staff         | 0.385*| 1.000 |       |       |       |       |       |
| Log of patent stock            | 0.607*| 0.635*| 1.000 |       |       |       |       |
| Local joint application ratio  | 0.202*| 0.015 | 0.194*| 1.000 |       |       |       |
| Incorporation dummy            | 0.192*| 0.203*| 0.221*| 0.261*| 1.000 |       |       |
| Kohsetsushi age                | 0.111*| 0.089*| 0.035 | -0.001| -0.221*| 1.000 |       |
| Log of royalty stock           | 0.509*| 0.321*| 0.478*| 0.249*| 0.302*| 0.002 | 1.000 |

Note: Level of significance: * 1%.

Appendix Table 3 Technological fields

| Biotechnology                  | Chemistry                                          | 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-     | IT methods for management                          | Optics                  | Other special machines                         |                        |                                    |
| technology                     |                                                    |                        | Textile and paper machines                    |                        |                                    |
| Surface technology, coating    | Semiconductors                                     | Thermal processes and apparatus Transport |                        |                        |                                    |
| Organic fine chemistry         |                                                    |                        |                                               |                        |                                    |
|                                  |                                                    |                        |                                               |                        |                                    |

Acknowledgements

This study was conducted as a part of the project Frontier of Innovation Policy: Evidence from Micro Data at the Research Institute of Economy, Trade and Industry (RIETI). I thank project members and participants in the RIETI Discussion Paper Workshop and the Innovation Economics Workshop for their comments on the earlier draft. I appreciate comments from anonymous referees. The usual caveats apply.
Hellmann, T., Thiele, V., 2011. Incentives and innovation: a multitasking approach. Am. Econ. J. Microecon. 3 (1), 78–128.

Henderson, R., Jaffe, A., Trajtenberg, M., 1998. Universities as a source of commercial technology: a detailed analysis of university patenting, 1965–1988. Rev. Econ. Stat. 80 (1), 119–127.

Holmstrom, B., Milgrom, P., 1991. Multitask principal–agent analyses: incentive contracts, asset ownership, and job design. J. Law Econ. Organ. 7, 24–52. Spl. Iss.

Imbens, G., Wooldridge, J., 2009. Recent developments in the econometrics of program evaluation. J. Econ. Lit. 47 (1), 5–86.

Intarakumnerd, P., Chaoroenporn, P., 2013. The roles of intermediaries in sectoral innovation system in developing countries: public organizations versus private organizations. Asian J. Technol. Innovat. 21 (1), 108–119.

Klerkx, L., Mierlo, B., Leeuwis, C., 2012. Evolution of systems approaches to agricultural innovation: concepts, analysis and interventions. In: Darnhofer, I., Gibbon, D., Dedieu, B. (Eds.), Farming Systems Research into the 21st century: the New Dynamic. Springer, Dordrecht, pp. 457–483.

Lach, S., Schankerman, M., 2008. Incentives and invention in universities. Rand J. Econ. 39 (2), 403–433.

Lee, L., 1978. Unionism and wage rates: a simultaneous equations model with qualitative and limited dependent variables. Int. Econ. Rev. 19 (2), 415–433.

Lehrer, M., 2007. Organizing knowledge spillovers when basic and applied research are interdependent: German biotechnology policy in historical perspective. J. Technol. Tran. 32 (3), 277–296.

Link, A., Van Hasselt, M., 2019. On the transfer of technology from universities: the impact of the Bayh–Dole Act of 1980 on the institutionalization of university research. Eur. Econ. Rev. 119, 472–481.

Lipscomb, C., Youtie, J., Shapira, P., Arora, S., Krause, A., 2018. Evaluating the impact of manufacturing extension services on establishment performance. Econ. Dev. Q. 32 (1), 29–43.

Madhava, S., 1983. Limited-dependent and Qualitative Variables in Economics. Cambridge University Press, Cambridge, UK.

Motohashi, K., Muramatsu, S., 2012. Examining the university industry collaboration policy in Japan: patent analysis. Technol. Soc. 34 (2), 149–162.

Mowery, D., Nelson, R., Sampat, B., Ziedonis, A., 2001. The growth of patenting and licensing by U.S. universities: an assessment of the effects of the Bayh-Dole Act of 1980. Res. Pol. 30 (1), 99–119.

Nagatka, S., Walsh, J., 2009. The R&D Process in the U.S. And Japan: Major Findings from the RIETI-Georgia Tech Inventor Survey, RIETI Discussion Paper Series 09-E-010.

National Institute of Standards and Technology, 2019. Return on Investment Initiative for Unleashing American Innovation, 1234. NIST Special Publication.

Rai, A., Eisenberg, P., 2003. Bayh-Dole reform and the progress of biomedicine. Law Contemp. Probl. 66, 289–314.

Sampat, B., 2006. Patenting and US academic research in the 20th century: the world before and after Bayh-Dole. Res. Pol. 35 (6), 772–789.

Sampat, B., Mowery, D., Ziedonis, A., 2003. Changes in university patent quality after the Bayh–Dole Act: a re-examination. Int. J. Ind. Organ. 21 (9), 1371–1390.

Sargan, J., 1958. The estimation of economic relationships using instrumental variables. Econometrica 26 (3), 393–415.

Setboonsarng, S., Leung, P., Stefan, A., 2008. Rice Contract Farming in Lao PDR: Moving from Subsistence to Commercial Agriculture. Asian Development Bank Institute, Tokyo. Discussion paper 90.

Sternitzke, C., 2010. Knowledge sources, patent protection, and commercialization of pharmaceutical innovations. Res. Pol. 39 (6), 810–821.

Suzuki, J., Tsukada, N., Goto, A., 2015. Role of public research institutes in Japan’s national innovation system: case study of AIST, RIKEN and JAXA. Sci. Technol. Soc. 20 (2), 133–160.

Thursby, J., Thursby, M., 2002. Who is selling the ivory tower? Sources of growth in university licensing. Manag. Sci. 48 (1), 90–104.

World Intellectual Property Organization, 2013. International patent classification. Concordance table, https://www.wipo.int/ipstats/en/statistics/patents/xls/ipc_tech nology.xlsx. Date of access. (Accessed 2 March 2022).