Equity Joint Ventures and the Scope of Knowledge Transfer between Diversified Firms: Evidence from U.S.-Japan Alliances

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This paper empirically analyzes the scope of knowledge exchange facilitated by equity joint ventures (JVs) in US-Japan technology transactions, when diversified firms are involved in patent licensing. The results from patent citation analyses on 509 licensing pairs reveal that licensees having JVs with licensors have advantages in obtaining wider scope of knowledge at the firm level, compared to licensees without JVs, even though the scope of JV product lines and the technological scope of patent licensing are much narrower than those of the parents. If JVs facilitate knowledge exchange only through personal contacts for the operation of JVs, improved knowledge transfer may be limited to the specific business area. However, collaboration across different technological areas via JVs suggests the attenuation of opportunistic behavior by hostage at the firm level. The results inductively define the unit of analysis question in

knowledge exchange transactions, which helps integrating resource-based view of the firm with transaction cost view. The range of traded technological resources between firms varies, and governance plays an important role in determining the scope of knowledge exchange between the knowledge base of firms.

1 Introduction

Interfirm alliances for technological knowledge exchange have been an attractive research agenda in strategic management literature, especially in international business research. Different kinds of theoretical framework – such as transaction cost economics (TCE) and resource-based view of the firm – are employed, and researchers attempt to contrast and synthesize diverse views (Chi, 1994; Conner and Prahalad, 1996; Silverman, 1999; Tsang, 2000). Among the received theories, TCE takes comparative approach to a variety of governance structures, such as license agreements and equity joint ventures, and seeks to define the dimensions along which firms' choices between governance forms are determined and by which the consequences of the choices differ. An established implication from TCE is that equity-based governance facilitates tacit and complex knowledge transfer, i.e., knowledge transfer is "enhanced" when a licensing pair has an equity-based governance structure compared to the case where they have market-based governance structure, e.g. simple licensing contracts (Davidson and McFetridge, 1984; Kogut and Zander, 1993).

Despite the established wisdom, there remains an unexplored dimension that describes "enhancement" in knowledge transfer occurring through equity-based governance, especially when large diversified firms are involved in equity-joint ventures and license agreements. Since diversified firms have different lines of business and different kinds of knowledge assets, potential inter-firm knowledge transfer can span a broad range of them. However, typical equity joint ventures are much smaller in size than their parents, and the product lines of the joint ventures are often much narrower. Individual license agreements are even narrower in technological scope than joint ventures. Thus, a question can be raised: do different types of governance vary in technological scope as media for knowledge exchanges, when compared to the scope of technological assets of the parents?

In order to explore the question empirically, this paper tests whether equity joint venture has an advantage in the scope, or *breadth*, of knowledge exchange, which is defined here by the technological range in patent class, compared to simple patent licensing contracts. Theoretically, it is the question of "the unit of analysis" in transaction cost arguments. Previous studies tend to consider each "alliance" as the unit of analysis in equity joint ventures as well as in licensing agreements without exploring what is actually exchanged between partnering firms. Given that firms often have diversified ranges of knowledge assets, the scope of their exchange defines one aspect of what is "transaction" – the basic unit of analysis in TCE. In addition, as resource-based view of the firm also interprets alliances are means to gain access to other firms' sticky and difficult-to-imitate resources, how governance types affects the access of resources is an important question in integrating resource-based view and TCE.

This paper proceeds as follows. The next section first explains the motivation of this study by the fact that the scope of joint venture product lines is usually much smaller than those of the parents. Theoretical considerations on the scope in knowledge transfer between diversified firms are discussed, and predictions from TCE are presented. Section 3 explains data and methodologies, and section 4 discusses the results. Conclusion is presented in section 5.

2 Practical and theoretical backgrounds

2.1 Diversification and the scope of joint ventures in product lines

It is reasonable to infer from prior studies that the scope of joint venture business[1], in the sense of product lines, is often much narrower than those of the parent firms when the parents are diversified. First, there were empirical findings in international management literature with respect to the positive correlation between diversification and the use of joint venture (Stopford and Wells, 1972, chapter 9). According to the observations by Stopford and Wells, joint venture is more likely to be used by diversified multinational firms than by less diversified firms, since diversification in product line reduces the relative benefit and possibility of fully controlled foreign subsidiaries. Put differently, increasing product lines require marketing capabilities in new product lines, and joint venture supplies such capabilities for specific products[2]. Implied in their

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[1] In this paper, "joint venture" implies equity joint venture and the two terms are used interchangeably.

[2] According to Stopford and Wells, acquisition of marketing know-how from joint venture partners is more important for diversified firms than non-diversified firms. "When a firm develops a wide range of new products, it is usually concentrating its resources on design and production. – Such an enterprise frequently does not have adequate

logic is that each joint venture is oriented for specific products. Moreover, diversification into many product lines leads to the adoption of global product division as the optimal organizational form by multinational firms instead of area division structure (Caves, 1996, p.65). As a result, the more diversified a multinational firm is, the more likely it is to form joint ventures with partners mainly on its product line basis than on geographical area basis. It is possible to have a diversified joint venture with the same partner, but it should be atypical at least at the initial stages of alliance formation.

Although the observations above were made before the years when alliances for technological resource access became essential and prevalent, joint venture formation oriented for specific product lines has become even more evident recently than before. For example, Toshiba, a Japanese multinational with extensive product lines, was found to have at least 26 alliances with other major firms worldwide in 1988, which span many fields of business but each of the alliances is specific to some products (Ross, 1993). A decade later, Toshiba is reported to have at least 70 international equity joint ventures[3] in 1999, including joint ventures by Toshiba's

Table 1. Example of equity joint ventures by Toshiba (Source: Toyokeizai Directory of foreign subsidiaries in Japan 1999; Directory of foreign subsidiaries by Japanese firms 1999; web pages of the joint venture firms)

NAME OF PARTNER FIRM	NAME OF EQUITY JOINT VENTURE	LOCATION OF J.V.	INDUSTRY OF J.V.	PRODUCTS OF J.V.

marketing skills. Each new line requires a different formula for marketing, specific to the product (Stopford and Wells, 1972, p.125)."

[3] Toyokeizai Directory of foreign subsidiaries in Japan 1999; Directory of foreign subsidiaries by Japanese firms 1999

Cummins Engine Co., Inc.	Enceratec,Inc.	U.S.A.	Ceramics	Ceramic materials
Data Dynamics Holdings Pte. Ltd.	Toshiba Data Dynamics Pte.Ltd.	Singapore	Telecommunications	Telecommunications equipment
GEC Alsthom S.A.	European Vacuum Interrupters S.A.	France	Electrical machinery	Vacuum valve
General Atomics	Applied Super Conetics,Inc.	U.S.A.	Electrical machinery	Magnetic Resonance Imaging (MRI) systems
General Electric	Toshiba GE Turbine Components Co.,Ltd.	Japan	General machinery	Gas turbines
General Electric	Toshiba GE Turbine Services Co.,Ltd.	Japan	General machinery	Gas turbines
GFC Kellerman	Shanghai GFC Toshiba Elevator Co.,Ltd.	China	General machinery	Elevators and escalators
IBM	Dominion Semiconductor LLC	U.S.A.	Electrical machinery	Semiconductor memory
International Fuel Cells	ONSI Corp.	U.S.A.	Electrical machinery	Fuel cells
Lockheed Martin Corp.	Toshiba Electronic Systems Co., Ltd.	Japan	Electrical machinery	Simulators, Radio navigation aid systems
NewsEdge Inc.	News Watch, Inc.	Japan	Information services	Information services
Potters Industries Inc. (A subsidiary of The PQ corp.)	Toshiba-Ballotini Co., Ltd.	Japan	Ceramics	Glass products
Saint-Gobain	Toshiba Monofrax Co., Ltd.	Japan	Ceramics	Ceramic materials
Schneider Electric S.A.	P.T.Schneider Manufacturing Batam	Indonesia	Electrical machinery	Magnetic switch
Schneider Electric SA	Schneider Toshiba Inverter Corp.	Japan	Electrical machinery	Inverter

subsidiaries such as Toshiba Machine and Toshiba Chemical Corporation. As table 1 shows, Toshiba's partners for joint ventures include very large and diversified firms, such as IBM, GE, and Lockheed Martin. Nevertheless, the objectives of the joint ventures are, at least seen from the outputs, specific to narrow product lines. For example, Toshiba and IBM may be able to gainfully form joint ventures in hard disk drive or personal computer manufacturing, but they do not do so. Or, Toshiba might be able to gain access to Lockheed Martin's technology by forming a joint venture in avionics and weapon systems, but the outputs of the joint venture does not include the product lines. Therefore, those diversified firms seem to choose the scope of outputs for their joint venture carefully within narrow product lines. Seemingly "narrow equity links" between large and diversified firms are observed very frequently. Not surprisingly, the size of the joint ventures is typically much smaller than the large parent firms.

Given the limited scope of product lines of joint ventures compared to those of parent firms, but given also that joint ventures have been recognized as means by which firms acquire other firms' knowledge assets (Killing, 1980; Kogut, 1988), a question naturally arises with respect to the scope of knowledge transfer between the diversified parents. This question has relevance with the resource-based view, if we focus on one aspect of the resources – technological resource – as discussed below.

2.2 Joint venture and technological resource transfer – theoretical considerations from resource-based view

When the product lines of joint ventures are narrower than those of their parents, the scope of "resources" that are exchanged through joint ventures can be considered in several different ways from the resource-based view. First, resource-based view of the firm presumes that several kinds of resources, such as production skills and marketing skills, can be utilized for a specific group of products (Wernerfelt, 1984). Therefore, as long as all strategic resources such as marketing capabilities and technological resources are concerned inclusively, a joint venture may serve as an intermediary of such resources between firms. On the other hand, the unit of analysis in the resource-based view is said to be the firm (Barney, 2001), but not a resource. Accordingly, it is difficult to quantitatively identify which resource is the most important for a specific set of products within a diversified firm, and to assess the role of a joint venture as an intermediary. Indeed, there have not been many empirical studies that identify different kinds of resources as independent drivers for corporate strategies concerning organizational form.

Nonetheless, recent developments in the empirical analyses of technological resources step forward in the operationalization of technological resource transfer, utilizing patent information as a measurement of innovative activities as well as technological assets that can be classified into different kinds of technologies (Jaffe, 1986; Mowery, Oxley, and Silverman 1996, 1998; Silverman, 1999)[4]. More importantly, hosts of research focused on technological competence or technological resources acknowledge that a particular technological resource is useful in only a narrow range of applications (Silverman, 1999). Therefore, a diversified firm in product lines can be considered as an entity with diversified technological resources, which can be measured by patent information. Assuming that a set of technologies corresponds to a set of products, we can expect that only a part of the technological resources of a diversified firm is utilized for the operation of a joint venture with another firm, because of the narrow range of outputs of joint ventures.

This does not necessarily preclude the possibilities of exchanging wider scope of technological assets between firms through some organizational device. Yet, resource-based view is primarily concerned about firm-specific resources and even doubts the tradability of those resources (Chi, 1994). Accordingly, it is not clear whether a particular technological resource or a collection of different resources in a firm can be the object of an exchange. On the other hand, there are many kinds of technology contracts, such as license agreements and joint ventures, and all of them are means to gain access to other firm's technological resources (Killing, 1980; Mowery, Oxley, and Silverman 1996, 1998). Therefore, at least a part of technological resources

[4] This paper assumes that tacit knowledge and patented knowledge are positively correlated, and that the characteristics of a firm's technological assets can be measured by patent information, following recent studies (Patel and Pavitt, 1995).

in a firm should be basically tradable, which is admitted in the resource-based view (Chi, 1994). The actual range of exchanged technologies through a particular type of governance is an unresolved question, and it is where TCE can offer complementary theories and testable hypotheses, as will be explained next.

2.3 Governance and the scope of technological resource transfer – predictions from TCE and the proposition

To understand the role of governance, TCE pays attention to the mechanism by which contractual hazards take place and how those hazards are attenuated through institutional apparatus enabling mutual forbearance (Williamson, 1975, 1985, 1996; Oxley, 1997). In the context of technological knowledge transactions, the source of contractual hazards include the fundamental dilemma with trading information as goods (Arrow, 1962), the difficulty of specifying tacit and complex knowledge, and the problem of enforcing incomplete contracts in the face of opportunism and weak property rights regime (Oxley, 1999). Equity joint venture is claimed to be a safeguarding device and has advantage over trading technologies in the market when those hazards are severe. An explanation is that an equity joint venture serves as administrative body for monitoring partner's behavior and for settling disputes (Pisano, Russo, and Teece, 1988). Another way of understanding is that partners' commitment of resources to a joint venture effects a stabilizing exchange of hostages (Buckley and Casson, 1988). Incentive alignment for collaborative activities despite of hold-up problems is also expressed in a formal model (Dasgupta and Tao, 1998)[5].

The extent and the scope of inter-firm knowledge transfer to be facilitated through equity joint venture depend on the understanding of the hazards mitigation mechanism. As long as the administrative control of a joint venture is concerned, personal contracts through a joint venture can mitigate information asymmetry problem in technology transfer, and help resolving disputes, at least within the range of joint venture operation. Yet, administering a joint venture does not necessarily facilitate firm-to-firm knowledge transfer in all technological resources of parent firms, though potential range of knowledge transfer may be broader than what is directly necessary for the joint venture operation. In the previous example, IBM's technology concerning hard disk drives should be useful for Toshiba, despite that the joint venture between the two firms is limited to the production of memory chips only. In this case, administration of the joint venture may or may not mitigate contractual hazards with respect to the disk drive technology transactions.

On the other hand, TCE also posits that hostage can be held to mitigate opportunism hazards. The key for incentive alignment is whether effective hostage is held or not, and any

[5] There are other formal models that may be relevant to the role of joint ventures. An example is that bundling of complementary contractible goods with non-contractible goods transactions is said to mitigate contractual hazards (Arora, 1996). While insightful, the analysis is different from the focus of this paper since the latter is concerned about knowledge transfer across different technological resources, which may not be complementary with each other.

product divisions of a parent firm can be influenced by the hostage. In other words, hostage holding is not limited by the technological scope of the joint venture. This interpretation has a testable implication. Namely, assuming that different kinds of governance have different degrees of efficacy as hostage, the scope of knowledge transfer is supposed to vary with governance types because of the difference in the effectiveness of hostage. An equity joint venture may facilitate wider knowledge transfer than simple licensing contracts, possibly beyond the scope of technologies needed for the operation of the joint venture, assuming an equity joint venture is effective as a hostage compared to a license contract. These arguments can be summed up in the following proposition.

Proposition

A firm having an equity joint venture as a strategic alliance can obtain wider scope of knowledge from its strategic partner than without equity joint venture.

3 The Data and specifications

3.1 Overview of the tests; hypotheses

There are several challenges for testing the proposition empirically. Questions include the choices of: (1) proxy for characterizing technological assets and their scope, (2) proxy for knowledge transfer, and (3) domain of the tests. This paper utilizes patent information for (1) and (2), following recent studies. That is, patent counts held by firms are calculated according to the International Patent Classification (IPC) system, from which vectors of firms' technological assets and their relative distance (Jaffe, 1986) can be obtained. Firm-to-firm knowledge transfer is also calculated by patent citation data (Trajtenberg, 1990; Trajtenberg, Henderson, and Jaffe, 1997; Jaffe, Trajtenberg, and Fogarty, 2000).

The third question poses the most serious question, because of the complementarity between licensing and joint venture. While previous empirical studies on strategic alliances presume that different modes of governance such as licensing agreements and joint ventures are alternatives, there is little empirical evidence that indicates they are substitutes. On the contrary, the data shown in the next section suggests that licensing agreements are not substitutes for equity joint ventures, and that licensing contracts between firms with equity joint ventures are not rare. For instance, firms license technologies to each other in order for a joint venture operation. Or, they sometime advance their technological partnership from simple license agreements to collaborative production or collaborative R&D by a joint venture. Firms combine different governance modes in those cases, since technology transfer is often a sequentially developing process. In other words, firms do not always choose one-time governance mode for a technology transfer.

Because of the need to set hypotheses consistent with TCE despite of the partial complementarity between license agreements and joint ventures, this paper focuses on the measurement of post-licensing knowledge transfer and its relationship with the existence of joint ventures, where joint ventures are established before licensing. That is, by limiting attentions to patent licensing pairs of firms with or without a joint venture between them before the licensing period, it is possible to test whether post-contracting knowledge transfer is enhanced in "breadth" by the existence of joint venture, while the firms license at least one patent.

Tests are conducted on the following three hypotheses. First, if the proposition is true, a licensee that already has an equity joint venture with its licensor can obtain more knowledge transfer at the firm level than without joint venture, other conditions being equal. That is,

H1: In post-licensing period, a patent licensee holding an equity joint venture with a licensor obtains larger number of patents which cite the entire patents that the licensor had by the time of licensing, compared to licensees without equity joint ventures.

Secondly, a licensee with a joint venture is supposed to have advantage in obtaining knowledge over licensed technology. This has been confirmed by previous TCE empirical studies, but the proposition above states that it holds even if the scope of the licensed technology does not coincide with the scope of joint venture technologies. Thus, H2: A patent licensee holding an equity joint venture with a licensor obtains larger number of patents that cite the licensed patents in post-licensing period.

H2A: In post-licensing period , a patent licensee holding an equity joint venture with a licensor obtains larger number of patents that cite licensor's patents in the same patent class with the licensed patents.

Thirdly, a licensee with joint venture is supposed to have advantage in obtaining knowledge outside of the licensed technologies. Namely, citing patents to licensors' patents in non-licensed patent classes are the question.

H3: In post-licensing period, a patent licensee holding an equity joint venture with a licensor obtains larger number of patents which cite the patents that the licensor had outside of the patent class with the licensed patents.

3.2 The data set

The basis of the tests is the U.S.-Japan patent licensing data, which were recorded from regulatory filings with the Japanese government between 1988 and 1992[6]. The domain was limited to the firm pairs of licensors in the U.S. and licensees in Japan, since country-specific

[6] Based on fiscal year. NISTEP has been publishing the statistical figures each year in detail (NISTEP, 1987-1998).

attributes such as patent law regimes are held constant. Analyses are based on 2105 licensed U.S. patents in 608 patent licensing contracts, each of which include at least one U.S. patent licensing. Among the gross 2105 patents, there are 1261 patents net of multiple licensing of the same patents to different licensees, and there are 509 licensing firm pairs net of multiple licensing within the same firm pairs.

The 509 licensing pairs consist of 203 U.S. licensor firms and 135 Japanese licensee firms after consolidating subsidiaries, utilizing "Who Owns Whom 1990" and "Toyokeizai Directory of Japanese firms and Domestic Subsidiaries 1990." All observations of parent-to-subsidiary licensing and subsidiary-to-parent licensing are excluded from the samples, since patent portfolio of the licensing parties becomes identical in those cases (as a result, it is impossible to use patent citation as a proxy for knowledge transfer). Among the 509 firm pairs, there are 23 firm pairs that have equity joint ventures within or before the sample years[7], and there were 54 licensing contracts observed between the 23 firm pairs (173 patents are licensed in the 54 contracts). The 203 licensors and 135 licensees, including their subsidiaries, together hold approximately 291 thousand U.S. patents in total by the end of 1990 (mid-year of the sample periods). Patent

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Previous empirical studies based on the data include the one by Montalvo and Yafeh (Montalvo and Yafeh, 1994).

[7] Toyokeizai Directory of foreign subsidiaries in Japan 1992 and Directory of foreign subsidiaries by Japanese firms 1990 were used to identify those firm pairs. The size and the scope of joint venture firm are much smaller than their parents in all cases, though direct evidence on the fact is to be collected. Besides, the small number of JV observation is a weakness. However, JV observation before licensing is the key of this study, and the quality of analysis is hard to improve if the number of observations is increased simply by adding firm pairs with joint ventures but without licensing information associated with the firm pairs.

information was taken from "Micropatent" U.S. patent database, which provides patent applications dates, issuance dates, assignee names, patent classification, and patent citations. U.S. patent data were obtained and used between 1975 and 1998. The assignees of the approximately 1.81 million patents that cite licensors' patents were tracked so that cross-citations (i.e., citing patents obtained by a licensee) are counted as the proxy for knowledge transfer from the licensors to the licensees.

As is the same with the entire licensing data, most of the licenses sampled for this study are in electronics and machinery technologies[8]. Of the 608 contracts, 93.8% (570 contracts) are either in electronics or in machinery technologies[9], according to NISTEP technology classification. Similarly, 53 out of 54 contracts between firm pairs with joint ventures are within electronics or machinery technologies. Therefore, the differential effectiveness of patent system to protect appropriability (Levin et al., 1987) is not expected to affect the result of this study much.

3.3 Variables

Dependent variables

The main dependent variable in this study is firm-to-firm cross-citation as the proxy for

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[8] The sample of this study includes all industries in FY1988 and FY1991 data, but lacks most of the data outside electronics technology in FY1989 and FY1990. This is because retrospective data inputting on FY1989 and FY1990 samples was not completed in time for this study by NISTEP.

[9] The rest of the contracts include chemistry, pharmaceuticals, ceramic materials, and so on.

knowledge transfer from a licensor to a licensee. It is the count of patents, which are citing licensor firms' patents and are obtained by licensee firms in post-licensing period[10]. **FFCITE** (Firm-to-Firm citation) is this variable and is used to test H1.

H2 through H3 also aim to find if joint venture affects knowledge transfer to a licensee, but different subsets of licensors' patents and their forward citations are used, depending on the focus. First, patents specifically citing the licensed patents are used to assess knowledge transfer concerning explicitly licensed patents. **CROSS_CITE**, which is the count of cross-citations[11] to the licensed patents, is the variable and is used to test H2. A similar but more inclusive measurement of knowledge transfer concerning licensed technologies is **FFCITE_IN**, which is the count of firm-to-firm cross-citation within the patent class of licensed patents (using IPC "Class"). To be more precise, counted patents are the patents that cite licensor firms' patents in the same patent class with licensed patents[12], and that are obtained by licensee firms in post-licensing period. Therefore, citing patents may not be within the same patent class with the licensed patents. While FFCITE_IN is calculated using "Class" of IPC system, **FFCITE_IN2** is calculated using

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[10] To simplify counting forward citations in "post-licensing period," citing patents applied to USPTO after 1990 are selected and counted. This also simplifies cross-citation counts in multiple licensing within the same firm pairs.

[11] Unlike other cross-citation counts, this CROSS_CITE is actually an arithmetic mean of direct forward citations and citing patents to the forward citations ("grand-child" citations) to obtain a comprehensive measurement of knowledge transfer to a licensee. This follows a previous study (Trajtenberg, Henderson and Jaffe, 1997). However, the number of firm-level citations is too great to keep track of all "grand-child" citations, and it was impossible to use this methodology in other cross-citation counts.

[12] When there is more than one patent in a contract, and more than one class is observed in a contract, licensors' patents in all the classes are considered "within" the licensed patent class. FFCITE_IN, FFCITE_IN2, FFCITE_OUT, and FFCITE_OUT2 are calculated by the same methodology.

"Section" of IPC. Since the "Section" of IPC is the broadest classification by IPC with only eight categories, the number of patents held by a licensor within the same section with licensed technologies is larger than the number by "Class," where all patents are divided into 118 classes, according to the IPC 6th edition.

Firm-to-firm cross-citations outside of the patent class of licensed patents are also counted by the same methodology. **FFCITE_OUT** is the count of patents that are citing licensor firms' patents in the different patent "Class" of IPC from those of the licensed patents and are obtained by licensee firms in post-licensing period. **FFCITE_OUT2** is the count of licensees' patents that are citing licensor firms' patents in the different patent "Section" of IPC from those of the licensed patents. As table 6a suggests, more than half of all cross-citations at the firm level (FFCITE) cite the patents within the same section with licensed patents. Therefore, FFCITE_OUT2 represents the set of technologies that is the most distant in technological sense from forward-citations to licensed technology.

<u>Explanatory and control variables</u>

<Governance types>

The focal explanatory variable of this paper is the existence of a joint venture between a patent licensing pair. **JV** is a binary variable, which equals to unity when a licensing pair has a joint venture within or before the sample years and equals to zero otherwise.

Closely related with the hypotheses of this paper is the use of cross-licensing, because cross-licensing may serve as a hostage by exchanging future innovation windows to each other (Wada, 1999). Therefore, when a patent licensing involves cross-licensing, it must be controlled so that the effect from joint venture can be separated. For this purpose, a binary variable **CRSLIC** indicating cross-licensing is coded from the regulatory filings and is used as a right-hand side variable. In fact, this variable should provide an insight on cross-licensing as hostages, in addition to joint ventures.

Furthermore, a dummy variable **UNILAT** is defined and used in the model 1 through 5, where firm-to-firm citations between all possible firm pairs are calculated to contrast licensing pairs with non-licensing pairs. More accurately, the variable UNILAT takes one when a firm pair is a licensing pair, and takes zero if a randomly chosen firm pair does not have any licensing contracts between them. This test can demonstrate whether unilateral licensing accelerates knowledge transfer between firms, in addition to the test of H1.

<Number of total citations>

Cross-citations by a licensee are influenced by the general possibility of follow-up innovations from licensors' patents. In other words, if a licensor has patents that have much technological impact and are therefore valuable (Trajtenberg, 1990), total number of forward citations by any party must be increased. Accordingly, total number of forward citations from a licensor, **FFCITE_ALL**, is defined. It is the number of all forward citations at the firm level, i.e., the count of patents, which are citing licensor firms' patents and are obtained by any firms in post-licensing period (after 1990). Similarly, **CITE_ALL**, i.e., total number of forward citations to licensed patents, is used for the H2 test.

<Technological asset characteristics of firms>

When two firms have similar technology portfolios, they are more likely to cite each other than in the case of technologically distant firms. Technological proximity should be therefore controlled. Following Jaffe (1986), this paper defines technological proximity between two firms by the cosine of the angle formed between two patent portfolio vectors. More accurately, firms' patent assets by the year 1990 are characterized by vectors of patent counts in each of IPC 118 Class, and the cosine of two vectors are given by the inner products 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.

A firm's technological diversification is another issue, since a diversified firm has many other technologies outside of a narrow range of licensing. In order to quantify the level of diversification in different technologies, a measurement similar to Hirfindahl-Hirschman Index is calculated by the patent portfolio vectors. **LSR_HHI** and **LSE_HHI** are licenscor's HHI and licensee's HHI, respectively, which are the sum of squared fractions in the IPC 118 Class.

<Firm size>

Firm-level cross-citations as well as cross-citations on licensed patents are influenced by the size of firms. Therefore, the variables **LSR_CAP** (LicenSoR CAPital) and **LSE_CAP** (LicenSEe CAPital) are defined and used as control variables. 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.

<Technology class dummies>

Technological attributes 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 H2 test. However, firm-level tests cannot use this variable because sections are observed in a firm-pair.

3.4 Specifications

The hypotheses are tested by way of estimating the three groups of equations below. First set of equations, Models 1-5, is for the tests on firm-level knowledge transfer, which is unconditional of technology class (H1). Firm-level citations are computed for all possibilities of firm pairs between the observed 203 licensors and 135 licensees, and regressions are conducted by the explanatory and control variables. Specifically, the equations have the basic form as follows.

<Models 1-5>

(FFCITE: Firm-to-firm cross-citations) = F (JV, CRSLIC, UNILAT, FFCITE_ALL, LSR_CAP, LSE_CAP, COS, LSR_HHI, LSE_HHI, C) (Results: Table 2.)

Since all data consisting of (203x135 =) 27,405 pairs cannot be accommodated in econometric software, and since there are many zero observations of firm-to-firm citations, firms having at least 15 patents in 1990 are selected. This makes smaller set of observations of 15,340 firm pairs (130 licensors and 118 licensees) in total, but the set includes most of the observations with joint ventures and cross-licensing[13].

[13] The number of observations of actual licensing pairs reduce to 64.2% (327 obs. from 509 obs.), but 95.6% (22 out of 23) of joint venture pairs and 96.3% (79 out of 82) of cross-licensing pairs are retained in the reduced set.

The second set of equations, Models 6-9, is for the tests on knowledge transfer specific to licensed technology (H2). The unit of observation is each licensed patent, and cross-citations to the 2105 licensed patents are the dependent variable. The specification is as follows, and this should provide results on the most micro-analytic knowledge transfer.

<Models 6-9>

(CROSS_CITE: Cross-citations to licensed patents) = F(JV, CRSLIC, CITE_ALL, LSR_CAP, LSE_CAP, COS, LSR_HHI, LSE_HHI, IPC_A-G, C) (Results: Table 3.)

Lastly, models 10-24 are for the test on firm-level knowledge transfer again (H2A and H3). Unlike the first set of models, cross-citations as proxies for transferred knowledge are segmented to "inside" and "outside" of the patent class of licensed technology. Also unlike the first set of models, the domain of the tests is the observed 509 licensing pairs, and therefore the variable UNILAT is omitted. Otherwise, specification is the same with the first set as:

<Models 10-24>

(Firm-to-firm cross-citations) = F (JV, CRSLIC, FFCITE_ALL, LSR_CAP, LSE_CAP, COS, LSR_HHI, LSE_HHI, C) (Results: Table 4a and 4b.)

4 Results and discussion

The results from the first set of equations (models 1-5) are displayed in Table 2. Because of large fraction of zero observations in the dependent variable (71.6%), models 1 through 4 are estimated by TOBIT. Model 5 includes the same variables as the model 4, except that the model is estimated by negative binomial, due to the fact that the dependent variable is a count variable[14]. The sample size reduced from 15,340 to 14,278 due to missing LSR_CAP observations.

Model 1 is the baseline model, which does not include any governance-related explanatory variables. It shows that citations by a firm to another firm are affected by total number of citations by all firms, firm size, technological proximities and technological diversification of firms. Specifically, coefficients of FFCITE_ALL, LSR_CAP[15], LSE_CAP, and COS are all positive and significant, while coefficients of LSR_HHI and LSE_HHI are negative and significant. When total citations by all firms, licensor size, licensee size, and technological proximities of two firms are larger or higher, citations at the firm level are increased, which is an intuitive result. On the other hand, negative coefficients of LSR_HHI and LSE_HHI mean that a technologically diversified firm is more cited by other firms than technologically concentrated firms is, and that a technologically diversified firm seems to cite other firms more often than less diversified firms do. Although this is not the focus of this paper, the result offers an interesting

[14] The author would like to thank Rene Belderbos for a suggestion on this point.

[15] Licensor size and total number of citations by all firms have rather strong positive correlation. Correlation coefficient is 0.4 in this model, whereas Table 6a indicates that the correlation exceeds 0.7 on 509 licensing pairs. It reduces the reliability of the coefficients for FFCITE_ALL and LSR_CAP. In fact, results in the following models are not consistent with respect to LSR_CAP, possibly because of this problem, and much smaller number of observations compared to Model 1-4.

perspective to "absorptive capacity" arguments (Cohen and Levinthal, 1989, 1990).

Model 2, 3, and 4 add governance dummies to the baseline model. Model 2 has UNILAT with a positive and significant coefficient, implying that licensing accelerates knowledge transfer between firms[16]. Model 3 adds CRSLIC to the model 2, and positive coefficients confirm that cross-licensing has an advantage over unilateral licensing in knowledge transfer. Model 4 further adds JV to the model 3, and again positive coefficients indicate that the existence of a joint venture is another driver for knowledge transfer. Negative binomial model 5 shows the same results. Thus, when firm pairs have unilateral licensing, cross-licensing, and joint venture, total firm-level citations become larger by each of governance instruments. All of those tests above consistently confirm H1.

Next, OLS estimation results on the second set of equations (models 6-9) are displayed in Table 3. Model 6 is the baseline for CROSS_CITE, which is the proxy for knowledge transfer to licensees specific to licensed technologies. CITE_ALL and COS are positive and significant, meaning that licensee's cross-citations are greater when outside innovation possibilities are larger and when licensor and licensee firms are technologically closer. Model 7 adds JV and model 8 adds CRSLIC to the baseline model, which test if joint venture and cross-licensing accelerate knowledge transfer to licensee firm. Together with the model 9, which have both JV and CRSLIC

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[16] While intuitive, this result supports the use of citations as a proxy for knowledge transfer (Jaffe et al., 2000).

as explanatory variables, the results consistently support H2.

Finally, OLS estimation results on the third set of equations (models 10-24) are presented in Table 4a and 4b. The tests are conducted on 509 firm pairs, which were actually involved in patent licensing. Dependent variable in all of the models is firm-level cross-citations, though different segments of licensor firms' patent portfolio are used as originating patents for the citations. Models from 10 through 19 do not include cross-licensing dummy (CRSLIC) and the results are shown in Table 4a. Models from 20 through 24 include the cross-licensing dummy variable and the results are shown in Table 4b. Remarkably consistent finding is the positive and significant coefficient for JV, regardless of the technological segments of licensors' portfolio and regardless of the inclusion of CRSLIC variable. Therefore, H2A and H3 are supported from the results. Joint ventures not only reinforce knowledge transfer with respect to the explicitly licensed technology or technologies close to the licensed technologies, but also help knowledge transfer from the whole knowledge assets of a licensor. Another interesting finding with Table 4b is the positive and significant coefficient for CRSLIC, meaning that cross-licensing also helps firm-wide knowledge transfer. Although cross-licensing is often agreed upon concerning a limited set of technologies, its influence on knowledge transfer seems to span wide range due to the hostage function at the firm level.

5 Conclusion

Despite of intense research interests with alliances and knowledge transfer, the issue of actual scope of knowledge transfer has been surprisingly unexplored. This paper utilizes simple methodology in trying to find the difference between equity-based joint ventures and market-based licensing contracts, while recognizing the possibilities of complementarities between them. Hypotheses are robustly supported by the results, indicating that there is indeed difference in the scope of knowledge transfer between equity-based joint venture and market-based licensing contracts. It offers unique evidence, which has relevance with the understanding of knowledge transfer mechanism through alliances.

The finding contributes to TCE in conjunction with resource-based view. The result is informative for the resource-based theory, in that technological resource trades do occur between firms and are influenced by the type of contractual forms. Also, the results support TCE by suggesting the role of joint venture and cross-licensing as hostages. In particular, cross-licensing is not always comprehensive so as to cover entire technological assets of a firm. The result with regard to cross-licensing as an intermediary of firm-wide resources further indicates that the scope of knowledge transfer can be broader than contractual scope when governance affects other parts of a firm. In other words, incentive alignment through governance as one of the core arguments of TCE seems to be a useful notion, where diversified firms face well known contractual hazards in contracting for technology transfer. Although there is a debate over the "opportunism" notion in understanding the role of joint venture (Conner and Prahalad, 1996), the results of the paper are intuitive if opportunism and safeguarding mechanism matter at the firm level. It would be correct that joint ventures facilitate transfer of organizationally embedded knowledge through personal contracts (Davies, 1977), yet incentive perspective at the firm level cannot be ignored.

The analyses are preliminary and there remain ample rooms to be improved. Obviously, more joint venture samples are needed. Also, patent classification is not a perfect proxy for technological diversification. In addition, quantification of joint venture product lines and technological requirements in comparison with parent firms would be useful. However, greatly needed is finer level of empirical analyses on strategic alliances, and patent information has much to be utilized for evidence finding.

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Table2. Firm-level citations and contracting types
Dependent variable: FFCITE

	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5
Method of estimation	TOBIT	TOBIT	TOBIT	TOBIT	Negative Binomial
JV				303. *** (11.3)	0.494 *** (4.68)
CRSLIC			204. *** (12.7)	193. *** (12.1)	0.919*** (10.1)
UNILAT		112.*** (14.8)	59.8*** (6.99)	41.5*** (4.83)	0.483*** (7.40)
FFCITE_ALL	0.285E-02*** (34.9)	0.265E-02*** (33.0)	0.260E-02*** (33.0)	0.254E-02*** (32.8)	0.214E-04*** (38.5)
LSR_CAP	0.169E-08** (2.96)	0.200E-08*** (3.59)	0.210E-08*** (3.86)	0.210E-08*** (3.92)	0.351E-10*** (7.10)
LSE_CAP	0.231E-03*** (15.8)	0.216E-03*** (15.0)	0.208E-03*** (14.8)	0.204E-03*** (14.7)	0.154E-05*** (17.4)
COS	229.*** (35.8)	209.*** (32.9)	203.*** (32.7)	200.*** (32.6)	2.44*** (42.3)
LSR_HHI	-94.5*** (-10.5)	-95.6*** (-10.8)	-93.2*** (-10.8)	-92.1*** (-10.8)	-1.92*** (-16.2)
LSE_HHI	-156.*** (-11.4)	-148.*** (-11.1)	-141.*** (-10.7)	-139.*** (-10.8)	-2.71*** (-17.8)
C	-159.*** (-34.9)	-154.*** (-34.5)	-151.*** (-34.5)	-148.*** (-34.4)	1.58*** (31.5)
Log likelihood	-28137	-28031	-27952	-27890.	-20336.

N= 14278, Fraction of positive dependent variable observations = 0.286
Estimated coefficients are in upper rows and t-values are in parentheses.
** indicates significance at 0.01 level. *** indicates significance at 0.001 level.

Table 3. Joint venture, cross-licensing, and post-licensing citations to licensed patents
Dependent variable: CROSS_CITE
Method of estimation: Ordinary Least Squares

	MODEL 6	MODEL 7	MODEL 8	MODEL 9
JV		1.44*** (4.03)		1.41*** (3.95)
CRSLIC			0.793** (3.15)	0.766** (3.05)
CITE_ALL	0.0976*** (13.6)	0.0979*** (13.7)	0.0961*** (13.4)	0.0965*** (13.5)
LSR_CAP	-7.76E-11 (-1.32)	-1.07E-10 (-1.81)	-5.16E-11 (-0.872)	-8.17E-11 (-1.37)
LSE_CAP	1.24E-07 (0.109)	-1.95E-07 (-0.172)	8.70E-08 (0.0766)	-2.25E-07 (-0.198)
COS	1.94*** (4.77)	1.81*** (4.45)	1.78*** (4.34)	1.65*** (4.03)
LSR_HHI	-0.614 (-1.40)	-0.471 (-1.07)	-0.418 (-0.945)	-0.284 (-0.643)
LSE_HHI	0.844 (0.990)	0.797 (0.939)	1.20 (1.40)	1.14 (1.33)
IPC_A	-0.494 (-0.529)	-0.450 (-0.484)	-0.495 (-0.531)	-0.453 (-0.488)
IPC_B	0.783* (2.23)	0.832* (2.37)	0.802* (2.28)	0.849* (2.43)
IPC_C	-0.279 (-0.758)	-0.157 (-0.428)	-0.213 (-0.579)	-0.0964 (-0.262)
IPC_D	-0.0688 (-0.0458)	0.0673 (0.0450)	-0.0153 (-0.0102)	0.116 (0.0778)
IPC_E	-0.216 (-0.195)	-0.217 (-0.197)	-0.109 (-0.0984)	-0.114 (-0.103)
IPC_F	-0.0196 (-0.0257)	-0.0407 (-0.0534)	0.0254 (0.0334)	3.34E-03 (4.39E-03)
IPC_G	0.295 (1.34)	0.349 (1.59)	0.237 (1.07)	0.292 (1.32)
C	-0.740 (-1.96)	-0.798* (-2.12)	-0.910* (-2.39)	-0.960* (-2.53)
Adjusted R-squared	0.0911	0.0977	0.0949	0.101

N=2105 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.

Table 4a. Equity joint ventures and firm-level citations between 509 licensing pairs

Estimation Method: Ordinary Least Squares

	MODEL 10	MODEL 11	MODEL 12	MODEL 13	MODEL 14	MODEL 15	MODEL 16	MODEL 17	MODEL 18	MODEL 19
Dependent Variable	FFCITE	FFCITE	FFCITE_IN	FFCITE_IN	FFCITE_OUT	FFCITE_OUT	FFCITE_IN2	FFCITE_IN2	FFCITE_OUT2	FFCITE_OUT2
JV		275*** (5.73)		154*** (6.01)		120*** (3.84)		200*** (5.72)		74.7*** (3.45)
FFCITE_ALL	4.39E-03*** (8.54)	4.07E-03*** (8.11)	1.73E-03*** (6.26)	1.55E-03*** (5.76)	2.66E-03*** (8.07)	2.52E-03*** (7.70)	2.89E-03*** (7.72)	2.66E-03*** (7.27)	1.49E-03*** (6.59)	1.41E-03*** (6.23)
LSR_CAP	-2.16E-08** (-2.74)	-2.08E-08** (-2.72)	-6.41E-09 (-1.51)	-5.93E-09 (-1.44)	-1.52E-08** (-3.01)	-1.48E-08** (-2.98)	-1.17E-08* (-2.03)	-1.10E-08* (-1.98)	-9.95E-09** (-2.85)	-9.72E-09** (-2.82)
LSE_CAP	3.12E-04** (2.66)	2.70E-04* (2.37)	1.19E-04 (1.88)	9.54E-05 (1.55)	1.93E-04* (2.57)	1.75E-04* (2.35)	1.97E-04* (2.30)	1.66E-04* (2.00)	1.15E-04* (2.23)	1.04E-04* (2.02)
COS	303*** (7.41)	278*** (6.98)	115*** (5.24)	101*** (4.75)	187*** (7.16)	176*** (6.80)	191*** (6.44)	174*** (5.98)	111*** (6.15)	104*** (5.81)
LSR_HHI	23.3 (0.603)	26.4 (0.704)	20.9 (1.00)	22.7 (1.12)	2.41 (0.0974)	3.76 (0.153)	28.3 (1.00)	30.6 (1.11)	-4.99 (-0.291)	-4.15 (-0.245)
LSE_HHI	38.8 (0.514)	12.5 (0.171)	39.4 (0.968)	24.6 (0.624)	-0.559 (-0.0115)	-12.0 (-0.251)	43.8 (0.794)	24.6 (0.460)	-4.94 (-0.147)	-12.0 (-0.365)
C	-140*** (-4.14)	-130*** (-3.95)	-65.4*** (-3.58)	-59.6*** (-3.37)	-75.0*** (-3.45)	-70.5** (-3.28)	-101*** (-4.09)	-93.6*** (-3.90)	-39.3** (-2.62)	-36.5* (-2.45)
Adjusted R-squared	0.281	0.323	0.164	0.219	0.265	0.284	0.233	0.279	0.200	0.217

N=509 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.

Table 4b. Equity joint ventures, cross-licensing and firm-level citations between 509 licensing pairs
Estimation Method: Ordinary Least Squares

	MODEL 20	MODEL 21	MODEL 22	MODEL 23	MODEL 24
Dependent Variable	FFCITE	FFCITE_IN	FFCITE_OUT	FFCITE_IN2	FFCITE_OUT2
JV	262*** (5.62)	149*** (5.90)	113*** (3.69)	191*** (5.61)	71.4*** (3.32)
CRSLIC	150*** (5.40)	71.0*** (4.70)	79.8*** (4.33)	109*** (5.39)	40.9** (3.19)
FFCITE_ALL	3.64E-03*** (7.36)	1.35E-03*** (5.05)	2.29E-03*** (7.04)	2.35E-03*** (6.51)	1.29E-03*** (5.70)
LSR_CAP	-1.58E-08* (-2.11)	-3.60E-09 (-0.89)	-1.22E-08* (-2.48)	-7.48E-09 (-1.36)	-8.38E-09* (-2.43)
LSE_CAP	1.93E-04 (1.72)	5.90E-05 (0.976)	1.34E-04 (1.82)	1.10E-04 (1.35)	8.32E-05 (1.62)
COS	244*** (6.20)	85.4*** (4.02)	158*** (6.12)	148*** (5.19)	95.0*** (5.26)
LSR_HHI	47.0 (1.27)	32.3 (1.63)	14.6 (0.604)	45.6 (1.70)	1.41 (0.0840)
LSE_HHI	49.8 (0.694)	42.1 (1.08)	7.68 (0.162)	51.8 (0.99)	-1.97 (-0.0598)
C	-140*** (-4.37)	-64.5*** (-3.72)	-75.9*** (-3.59)	-101*** (-4.32)	-39.3** (-2.66)
Adjusted R-squared	0.359	0.250	0.309	0.317	0.231

N=509 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.

Table 5. Variable Descriptions

Variable	Descriptions
JV	Binary variable, which equals to unity when a firm pair has a joint venture and equals to zero otherwise
CRSLIC	Binary variable, which equals to unity when a cross-licensing is observed between a firm pair. In the H2 test, this variable equals to one for a patent when the patent is licensed through cross-licensing.
UNILAT	Binary variable, which equals to unity when a firm pair has at least one patent licensing
FFCITE	Firm-to-firm all citations after 1990 (Counts of citations by one firm's patents obtained after 1990 to all of another firm's patents obtained before 1990; this restriction is the same with the four variables below.)
FFCITE_IN	Counts of firm-to-firm cross-citations within the patent class of licensed patents (using IPC "Class")
FFCITE_OUT	Counts of patents that are citing licensor firms' patents in the different patent "Class" of IPC from those of the licensed patents, and are obtained by licensee firms in post-licensing period.
FFCITE_IN2	Counts of firm-to-firm cross-citations within the patent class of licensed patents (using IPC "Section")
FFCITE_OUT2	Counts of patents that are citing licensor firms' patents in the different patent "Section" of IPC from those of the licensed patents, and are obtained by licensee firms in post-licensing period.
FFCITE_ALL	Count of patents, which are citing licensor firms' patents and are obtained by any firms in post-licensing period (i.e., after 1990)
CROSS_CITE	Counts of forward citations (after 1990) to licensed patents
CITE_ALL	Count of patents, which are citing licensed patents and are obtained by any firms in post-licensing period (after 1990)
LSR_CAP	LicenSoR CAPital
LSE_CAP	LicenSEe CAPital
COS	Technological proximity between two firms by the cosine of the angle formed between two patent portfolio vectors based on IPC "Class"
LSR_HHI	Hirfindahl-Hirschman Index calculated by the patent portfolio vector for a licensor firm
LSE_HHI	Hirfindahl-Hirschman Index calculated by the patent portfolio vector for a licensee firm
IPC_A	Dummy for International Patent Classification, Section A (Human Necessities)
IPC_B	Dummy for International Patent Classification, Section B (Performing Operations ; Transporting)
IPC_C	Dummy for International Patent Classification, Section C, (Chemistry/Metallurgy)
IPC_D	Dummy for International Patent Classification, Section D (Textiles/Paper)
IPC_E	Dummy for International Patent Classification, Section E (Fixed Constructions)
IPC_F	Dummy for International Patent Classification, Section F (Mechanical Engineering; Lighting; Heating; Weapons; Blasting)
IPC_G	Dummy for International Patent Classification, Section G (Physics)
IPC_H	Dummy for International Patent Classification, Section H (Electricity)

Table 6a. Descriptive Statistics (509 licensing pairs)

	Mean	Sum	Std Dev	Minimum	Maximum
JV	0.045	23.000	0.208	0	1
CRSLIC	0.161	82.000	0.368	0	1
LSR_CAP	9.20D+08	4.68D+11	1.80D+09	0	1.64D+10
LSE_CAP	108966.2	5.54D+07	96873.5	927.0	780000.0
COS	0.424	216.013	0.272	0	0.997
LSR_HHI	0.321	163.225	0.301	0	1
LSE_HHI	0.153	77.675	0.146	0	1
FFCITE_ALL	16931.7	8618240	28537.6	0	104326
FFCITE	90.1	45906	266.6	0	2535
FFCITE_IN	32.7	16671	133.1	0	1789
FFCITE_OUT	57.4	29235	168.9	0	1666
FFCITE_IN2	55.8	28437	188.3	0	2090
FFCITE_OUT2	34.3	17469	111.7	0	1330

Correlation matrix

	JV	CRSLIC	LSR_CAP	LSE_CAP	COS	LSR_HHI	LSE_HHI	FFCITE _ALL	FFCITE	FFCITE _IN	FFCITE_ OUT	FFCITE_I N2	FFCITE_ OUT2
JV	1.000												
CRSLIC	0.111	1.000											
LSR_CAP	0.105	0.050	1.000										
LSE_CAP	0.061	0.215	-0.129	1.000									
COS	0.154	0.276	0.181	0.251	1.000								
LSR_HHI	-0.115	-0.202	-0.358	0.029	-0.321	1.000							
LSE_HHI	0.019	-0.178	0.012	-0.400	-0.176	-0.033	1.000						
FFCITE_ALL	0.166	0.181	0.702	-0.101	0.192	-0.439	0.007	1.000					
FFCITE	0.318	0.365	0.216	0.155	0.390	-0.224	-0.078	0.404	1.000				
FFCITE_IN	0.320	0.307	0.189	0.104	0.291	-0.159	-0.033	0.327	0.849	1.000			
FFCITE_OUT	0.251	0.334	0.192	0.163	0.386	-0.228	-0.097	0.380	0.909	0.552	1.000		
FFCITE_IN2	0.316	0.349	0.218	0.129	0.347	-0.194	-0.055	0.384	0.937	0.943	0.736	1.000	
FFCITE_OUT2	0.228	0.282	0.149	0.153	0.346	-0.208	-0.093	0.318	0.808	0.438	0.930	0.550	1.000

Table 6b. Descriptive Statistics (2105 licensed patents)

	Mean	Sum	Std Dev	Minimum	Maximum
CROSS_CITE	1.24	2621	4.60	0	79.5
JV	0.0821	173	0.274	0	1
CRSLIC	0.199	419	0.399	0	1
CITE_ALL	10.1	21430	13.6	0	219
LSR_CAP	9.74D+08	2.05D+12	1.80D+09	0	1.64180D+10
LSE_CAP	116756.0	2.45D+08	97105.9	927	780000
COS	0.484	1020.4	0.256	0	0.99673
LSR_HHI	0.254	536.1	0.245	0	1
LSE_HHI	0.135	286.0	0.129	0	1
IPC_A	0.0109	23	0.103	0	1
IPC_B	0.0950	200	0.293	0	1
IPC_C	0.0864	182	0.281	0	1
IPC_D	0.00427	9	0.0652	0	1
IPC_E	0.00807	17	0.0895	0	1
IPC_F	0.0166	35	0.127	0	1
IPC_G	0.367	773	0.482	0	1

Correlation Matrix

	CROSS_CITE	JV	CRSLIC	CITE_ALL	LSRCAP	LSE_CAP	COS	LSR_HHI	LSE_HHI
CROSS_CITE	1.000								
JV	0.082	1.000							
CRSLIC	0.105	0.046	1.000						
CITE_ALL	0.282	-0.040	0.062	1.000					
LSR_CAP	-0.029	0.171	-0.081	-0.066	1.000				
LSE_CAP	0.013	0.095	0.112	-0.016	-0.054	1.000			
COS	0.096	0.147	0.173	-0.030	0.184	0.220	1.000		
LSR_HHI	-0.003	-0.146	-0.109	0.150	-0.360	0.018	-0.219	1.000	
LSE_HHI	-0.004	-0.045	-0.158	-0.056	-0.050	-0.430	-0.163	0.006	1.000
IPC_A	-0.026	-0.015	-0.018	-0.037	-0.034	-0.062	-0.020	0.035	0.059
IPC_B	0.029	-0.020	-0.024	-0.050	-0.088	-0.005	-0.071	-0.088	0.042
IPC_C	-0.036	-0.037	-0.077	-0.010	0.194	-0.088	-0.012	-0.140	-0.063
IPC_D	-0.005	-0.020	-0.033	-0.039	-0.015	-0.042	0.082	0.080	0.119
IPC_E	-0.020	-0.027	-0.045	0.028	-0.049	-0.095	-0.163	0.064	-0.089
IPC_F	-0.032	0.002	-0.046	-0.071	-0.040	-0.005	-0.054	0.088	0.024
IPC_G	0.044	-0.056	0.104	0.060	-0.087	-0.057	0.001	0.058	0.093