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Running royalty and patent citations:
The role of measurement cost in unilateral patent licensing[1]

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[1] This paper is a product out of the NISTEP research project on international patent licensing. This paper also benefited from the discussion with Noriyuki Yanagawa, with whom a joint project is under way along with this paper. The text of this discussion paper is solo-authored by the time of this publication, and therefore all misunderstandings are author's own.

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Abstract

This paper empirically examines and interprets how royalty is structured by combining the fixed royalty component and the running royalty component, utilizing the U.S.-Japan patent licensing data. Risk sharing theory predicts that the increase of risk (implied by more forward citations to a licensed patent) will favor the use of running royalty rather than simple fixed royalty to share the risk. The principal and agent framework predicts that, if a licensee has greater scope of entrepreneurial effort (as well as of moral hazard) than a licensor, it will favor fixed royalty. The same framework also predicts that, if a licensor has a margin of moral hazard, it will favor running royalty. Thus, as long as transaction cost (TC) is neglected, theoretical predictions critically depend on the ad hoc assumptions of risk aversion, the scope of entrepreneurial effort, and of moral hazard. Instead of this TC-free argument, this paper follows prior studies in agriculture and in movie film, which recognize the importance of measurement cost. While running royalty is computed from royalty base, i.e., sales of final products, a patent with larger number of citing patents has a more diversified royalty base, which is more costly to specify and measure. As the scope of the royalty base becomes more complex, it is more costly to determine whether or not those products based on citing patents infringe the originating patent. Thus, running royalty is expected to incur more costs to measure royalty base, as the number of citing patents increase. The efficiency gain from share contracting will be eventually overridden by the increase in measurement cost. The empirical evidence indeed shows that running royalty is less frequently used when there are more citing patents (forward citations) to licensed patents. The finding is consistent with the interpretation that measurement cost matters in share contracts of technology licensing.

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1. Introduction

Running royalty is said to be the most typical form of royalty in technology licensing (McGavock, Haas, and Patin 1993). Running royalty is a royalty scheme which is derived from a royalty rate (percentage rate or dollar amount) applied to a royalty base (dollar of sales, or units sold of final products, in realized terms), and therefore belongs to the family of share contracts (Smith and Parr, 2000; Bhattacharyya and Lafontaine, 1995). An ongoing relationship between licensing firms with a need for collaboration and mutual monitoring is thus indicated.[1] In addition to running royalty, many licensing contracts require a fixed amount of initial payment (Smith and Parr, 2000). Despite theoretical efforts to model share contracting (Gallini and Wright 1990; Beggs 1992; Bhattacharyya and Lafontaine, 1995), there are few empirical investigations into how different royalty schemes are structured from fixed royalty and running royalty components in technology licensing contracts. This paper empirically examines how royalty is structured by combining the running royalty component and the fixed royalty component by utilizing U.S.-Japan patent licensing data[2].

There exist a number of empirical investigations on share contracts, however, in the context of sharecropping and franchising. Among several factors determining royalty types, "risk" was first identified and tested, with mixed results (Cheung, 1969; Rao, 1971). The principal-agent framework was then introduced (Stiglitz, 1974) and employed for empirical testing. Findings from the tests supported certain relationships between moral hazard and royalty types (Brickley and Dark, 1987; Sen, 1993). This approach further evolved into double-sided moral hazard models (Lafontaine, 1992; Bhattacharyya and Lafontaine, 1995). In the meantime, a rather different approach focusing on measurement cost (Barzel, 1982)

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[1] Practitioners consider running royalty as a form of deferred payment plan where installments can be made over a period of a licensing contract (Martone 1994), and/or as a sign of a "participation by licensor in success" (Goldscheider 1994) where "success" is to be realized ex post. Thus, unlike pure fixed royalty, a running royalty contract can be interpreted as one kind of long-term contractual arrangement.

[2] Attention is given to unilateral patent licensing only, i.e., cross-licensing or licenses between joint venture partners are excluded.

was also introduced with empirical supports (Allen and Lueck, 1992, 1993). The last approach does not require ad hoc assumptions of risk-aversion such as in the principal and agent models (Allen and Lueck, 1995, 1999). Measurement cost must not be neglected in technology licensing contracts, because the royalty base, e.g., realized sales of specific products, should be monitored and measured when running royalty is to be enforced.

As I will argue later, the number of patent citations (in the sense of forward citations) is relevant to the measurement cost of final output. In short, if a patent has a large number of citing patents, it suggests that the originating patent has many applications in final products. While running royalty is computed from royalty base, i.e., sales of final products, a patent with larger number of citing patents may have a more diversified royalty base, which is more costly to specify and measure. Assuming that the number of citing patents is positively correlated with the cost of measurement, an exploration between citation counts and royalty types will shed light on the relationship between measurement cost and share contracting in technology licensing, which has not been studied empirically.

This paper first reviews existing literature on share contracting, especially sharecropping (section 2), and discusses the implications of risk, moral hazard, and measurement cost for the choice of royalty types. The following section (section 3) explains an interpretation about the number of forward citations with respect to measurement costs. Hypotheses consistent with this interpretation are presented. Then, the data (section 4) and the specifications of econometric tests are explained (section 5), which is followed by results and discussion (section 6), and conclusion (section 7).

2. Prior literature on share contracting

Cheung (1969) first proposed “risk” as a determinant of the choice between sharecropping and a fixed-rent contract. On the one hand, “transaction cost” was claimed to be higher in share contracting than in fixed-rent contracting, because of higher costs in negotiation and enforcement, e.g., those costs of specifying the types of crops to be grown, or of measuring the actual yield of the crops. If "transaction cost" is the only consideration, he pointed out, "share contracts will never be chosen." On the other hand, since risk exists in any tenancy and agents are risk-averse, a share contract should always be preferred to fixed-rent contract if there is no cost associated with complex share contracting. He posited that the balance be made between risk dispersion and "transaction cost," in such a way that:

> … since some dispersion of risk is preferred to no dispersion at all, a share contract will be chosen … if the higher transaction cost is at least compensated for by the gain from risk aversion (Cheung, 1969, p.27).

According to the inference, share contracts are preferred to fixed-rent contracts when risk is high, and when the merit in dispersion of risk exceeds the "transaction cost" of share contracting. Comparative analysis of alternative contractual arrangements is thus introduced, where comparison between the gain from risk sharing and "transaction cost" is the underlying logic. However, the notion of "risk" and "transaction cost" was left for further development.

After Cheung's pioneering work, follow-up literature mainly focused on elaborating the "risk" concept, and on formalizing the notion of asymmetric information in the face of risk within the principal and agent framework. As an initial step, Rao (1971) refuted Cheung's proposition by showing that Indian crops with higher variance in harvest yield tended to be grown on cash-rented land than on a crop-shared basis. Rao (1971) further found that fixed-rent contract predominated when the range for decision making by the farmer, such as factor substitution, was significant. The explanation was that fixed-rent leaves more entrepreneurial profit for farmers and that efficiency gain is added when there is a wide scope of entrepreneurship for farmers, where decision making is hard to be observed by land owners. In fact, this explanation was a forerunner of the principal and agent framework (Stiglitz 1974), because unobservable efforts made by farmers are the margin for moral hazard behavior, and efficiency can be enhanced by increasing residual profit to farmers when the margin is larger.

In the following two decades, the models based on the principal and agent framework flourished. A number of papers have tried to analyze how running royalty works from this viewpoint. For example, a line of literature has shown in formal models that information asymmetry regarding the value of a licensed patent leads to the use of running royalty as a signaling device of its value (Gallini and Wright 1990, Beggs 1992), though empirical findings do not clearly support the results of the signaling model (Lafontaine 1993). Another body of literature emphasizes the need for supporting effort by a licensor for a licensee in explaining the choice of fee types (Lal 1990, in franchising contexts). In addition to the models that assumed private information only in a single actor, double-sided moral hazard models were developed and used for empirical tests (Lafontaine, 1992; Bhattacharyya and Lafontaine, 1995). Risk in the sense of uncertainty from external or natural forces is an indispensable factor in most of the principal and agent literature. The degree of risk aversion of the participating actors is assumed rather than derived from reality, though the relative importance of risk-aversion, i.e., which party is more risk-averse, is critical for the predictions of royalty types in the models.

While theoretical formalization in the principal and agent framework was in progress, the notion of "transaction cost" depicted for sharecropping by Cheung (1969) was also elaborated in the sense of measurement cost (Barzel, 1982; Kenny and Klein, 1983). In a sharecropped contract, output must be measured and divided, where a farmer has an incentive to underreport the harvest to the landowner, implying a high enforcement cost borne by the landowner to receive the pre-specified share (Allen and Lueck, 1992). The measurement cost is not uniform among different crops, because some are weighed and graded by an independent party (Allen and Lueck, 1992, p.408) while others are not. When measurement cost is high, efficiency improvement supplied by sharecropping (in terms of decreased distortion in factor inputs in the Allen and Lueck study) may be overridden. Indeed, it was found that crops with higher measurement cost tended to be on a cash-rent basis, not on sharecropping. In addition to the example from farming studies, there are other findings where measurement cost has important efficiency implications in contractual choices, such as in film distribution and in uncut diamond transactions (Kenny and Klein, 1983). This approach does not require the ad hoc assumptions about risk-aversion placed in the standard principal and agent models (Allen and Lueck, 1995, 1999). Thus, whereas the principal and agent framework sophisticated the notion of private information under the existence of external shocks from natural forces, the cost of measurement per se was found to affect the efficiency of contractual choices.

3. The framework and hypotheses

3.1 Risk, private information, measurement cost, and patent citations

The number of patent citations (in the sense of forward citation) to licensed patents may be associated with many of the aforementioned factors in the literature of share contracts, namely, risk, the value of patents to be signaled by licensors, entrepreneurial scope and efforts by licensees, moral hazards by both parties, and the cost of measuring the final output to be split. I first consider the meanings of patent citations in relation to these issues. I then draw some testable implications and establish hypotheses.

Patent citation is assigned to U.S. patents when a previously granted patent represents a prior piece of knowledge for a patent. Because of the characteristics of technological antecedents and descendents represented by citations, patent citations have been utilized for empirical studies on R&D spillover and/or knowledge flow (Jaffe, Trajtenberg, and Henderson 1993). The uncertainty associated with a highly-cited patent is relevant to the entrepreneurial scope by licensees, as was indicated by Rao (1971). When a licensed technology has great potential for further improvements and applications, a licensee has a wider scope of decision making in the choice of development objectives and in the allocation of resources for the development. The preferences and choices made by a licensee are not always observable by a licensor. The room for private information implies the possibility of moral hazard, in the sense that a licensee may not make the "proper" endeavor to maximize joint profits of the licensee and the licensor.

Not only a licensee but also a licensor has chances to keep some information private. For instance, a licensor, being usually an inventor as well, may have superior knowledge, compared to outside technology buyers, about the future potential of the technology. The value and future path of the technology as private information may be signaled to a potential buyer, but the transmission cannot be complete before contracting due to the difficulty of trading information (Arrow, 1962). Also, technology transfer often requires a long and costly process, and active participation by a licensor is sometimes indispensable for effective transfer of technology (Teece, 1976; Kogut and Zander, 1993). Namely, collaborative efforts supplied by a licensor are necessary for the absorption of licensed technology as well as for the development and sales of products. However, a licensor's effort is only incompletely observable, and moral hazard is possible. That is, the licensor may not make "proper" endeavor to maximize joint profits between the licensee and the licensor.

In addition to risk and private information problems, measurement cost is pertinent, especially when a large number of citations are given to a licensed patent. In short, the measurement cost of determining the royalty base is higher for a patent with a large number of forward citations, when running royalty is used. In order to validate this argument, the nature of patent citation and the cost of litigation to determine infringement must be considered.

In order to obtain a patent, an inventor must show that her/his invention is innovatively different from relevant prior art, and the relevant prior art is acknowledged as patent citations (Meyer, 2000). As a result, patent-to-patent citation delimits the scope of the claims of a patent in relation to the claims of its citing patent. It means that citing patents, being close to the cited patent in technological space, may be substitutive or complementary to their originating patent when the patents are actually commercialized. However, statutory patent documents do not specify whether a citing patent is complementary or substitutive to its originating patent. In other words, an inventor of a citing patent cannot officially determine whether the citing patent is "inventing around" the cited patent, or the citing patent is an "add-on" to the cited patent in commercialization. Litigation is eventually needed to determine whether a product based on a patent is infringing another patent that is owned by another holder. As recent evidence shows (Lerner, 1995; Lanjouw and Schankerman, 2001) patent infringement litigation is very costly.

Since running royalty is derived from a royalty rate applied to a royalty base (dollar of sales, or units sold of final products, in realized terms), the royalty base must always be specified and measured as long as running royalty is to be implemented. On the other hand, if a licensed patent has many citing patents in a short period of time, the technological area to which the patent belongs experiences fast innovation. It is likely that there are many new applications of the originating patent as well. Each of a licensee's new products must be examined to determine whether it is infringing the original patent or not – namely, whether it is a part of the royalty base or not. However, it is also possible that a licensee no longer needs to pay for the original patent for newly released products, because they are based on substitutive technology. Because the cost to determine the scope of infringing products concerning a patent is very high, and because a large number of citing patents suggest that a variety of potentially infringing and non-infringing products are emerging, the cost to determine the scope of the royalty base by way of litigation can be enormous when there are many citing patents. With or without judicial procedure, a licensee tends to underreport the royalty base, whereas a licensor tends to overstate the scope of the royalty base. Therefore, measurement cost over the royalty base becomes higher with the cost of haggling if a patent has many citations in a short period of time. The cost of measurement increases rapidly as the number of citing patent increases, because potential conflicts of infringement/non-infringement increase fast with the emergence of a number of new products and new patents.

3.2 Hypotheses

The argument above is that the problem of risk, moral hazard, hidden information, and measurement cost become more significant as forward citation counts to a patent increase. The way in which the increase of the number of citations influences the royalty structure is complex. An individual contributing factor, such as “moral hazard effect,” cannot always be tested independently from another factor. While it is impossible to test all of the individual predictions from risk-sharing theory or the principal-agent framework, it is possible to make gross predictions of the comparison between the measurement cost associated with the use of running royalty and the merit of using running royalty in terms of risk dispersion or of incentive adjustment perceived by the principal-agent framework. The basis for the argument is that the measurement cost associated with running royalty increases fast with the increase of follow-up innovations. As a result, the marginal merit from employing running royalty decreases with the increase of follow-up innovations, as will be argued below. This is essentially an argument similar to the work by Cheung (1969) comparing the cost of measurement with “the gain from risk sharing.”

First, it should be noted that the rate of running royalty in technology licensing is usually low. Annual reports of technology importing contracts by the National Institute of Science and Technology repeatedly show that most running royalty rates in electronics and machinery industries are less than 5% of the final sales, and that running royalty rates exceeding 10% are rare, especially when software is not involved (NISTEP, 1987-2000). Also, another survey of domestic licensing in the U.S. shows that approximately 90% of running royalty rates are less than 5% in the automotive and computer industries (McGavock, Haas, and Patin, 1993).[3] The rate of running royalty is often negotiated according to the industry's customary rate (McGavock, Haas, and Patin, 1993). As a result, it is unlikely that firms can employ very different rates for individual licensing transactions, even if the extents of risk-aversion differ significantly. Since the rate of running royalty is low in most cases, most of the variation in the sales is borne by licensees. For instance, when the rate of running royalty is at 5%, a licensor faces only 5% of the variation of the sales, assuming that sales are the royalty base. Thus, the licensor does not bear most of the variation.

Even if it is possible to employ high royalty rates in some cases, it is impossible to insure both agents at once completely. As far as bilateral contracts with running royalty are concerned, risks can be shifted from one party to the other, but the risk cannot be removed from both parties simultaneously. For example, even when a transaction is expected to bear ten-fold variance compared to another, a high rate of running royalty such as 50% can only distribute the risk evenly to each party. This means that both parties are not well-insured. The increase in risk should be borne by either party. It means that the gain from running royalty in risk-dispersion does not increase linearly with the increase in external risk. The marginal benefit to employing running royalty will be eventually decreasing, as overall risk increases to a significant level. Namely, the gain from utilizing running royalty in terms of risk-dispersion will be limited when there is significant amount of risk.

The gain from employing running royalty in order to induce a licensor to make an effort in the interest of its licensee, as the principal and agent framework formalizes, is also limited when external shocks become large. It is true that a licensor is willing to support the absorption and commercialization of a technology by a licensee if running royalty is present, because the licensor has a stake in the amount of final sales. Accordingly, running royalty

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[3] The survey results presented by McGavock, Haas, and Patin (1993) also indicate that the rate of running royalty is higher in the pharmaceutical and health-care equipment industry. "Less than six out of every ten licenses for pharmaceutical and health-care equipment industry respondents were at royalty rates less than 5%." However, rates exceeding 10% are rare in these industries as well (McGavock, Haas, and Patin, 1993).

will be more likely to be used when moral hazard by a licensor is more important, holding all other conditions such as the significance of external shocks or the degree of risk-aversion constant. However, the "incentive" assumed in the principal and agent framework has a basic trade-off between the power of incentive and the provision of insurance (Milgrom and Roberts, 1992; Laffont and Martimort, 2002). When external shocks become very large, it is more difficult to give incentives for an agent (in the example here, it is the licensor) in the principal-agent model, given that the agent is risk-averse to some extent. Intuitively, an agent will no longer be happy to make an effort when the outcome is largely determined by external shocks. Thus, the marginal merit of using running royalty will be decreasing as external shocks become greater in the principal and agent framework.

The same logic applies when running royalty is used for signaling the value of a technology prior to contracting. Namely, a licensor is supposed to signal the value of a technology to a potential licensee by the use of running royalty where the potential licensee does not have the information, because the licensor has less incentive to misguide a licensee in that the actual amount of royalty is determined after the amount of sales is realized. However, as external shocks become greater, realized sales ex post are mostly determined by the external shocks, and the licensor finds little difference in outcome whether or not disclosing better knowledge about the probability of the success prior to contracting. In either explanation, the gain from the use of running royalty critically rests on the share of variation in final sales that a licensor bears. It means that any efficiency gain from using running royalty becomes less as external shocks become greater, according to the principal and agent framework.

In comparison with the merit of using running royalty, the measurement cost of the royalty base increases rapidly with the increase of citations and related innovations, as argued in the previous section. While the marginal merit of running royalty will be eventually decreasing, the marginal cost of measurement with the increase of follow-up innovations will remain at least constant, or may be increasing. This is because the number of potential conflicts with respect to the borders between patent claims rises with the increase of potentially substitutive and complementary patents, and because multiple relationships between patents and products will be more complex, as innovations are ongoing. Therefore, as Cheung (1967) argued in sharecropping, the efficiency gain from share contracting will be eventually overridden by the increase in measurement cost. Since fixed royalty contract is free from the measurement cost of royalty base, running royalty is expected to be less used with the increase of patent citations, assuming that patent citation is a proxy of measurement cost. Summarizing the argument, the main hypothesis comes down to:

H1: As the number of total forward-citations from a patent in the pre-licensing period becomes greater, it is more likely for the patent to be licensed without running royalty.

In this hypothesis, citation before the licensing period is the focus in order to avoid the endogeneity problem with the number of post-contract citations. Namely, running royalty may give an incentive to supply tacit knowledge for a licensor, because the licensor has a continuing stake. Then, post-licensing citations may be influenced by the choice of royalty.

It should be noted that the hypothesis above is not inconsistent with, but not the same as, alternative explanations from the principal-agent framework with an emphasis placed on moral hazard on the licensee side. Namely, if the number of citations means the scope of entrepreneurial effort by a licensee (Rao, 1971), fixed royalty compares more favorably with running royalty from the viewpoint of moral hazard on licensees. However, this argument not only makes ad hoc assumptions about the degree of risk aversion, but also presumes that the fruit of a licensee's effort can be measured and divided without significant cost (since what is not measurable is the hidden action of a licensee). Although the prediction of the relationship between citations and the use of running royalty is the same, the logic is different.

While the hypothesis predicts that the number of total citations is positively related with the measurement cost of the royalty base, it is difficult for the other party to argue against the scope of the royalty base if most of the citing patents are obtained by the original licensor. In an extreme case, when a licensor of a patent has all of the citing patents, it will be easy to show that follow-up new products will continue to use the original patent, or the licensor's substitutive patents. Conversely, when a licensor obtains a smaller share of follow-up innovations, it may be more costly to measure the royalty base, ceteris paribus. The share of self-citations over total citations thus can be used as a proxy of the reduction in measurement cost.

Also, how citing patents are distributed in the technology space may be another driver for measurement cost of the royalty base. If a technological impact by a patent is diverse in technological space, it is unlikely that the citing patents are substitutive to the originating patent, because the citing patent is technologically different. If a patent is not substitutive to an existing patent, a product using the prior patent continues to depend on it. Haggling over the royalty base is less likely to occur in this case than in other cases where there are many substitutive patents. On the other hand, if citing patents are concentrated in the technological area that is close to the originating patent, it would be costly to determine whether the citing patents are substitutive or complementary. Therefore, the measurement cost will be higher when citing patents are concentrated in a narrow range, rather than dispersed widely. Running royalty will be less used when the measurement cost of the royalty base is higher. In sum,

H2: As the share of a licensor's self-citations to total citations from a patent before licensing increases, or as technological diversity of citing patents before licensing increases, it is more likely for the patent to be licensed with running royalty, ceteris paribus.

4. The data

The data on licensing contracts are taken from the files in the Japanese government, specifically the filing of technology importing contracts required by the Article 29 of the Foreign Exchange Law of Japan (1949 Law 228), which was effective until April 1998.[4] The licensing data have not previously been exploited for academic research.[5] According to the regulation, residents of Japan (including foreign subsidiaries in Japan) must file with the government if they acquire patents, trademarks, and other intellectual property rights from abroad, or if they are licensed, or if contracts for teaching knowledge regarding business administration are made or changed. The National Institute for Science and Technology Policy (NISTEP) has published a statistical summary of the data in Japanese language each year ("Analysis of Trends in Technology Imports").

This paper uses licensing contracts and licensed patents data, which were recorded from the filings between 1988 and 1992.[6] The domain was limited to the firm pairs between licensors in the U.S. and licensees in Japan, so that country-specific institutional environment such as patent law regimes is held constant.[7] The number of patents in the sample is 1,378 (849 patents net of multiply licensed patents), which are found in 407 contracts. All observations are unilateral patent licensing, most of which are in electronics and machinery technologies.[8] As is noted above, all cross-licensing contracts are excluded

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[4] The filing requirement was abolished except for limited fields of technologies (e.g., those concerning national security) in April 2000.
[5] There exists a previous study based on this data (Montalvo and Yafeh, 1994).
[6] The period was chosen primarily because patents being licensed were not required to be filed after April 1992, while most of the files prior to 1988 were not available. NISTEP had published the statistical figures each year in detail (NISTEP, 1987-1999).
[7] Technology imports from the U.S. have by far the largest share in all technology imports to Japan. Within 3,175 agreements in total in 1991 fiscal year, U.S. accounted for 2,002 (63.1%) of the total, followed by the U.K. (213 agreements or 6.7%), France (205), Germany (170) and Switzerland (102). (NISTEP, "Analysis of Technology Imports," 1998)
[8] According to NISTEP's two-digit technology classification, codes from 40 to 53 are machinery, and codes from 60 to 71 are electronics. 376 out of 407 contracts of the sample are within this range.

from the sample, and all contracts between the firms with direct or indirect equity relationship are also excluded. Thus, the observations consist only of pure unilateral licensing.

The patent portfolio of the U.S. licensor firms and Japanese licensee firms is defined by consolidating subsidiaries. Consolidation was conducted by "Who Owns Whom 1990" on the U.S. licensor side. Toyo Keizai's "Nihon no Kigyo Group (the corporate groups in Japan) 1990," "Kaisha Shikiho (Quarterly reports of companies) 1990," and "Kigyo Keiretsu Soran (Keiretsu lists) 1990" were utilized on the licensee side. The patents that have been assigned to the subsidiaries of the sample firms were also searched through the database above, and were consolidated with the patent portfolio of the parent firms.[9] All observations of parent-to-subsidiary licensing and subsidiary-to-parent licensing were excluded from the samples for this paper, since by definition the patent portfolio of a parent firm becomes identical with that of its subsidiaries.

The focus is placed on the choice between fixed royalty versus running royalty, which are often used simultaneously. Since running royalty is conditional on post-licensing sales, it is difficult to know the realized amount of royalty in the years after licensing. In order to assess relative importance between fixed royalty component and running royalty component in a contract, it would be ideal if realized sales, royalty percentage (or charge per units, depending on the way running royalty is specified), and the amount of fixed royalty are all available as observed data. However, there are no such data as realized sales. Due to the limitation of the data, a three-category variable of pure fix royalty contract, pure running royalty contract, and the combination of fixed and running royalty components in a contract,

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Only 12 contracts concern chemicals and pharmaceuticals. All 407 contracts are licenses of manufacturing technologies.

[9] The patent portfolio of the subsidiaries may be managed separately from that of parent firms to some extent. However, the focus of the paper is the knowledge assets of transacting firms, and the knowledge assets of a firm is better captured by the entire patent portfolio of the firm, rather than that of a single parent or a subsidiary. This way of patent data construction follows recent studies (Mowery, Oxley, Silverman, 1996; Silverman, 1999).

is defined and used. This variable is essentially a combination of two binary variables – whether fixed fee is charged or not, and whether running royalty is included or not. I assume that the three-category choices are ordered, because pure running royalty (without any fixed royalty) is more sales-sensitive than the combination of fixed fee and running royalty, while this combination is more sales-sensitive than a pure fixed fee contract. Namely, the three-category variable can be understood as representative of the degree of sales-sensitiveness. However, it should be noted that the category of “fixed fee combined with running royalty” contains a variety in combination. If the amount of fixed fee in a contract is very small, the contract is close to running royalty only. Similarly, if the percentage of running royalty is very small, it is close to fixed fee. Interpretation of this category thus needs particular attention.

5. Methodologies for statistical tests

I test the hypotheses above using a categorical dependent variable. The three-category variable of pure fix fee contract, pure running royalty contract, and the combination of fixed and running royalty components in a contract, is the main dependent variable. Specifically,

FEE = 0 if the royalty is fixed royalty only[10]
1 if the royalty includes both fixed sum and running royalty
2 if the royalty is running royalty only

The main hypothesis (H1) is that running royalty creates a large measurement cost of specifying royalty base when forward citations are many. As the choice is made ex ante of contract, I basically take forward citations to the licensed patents before licensing as representing the general possibility of ex post non-contractible innovations by licensees.

[10] This includes 8 contracts without any fee, which we categorize into fixed-fee-only licensing.

Namely, ***CITE_BFR_LY***, the number of citations[11] before the licensing year, is the main explanatory variable to be assessed. Its predicted sign of coefficient is negative.

The next hypothesis (H2) is concerned about the ratio of citing patents appropriated by the patent holder of an originating patent. ***PSELF_BFR_LY*** is the measurement for a licensor prior to licensing time. Its predicted sign is positive, because a higher share of citing patents appropriated by a licensor implies fewer measurement costs in using running royalty. Also, ***HHI_CITE*** is the concentration of citing patents in IPC Class. It is negatively correlated with the diversity of technological impact by the originating patent. The predicted sign is negative, because technologically concentrated citing patents will raise the cost of determining if citing patents are substitutive or complementary to the originating patent.

Other explanatory variables are pertinent. In particular, those variables that are expected to be significant as proxies for contractual hazards should be included. Namely, ***TRDMRK***, ***AP_LY***, ***COS***, and ***KNWHW***, were used as explanatory variables.

A patent licensing accompanied by trademark licensing is a complex transaction, and therefore it is likely to require more cost for measurement. A contract level variable, ***TRDMRK***, is derived from the NISTEP licensing database. The variable takes the value 1 when a patent is licensed along with trademark licensing. The predicted sign of the estimated parameter is negative, since more measurement cost will lead to less use of running royalty. The variable ***AP_LY*** indicates the age of the technology. It means "years between application year of a patent and its licensing year." If the value for a patent is smaller, the patent is newer. When a technology is old, the fruit out of it is more predictable (Davidson and McFetridge, 1984). The predicted sign of ***AP_LY*** is positive.

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[11] Citing patents are counted in two "generations," following Trajtenberg, Henderson, and Jaffe (1997). That is, since a patent's influence on subsequent innovation may go beyond direct citing of patents, it is better to quantify impacts on follow-up innovation by considering indirect effects, or citation to citations. The (equally weighted) average of the number of direct citations and the number of "citations to citations" is used for econometric analyses.

Following Jaffe (1986), this study defines technological proximity between two firms by the cosine of the angle formed between two patent portfolio vectors. More accurately, vectors of patent counts in each of 118 "Classes" of the International Patent Classification system (IPC) characterize a firm's patent assets by the year 1990 (accumulated from 1975). The cosine of two vectors is then given by the inner product divided by the product of norms of two vectors. This measurement, named ***COS*** here, approaches to unity when two vectors are close to parallel, and equals to zero when two vectors are orthogonal. If transacting parties are within technological proximity, it is less costly for them to measure the royalty base. Therefore, estimated coefficient on this explanatory variable is expected to be positive.

Contract-level variable about whether or not explicit know-how transaction exists is also derived from the NISTEP licensing database. This variable, ***KNWHW***, is a dummy variable for know-how transfer, where the existence of know-how is defined by the regulation. Namely, the regulation requires firms to report know-how transfer only if their contract explicitly contains know-how transfer. The "know-how" according to the regulation includes product manuals, procedure instructions, and software, which economists may not consider as know-how. If the object of transfer is only tacit know-how, it is impossible to specify on a contract, and there is no obligation for it to be reported. From the reasons above, this variable ***KNWHW*** is supposed to represent the existence of codified knowledge. If codified knowledge adds measurement cost, the parameter will be negative.

In addition, some control variables are included. The variables ***LSR_CAP*** (LicenSoR CAPital) and ***LSE_CAP*** (LicenSEe CAPital) are defined and used as firms size proxies. The former is the size of U.S. licensor firm capital, expressed in dollars. The data were derived directly from the filings with the Japanese government. When a firm is involved in more than two contracts and the capital size data differs, arithmetic mean is used, while the size of a subsidiary licensor is measured by its parent firm. LSE_CAP (LicenSEe

CAPital) is Japanese licensee firm capital size, expressed in millions of yen. Toyo Keizai's "Nihon no Kigyo Group (Directory of Japanese firms and domestic subsidiaries) 1990" was used for this information instead of the filings with the government, because the data provided better consistency when a licensee firm and its subsidiaries were involved in more than two contracts. In addition to the control variables for size, ***INDVNPFT***, which represents non-commercial firm licensor (individuals, non-profits, universities, government organizations), is added where possible. It is because the special types of licensors may behave differently from commercial firms, due to the possibility of different objective function (maximizing reputation instead of maximizing profit, etc.).

Technological classifications are controlled by patent classification where possible. The international patent classification system assigns "section" to each patent as its top categories, and the sections in IPC ranges from A to H. ***IPC_Xi*** (Xi: A-H) are dummies for the sections, and used for the patent-level tests. Due to perfect prediction of the qualitative results in econometric tests, though, only sections of B, C, G, and H are controlled by the dummies.

With those variables, I test the hypotheses by the following discrete choice model, ordered PROBIT, with an assumption that the dependent variable is ordered. The error term *e* is assumed to be normally distributed.

$$\text{Prob}(\boldsymbol{FEE} = 0, 1, 2) = F(\beta_0,\ \beta_1 \boldsymbol{CITE\_BFR\_LY},\ \beta_2 \boldsymbol{PSELF\_BFR\_LY},\ \beta_3 \boldsymbol{HHI\_CITE},\ \beta_4 \cdot \boldsymbol{TRDMRK},\ \beta_5 \cdot \boldsymbol{AP\_LY},\ \beta_6 \cdot \boldsymbol{COS},\ \beta_7 \cdot \boldsymbol{KNWHW},\ \boldsymbol{CONTROLS},\ e)$$

6. Results and discussion

Table 3 shows the estimation results concerning H1 and H2 by way of ordered PROBIT. Model 1 shows the result from ordered probit only with those variables being related to firm size and technology class. LSR_CAP (licensor capital size) is found to be positive and significant, and INDVNPFT (individual, non-profit or government licensor) is negative and significant. When a licensor becomes bigger, it shares more risk by accepting running royalty. On the contrary, individual and non-profit licensors seem to circumvent running royalty. Since most of the observations INDVNPFT=1 are in fact individual licensors, both of the results are consistent with predictions from risk aversion. Although significance is smaller than the two variables, LSE_CAP, the size of licensees, has a negative sign as predicted from the same reason.

Model 2 adds TRDMRK, KNWHW, AP_LY, and COS. TRDMRK has a coefficient with a negative and significant sign, which indicates that more measurement cost added by trademark licensing shifts royalty structure towards fixed fee and away from running royalty. It suggests that there is a cost in measuring the sales that is contributed by the licensed brand name, and that the measurement cost works against the use of running royalty. A positive and significant coefficient for COS is also consistent with the basic argument here, because as the proximity of technological assets increase between licensing firms, it is less hazardous in the sense of lowered measurement cost to use running royalty. Transfer of codified knowledge, or KNWHW, and the age of licensed patent, AP_LY, have insignificant results.

Model 3 includes all explanatory variables. The coefficients of CITE_BFR_LY, PSELF_BFR_LY, and HHI_CITE have signs as predicted by hypotheses. A negative and significant coefficient for CITE_BFR_LY supports H1. A positive and significant coefficient for PSELF_BFR_LY and a negative and significant coefficient for HHI_CITE[12]

[12] However, the result with respect to HHI_CITE may require some caution, because it is one of Hirfindahl-type indices. It is shown that HHI on citations is biased upwards when patents in question have few citations (Hall, 2001, in the Appendix of Hall, Jaffe, and Trajtenberg 2001). Namely, a patent with few forward citations seems to have a more concentrated distribution than true distribution. While running royalty is preferred for a patent with a small number of forward citations, those patents with a small number of citations may have a seemingly concentrated technological impact due to this bias, resulting in a seemingly positive relationship between the concentration of citing patents and the use of running royalty. This is possible but not scrutinized here, and is a subject for further research.

support H2. AP_LY also have an interesting result in Model 3 since older technology is more likely to be licensed with running royalty, though its statistical significance needs more scrutiny due to the insignificant result in model 2.

7. Conclusion

I argue that fixed royalty is preferred to running royalty when the measurement cost of the royalty base used for running royalty is high. Supportive evidence consistent with the argument is obtained, when other factors such as firm size are controlled. Fixed royalty, which is free from haggling over the royalty base, is preferred when a patent licensing is subject to a large number of citing patents, and therefore a high measurement cost.

The findings are supportive for transaction cost economics, in that measurement cost indeed plays an important role in patent licensing contracts, as was found in sharecropping (Allen and Lueck, 1995). The results are also informative for the principal and agent framework, in that the use of running royalty is consistent with the assumption of risk-aversion. The results does not imply that transaction cost economics and the game-theoretic principal-agent framework are mutually exclusive to each other. Instead, transaction cost economics can shed light on an important cost which tends to be overlooked by orthodox microeconomics, including the principal-agent models.

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Tables

Table 1: Other variables

Variables	Description
FEE	Defined for a licensed patent as: 0 when a license uses fixed fee only, 1 when both fixed sum and running royalty are simultaneously used, and 2 when there is running royalty only.
CITE_BFR_LY	Total counts of citing patents (weighted in two generations) by any firm, which are applied to the USPTO *on or before* Licensing Year
PSELF_BFR_LY	Ratio of self citations to total citations (weighted in two generations) before licensing year
HHI_CITE	Hirfindahl-Hirschman Index calculated by the patents that cite a licensed patent (only citing patents that were applied on or before licensing year) based on IPC “Class”
AP_LY	Years between application year of a patent and its licensing year
TRDMRK	Dummy variable for trademark licensing along with patent licensing
KNWHW	Dummy variable for knowhow transfer (defined by the regulation) along with patent licensing
COS	Technological proximity between two firms by the cosine of the angle formed between two patent portfolio vectors based on IPC “Class”
LSR_CAP	LicenSoR CAPital: U.S. licensor firm capital, expressed in dollars.
LSE_CAP	LicenSEe CAPital: Japanese licensee firm capital, expressed in millions of yen.
INDVNPFT	Individuals and Non-Profits: dummy variable, 1 if licensor is individual, non-profits or government organizations
IPC_B	Dummy for International Patent Classification, Section B (Performing Operations ; Transporting)
IPC_C	Dummy for International Patent Classification, Section C, (Chemistry/Metallurgy)
IPC_G	Dummy for International Patent Classification, Section G (Physics)
IPC_H	Dummy for International Patent Classification, Section H (Electricity)

Table 2: Descriptive Statistics

Variable	Mean	Std. Dev.	Min.	Max.	Sum
FEE	0.876	0.683	0	2	1208
$CITE\_BFR\_LY$	21.36	49.04	0	542.5	29437
$PSELF\_BFR\_LY$	0.0893	0.186	0	1	123.066
HHI_CITE	0.610	0.312	0	1	840.868
AP_LY	9.28	4.68	1	29	12789
$TRDMRK$	0.0391	0.194	0	1	54
$KNWHW$	0.496	0.500	0	1	684
COS	0.458	0.237	0	0.99673	632.43504
LSR_CAP	1.101D+09	1.997D+09	10	1.64180D+10	1.5182D+12
LSE_CAP	109053.8	102488.9	927	780000	1.5027D+08
$INDVNPFT$	0.0740	0.261	0	1	102
IPC_B	0.0972	0.296	0	1	134
IPC_C	0.106	0.308	0	1	147
IPC_G	0.344	0.475	0	1	475
IPC_H	0.413	0.492	0	1	570

N=1378

Table 3: Royalty choice and pre-contracting conditions

Estimation method: Ordered Probit

	MODEL 1	MODEL 2	MODEL 3
Variable	*FEE*	*FEE*	*FEE*
CITE_BFR_LY			-.416E-02*** (-5.41)
PSELF_BFR_LY			.835*** (4.86)
HHI_CITE			-.352** (-3.35)
TRDMRK		-.356* (-2.06)	-.393* (-2.26)
KNWHW		-.062 (-.855)	-.035 (-.486)
AP_LY		.752E-02 (.984)	.025** (3.13)
COS		.473** (3.39)	.455** (3.24)
LSR_CAP	.100E-09*** (6.34)	.867E-10*** (5.20)	.811E-10*** (4.82)
INDVNPFT	-.766*** (-5.88)	-.867*** (-6.45)	-.862*** (-6.31)
LSE_CAP	-.866E-06** (-2.80)	-.770E-06* (-2.36)	-.735E-06* (-2.23)
IPC_B	.334 (1.79)	.247 (1.27)	.275 (1.41)
IPC_C	.611** (3.27)	.464* (2.38)	.537** (2.74)
IPC_G	-.081 (-.483)	-.210 (-1.19)	-.088 (-.497)
IPC_H	.551** (3.30)	.397* (2.25)	.475 (2.67)
C	.305 (1.90)	.216 (1.04)	.207 (.973)
Log likelihood	-1287.	-1275.	-1245.

N=1,378
Estimated coefficients are in upper rows and t-values are in parentheses.
* indicates significance at 0.05 level. ** indicates significance at 0.01 level.
*** indicates significance at 0.001 level

ロイヤリティ形態選択における派生技術の計測費用

要　旨

本研究は、クロスライセンスなどの複雑なライセンスでなく、単純な一方向の特許ライセンスにおいて、固定額ロイヤリティのみが用いられるか、それともランニング・ロイヤリティも用いられるか、の決定要因を探ろうとするものである。とりわけ、ライセンスされた特許の被引用数と、ロイヤリティ構造選択の関連に着目した。プリンシパル・エージェント型の説明をとるならば、情報の非対称性やリスク許容度によってロイヤリティ構造の選択を予想することになる。たとえば、被引用数が多い特許とは、ライセンス契約後のライセンシの（隠れた）努力余地が大きい特許だ、と仮定により見なすならば、ライセンシへのインセンティブ増加のためランニング・ロイヤリティの比重を下げ、固定額ロイヤリティに依存することがより合理的といえる。しかし、被引用数が多い特許においては、ライセンサの契約後の技術援助努力も同時に重要になるのではないか、あるいは、増大するリスクをシェアするためランニング・ロイヤリティを使うのではないか、といった批判がありうる。つまり、プリンシパル・エージェントの枠組みを使おうとする限り、リスク許容度などに関する恣意的な仮定から逃れられない。そこで、農作物に関する契約の実証研究にみられるように、成果の計測コスト（measurement cost）に着目した。ランニング・ロイヤリティを使うためには、その算定基礎となる製品群（ロイヤリティベース）を特定することが必要になる。ライセンスされた特許の被引用数が多くなるほど、引用特許とライセンス対象特許の補完性・代替性を決定することが煩雑になり、ロイヤリティベースの決定に大きな費用がかかると考えられる。したがって、その計測コストがあまりにも高くなるときには、ランニング・ロイヤリティによる他の効率性向上効果が相殺されるので、固定ロイヤリティのみを使う確率が高まると予想される。日米技術導入データに基づいて実証的に検証したところ、ライセンス対象の特許の被引用数が多いほど、ランニング・ロイヤリティが使われないことがデータ上明らかに観察された。つまり、計測コストがロイヤリティ選択に影響しているという理解と整合的であった。特許の被引用数の多さは一般に特許の価値の高さを示すと理解されているが、継続的に派生技術が生まれることにより、ライセンス対象の成果計測コストを上昇させるという理解が可能であろう。