RIETI Discussion Paper Series 21-E-028

Leveraging Standard Essential Patents for Capturing Innovation Rents: The Strategic Disclosure of License Rules

HUO, Dong
Harbin Institute of Technology, Shenzhen

DANG, Jianwei
Tongji University

MOTOHASHI, Kazuyuki
RIETI

The Research Institute of Economy, Trade and Industry
https://www.rieti.go.jp/en/

RIETI Discussion Paper Series 21-E-028
March 2021

Leveraging Standard Essential Patents for Capturing Innovation Rents: The Strategic Disclosure of License Rules [1]

Dong Huo
Harbin Institute of Technology, Shenzhen

Jianwei Dang
Tongji University

Kazuyuki Motohashi
RIETI

Abstract

A general view of standard essential patents (SEPs) is that they provide profiting opportunities by licensing-out, in general, under the FRAND (Fair, reasonable and non-discriminatory) terms. However, a large part of SEPs holders declares "generous" free-license terms, thus abandon direct profiting opportunities. A patent can be used not only for appropriating rent from itself, but also for using it as a leverage to sustain the patent holder's competitive position in the market. This paper empirically addresses the determinants of such motivation for patenting (leverage strategy), by using the license terms of SEPs (free vs. royalty-bearing, and the inclusion of reciprocal terms). Using intellectual property rights disclosure data of IETF, a standard development organization, this paper investigates both firm-level and patent-level factors in shaping the license terms based on three-stage estimation of structural equations. Two types of strategy, "generic" leveraging against all potential competitors in a technology market and "specific" leveraging for keeping firm's competitive position to specific competitor as a licensee, are identified, and it is found that the former motivation works stronger for SEPs holders.

Keywords: standard-essential patent; license contract, leveraging strategy
JEL classification: L24; O34

[1]This study was conducted as part of the "Digitalization and Innovation Ecosystem: A Holistic approach" project undertaken at the Research Institute of Economy, Trade and Industry (RIETI). An earlier version of this paper was presented at Academy of Management Annual Conference, August 2020. The authors would like to thank Professor Nagaoka and RIETI discussion paper seminar participants for their helpful comments.

1. INTRODUCTION

The value of patents as strategic asset for technology firms has been continually increasing. Meanwhile, the strategy to capture value from patents has becoming more and more complex. Patent strategies had gone beyond the traditional "stake out and defend a proprietary market advantage" approach (Rivera and Kline 2000), and even gone further beyond the view of patent "licensing as a means for generating revenues" (Arora and Fosfuri 2003). A particular example is patent strategy in standard setting process.

In technology standard setting, patent holders face a series of complex decisions in maximize the strategic values of patents. To solve the holdup problem incurred by fragmented standard essential patents (SEPs) ownership, the participants need to commit to grant licenses to other parties, including its competitors, eliminating the choice of using SEPs for defending a proprietary market advantage(Shapiro 2000). In return, SEP holders gain opportunities to capture innovation through licensing royalties, though the royalty rate and license terms may be constrained by some general rules set by standard-setting organizations (SSOs). Calibration of license terms highly depends on the firms' technology and patent competitiveness, business strategies, and competition status.

The complex nature of patent assets, and how firms manage it in different contexts, has gained more and more attentions in management literature. Somaya (2012) proposes an integrative overview of patent strategy research by classifying three generic patent strategies: proprietary strategy, defensive strategy and leveraging strategy. Propriety patent strategy aims to build business advantage for a firm by protect it from imitation, while defensive strategy is to retain operation freedom through patent portfolio building, preemption, validity challenge, etc. The leveraging strategy, by Somaya's definition, is to take the bargaining advantage conferred by patent ownership for securing direct and indirect profits. The obvious example of direct revenues are royalties and compensation for infringement damages. The indirect benefits

may include advantages in standard settings or negations supply contract (Somaya 2012). The key logic of leveraging strategy is to exploit the barging power conferred by exclusivity of patent rights, and the effectiveness of leveraging strategy is highly constrained by the relative bargaining power of the counterparty, which is well-explained by aggressive litigation strategies taken by "patent trolls" (Somaya 2012). As "patent trolls" generally does not commercialize patents by themselves, thus asymmetrically hold up to other firms, they exploit bargaining power to capture large direct rents from settlements with targeted infringers.

Somaya's classification of leveraging strategy as a separate category has provided a new perspective in understanding patent strategies in standard setting process. The pivotal value of SEPs as a strategic asset is that it empowers its holders strong bargaining power, allowing it to capture direct and indirect rents. However, successful exploitation of SEPs value is highly context dependent, and requires strategic considerations. The direct revenue from license royalties and other indirect benefits, such as higher acceptance and influence of the standards may be at odds, thus tradeoff are needed. A detailed study with a theoretic framework is needed to understand how firms leverage their SEPs for maximize their rents.

In this paper, we study an important strategic decision by SEPs holders—setting license terms of their declared SEPs. We observed that many SEP holders declares "generous" free-license terms for their SEPs, thus abandon direct profiting opportunities. We try to clarify the factors leading to such decisions by investigating potential patent leveraging strategies. Meanwhile, we also observed that some SEP holders include reciprocal terms in their IPR policies for defensive purpose. Therefore, we decouple the license terms of SEPs into two strategic decisions: free vs. royalty-bearing, and the inclusion of reciprocal terms, then discusses the strategic value of the two license decisions.

The reminder of the article is organized as follows. Section 2 introduces the general licensing policy in SSOs, especially IETF. Section 3 develops theory and hypotheses from the

perspective of leveraging strategy as a strategic management of patent. Section 4 specifies the methodology for the empirical examination on our sample organized from the IPR information at IETF, and Section 5 presents the empirical results. Finally, we discuss the results and future directions, and conclude our contributions to the literature in Section 6.

2. LICENSING COMMITMENTS IN STANDARD-SETTING PROCESS

Standards have become increasingly important to firms in high-tech industries, where standard-setting organizations (SSOs) are inevitable in setting up standardization policies while managing standardization processes(Farrell and Simcoe 2012; Kang, Huo, and Motohashi 2014; Simcoe 2012). Among other polices in SSOs, intellectual property rights (IPR) policy draws broad attention from SSO participants(Bekkers, Duysters, and Verspagen 2002). Each SSO has its policy about IPR with respect to the standards proposed and established in the SSO. For example, IETF issued a series of Request for Comments (RFCs) (an updated version RFC 8179) to guide all IPR relevant issues in the scope of IETF (Bradner and Contreras 2017)

In general, IPR policies in SSOs request participants to disclose information about their own or others' IPR, including, but not limited to, standard-essential patents (SEPs) and licensing commitments to offer these SEPs for license on fair, reasonable, non-discriminatory (FRAND or RAND) terms.[1] The RAND terms can help to mitigate the risk of patent holdup and royalty stacking (Lemley and Shapiro 2006).

Albeit differences across SSOs (Chiao, Lerner, and Tirole 2007), IPR policy is generally purposed for encouraging (or sometimes even enforcing) SSO participants to timely provide adequate information for decision-makers in these SSOs to consider when conducting relevant

[1] "FRAND" is commonly used in European-based SSOs, while "RAND" commonly appears in U.S.-based SSOs. The two terms are acknowledged interchangeable in all circumstances.

standards. For example, in RFC 8179 issued by IETF, the general policy is written: "*In all matters relating to Intellectual Property Rights, the intent is to benefit the Internet community and the public at large, while respecting the legitimate rights of others. The disclosures required by this policy are intended to help IETF working groups define superior technical solutions with the benefit of as much information as reasonably possible about potential IPR claims relating to technologies under consideration*" (Bradner & Contreras, 2017) (page 8).

On the one hand, disclosing IPR information is rather flexible for SSO participants as such an act appears to be merely informational to SSOs. Sometimes, firms even strategically make generic or blanket statements that do not provide detailed IPR information to specify SEPs or licensing terms for a variety of reasons(Lerner, Tabakovic, and Tirole 2016). The most critical essence of RAND principles is *reasonable*, that is the SEP holders needs to grant license on a "reasonable" royalty. In most SEP declarations, patent owners provide additional licensing information that detail the specific terms, including an explicit statement of RAND term and whether it is royalty-free or royalty-bearing. Nevertheless, upon a specific lawsuit for patent infringement or a decision on the incorporation of the SEP into a standard, decision-makers such as court judges and SSO directors would not rely fully on such unlimited-scope clauses but rather evaluate them *reasonably*.

Once a patent holder makes a RAND commitment, it gives up the right that it otherwise would have had to refuse to license its SEP to others keeping for its own exclusive use, and the right to discriminate among licensees. However, some SEP license terms may include a "defensive suspension" clause that specifies the necessary condition of the RAND term, allowing a SEP licensor to terminate (or alter) a license upon the occurrence of a certain event, such as being excluded from *reciprocal* licensing and being sued for infringement by a licensee. Despite that most SSOs appear to limit reciprocal licensing obligations to only the standard (or standards) at issue, some reciprocal licensing clauses are not properly made within the scope

of the standard(s), which could allow an SEP owner for a *de facto* license to a licensee's entire portfolio.

Nevertheless, it is worth to notice that RAND commitments are made to commit a future act to offer licenses to implementers on declared RAND terms. In other words, most of time, actual negotiation remains needed to direct at licensing a patent subject to the RAND commitments; otherwise, SEP owners may assert their rights to claim injunctions or patent damages from implementers.

Specifically, IETF explicitly provides the following six SEP declaration options for SEP owners to select. They are: *a) no license required for implementers; b) royalty-free, reasonable and non-discriminatory license to all implementers; c) reasonable and non-discriminatory license to all implementers with possible royalty/fee; d) licensing declaration to be provided later (implies a willingness to commit to the provisions of a), b), or c) above to all implementers; otherwise, the next option 'unwilling to commit to the provisions of a), b), or c) above'. - must be selected); e) unwilling to commit to the provisions of a), b), or c) above; and f) see text below for licensing declaration*. We classify the IETF's RAND terms and give license term examples in Table 1. The last row shows terms with defensive suspension clauses.

(TABLE 1 HERE)

3. THEORY AND HYPOTHESIS

3.1 Strategic Management of Patents

Though the patent system is designed to grant monopoly right to commercialize patented inventions in exchange of technology information disclosure to the public, the strategy to exploit patent assets advances much further than securing a monopolized market. Licensing patents for accruing revenues from royalties, active technology disclosure through patenting to prevent others from patenting first, cross-licensing and creating of patent-pools, are all widely adopted approaches and has been widely discussed in management literature (Ziedonis 2004;

Pénin and Neicu 2018; Shapiro 2000). Somaya (2012) proposes an integrative overview of patent strategy research by classifying three generic patent strategies: proprietary strategy, defensive strategy and leveraging strategy. Propriety patent strategy aims to build business advantage for a firm by protect it from imitation, while defensive strategy is to retain operation freedom through patent portfolio building, preemption, validity challenge, etc. The leveraging strategy, by Somaya's definition, is to take the bargaining advantage conferred by patent ownership for securing direct and indirect profits. The direct benefits include royalties and damage awards. The indirect benefits can be highly context dependent, with examples such as advantages in standard settings or negations supply contract (Somaya, 2012).

Somaya proposes that leveraging strategies are facilitated by asymmetry holdup—one party is less constrained by fragmented patent ownership and value creation. A typical example of asymmetric holdup is licensing deals with a non-practicing NPE. As NPEs does not commercialize patents by themselves, they can leverage this advantage to charge high royalties and infringement damages (Somaya, 2012). The proposition is insightful for understanding patent strategies. However, as Somaya clarified, research on the indirect leverage of patents is quite sparse.

The relative importance of three types of strategies depends on the technology characteristics of a patent (as well as many other factors). For example, A patent found in discrete type of technology, such as pharmaceutical patents, pursuing royalty revenue by individual patent (proprietary strategy) is important. In contrast, in complex type technology such as a patent in electronics industry, a patent is rarely used individually, but is in its bundle, as is the case of cross licensing. The underlining motives of patent holding is not only generating royalty but leveraging patent holder's competitive position in a complex nature of technology market with inter-related patents (or even called "patent thicket"). That is, leveraging strategy is more relevant in strategic management if patents of such case.

3.2 Leveraging Strategy in SEP of Technology Standard

Underlining motivations behind cross licensing in complex technology case is to sustain freedom of R&D and business operation without fear of patent infringement to other's patents or holdup in the worst case. In case of technology standard, an implementation of existing standard is constrained by fragmented patent ownership and each patent holder is at risk of failing to get license from others. In a cooperative standard setting, commitment of a RAND license term helps to solve such mutual holdup problem.

However, the RAND commitment itself does not solve the problem perfectly, mainly because that a "reasonable" rate is a vague commitment with high uncertainties (Lemley 2002). There is not a clear upper limit of royalty rate (Geradin 2013), putting the potential licensees at risk of relying on court decision on a "reasonable" rate. An exception is that a SEP holder may declare to offer royalty-free license which fully eliminates the implementors' risk of paying unreasonably high royalties.

In some instances, firms may seek indirect benefits from their declared SEPs, for instance, getting a better position in a network (Bekkers, Duysters, and Verspagen 2002), increasing its influence in the standard setting process (Shapiro and Varian 1998), or securing operation freedom by including reciprocal terms in their IPR policy. In such cases, they may not pursue direct royalty revenue aggressively, or even provide generous free license offers.

We call this (free license declaration) as generic leveraging strategy, since free license will be applied to all potential users of the technology standard, instead of solving asymmetric holdup problem with some particular player, such as NPEs. Offering free license helps increase the size of eco-system built around the standard, thus creating friends using such standards could help increasing bargaining power of negotiation, in case of incident of NPE's challenge to a whole society (or influencing court decision favorably in a subsequent lawsuit).

All firms do not have such incentives for generic leveraging strategy equally. Or the relative importance depends also on a technology field and standard type, even within the same company. Instead of pursuing "generic" leveraging strategy, a reciprocal grant-back term in their license policies (in case of holdup) possible. Since this is targeted at a specific counterpart in bilateral licensing negotiation, we call this as "specific" leverage strategy.

3.3 Determinants of Two Types of Leverage Strategy

First, we look at firm level characteristics as determinant of two type of leveraging strategy. When the holdup is asymmetric, that is, an SEP holder is held up much less than its counterparty, the incentive to offer free license for eliminates holdup risk decreases significantly. A typical case is when negotiations are carried out between a practicing entity (e.g., manufacturers) and non-practicing entity. As the non-practicing generally does not implement technology standards and provide final products, they are somewhat insulated from being blocked by other patent holders(Reitzig, Henkel, and Heath 2007; Somaya 2012), thus a either generic leveraging strategy (free license) or specific leveraging strategy (reciprocal term) does not have much value for them. In contrast, practicing entity with downstream business (e.g. manufacturer) is more likely to face to asymmetric holdup, therefore

Hypothesis 1a. A SEP held by a practicing entity is more likely to be licensed for free.

Hypothesis 1b. A SEP held by a practicing entity is more likely to be licensed with a reciprocal licensing clause.

Besides the characteristics of firms (e.g., Practicing vs. non-practicing entities), the SEPs can be heterogenous. Before declaration as SEP, the focal patents may be applied for different business operations, and the protected inventions have substantial difference in terms of technological sources, quality, etc. The heterogeneity of SEPs may result in asymmetric holdup, which can affect the licensing term commitment.

For both patent applicants and examiners, non-patent literature (NPL) is necessary in their search for prior art to fulfilling the report duty and determining a patent application's patentability. Standard is a critical source of NPL, which is particularly relevant to SEPs examined in our research context. A patent that cites an extant standard is, to a certain extent, related to a technology component in the standard. Such a patent may create a sizable revenue for its owner either from product market or technology market (Arora & Fosfuri, 2003; Gambardella, Giuri, & Luzzi, 2007; Motohashi, 2008), since the standard could facilitate implementers' adopting technology in product market.

At the same time, a patent citing to a particular technology standard is relatively important to component (as compared to a patent not citing to standard) of existing standards, implying that such patent is backed by all (potential) users of the standard. It is important for a firm to enlarge the size of supportive community (or ecosystem) on the technology standard, so that a firm is motivated more toward generic leveraging strategy for such patent.

Given that a stronger bargaining position ensured by (potential) user community of the standard, a firm can use such patent as a leverage for a particular holdup incident (specific leveraging strategy) as well.

Hypothesis 2a. A SEP that references a standard is likely to be licensed with a reciprocal licensing clause when it is licensed for free.

Hypothesis 2b. A SEP that references a standard is less likely to be licensed with reciprocal clause.

The degree of leveraging strategy depends on prior or complementary technologies of the focal patents. We can measure the cumulative nature of patent by backward citation. In the context of patent strategy, self citation and non-self citation have completely different meaning. The former backward citation reflects that the patent holder construct strong patent portfolio in the technology field corresponding to these patents. The latter one shows rather weaker

position of the patent, relying on the technology held by others, or may not be a strategically important for the patent holder. Therefore, we focus on the former one, as a determinant of leveraging patent strategy.

We would posit a backward self-citation (signaling strong portfolio in corresponding technology) as a basis for generic and specific leveraging strategy. Given that such patent holder operates based on technology standards with other firms, a stronger position in certain component of such standard induces the firm to attract more players to that field. Therefore, such patent is likely to be used as a generic leverage to other players. In addition, such patent could be effective in case of being faced by holdup problem by some specific player.

Hypothesis 3a. A SEP w*ith backward self-citation is more likely to be licensed for free.*

Hypothesis 3b. A SEP w*ith backward self-citation is more likely to be licensed with reciprocal clause.*

4. METHODOLOGY

4.1 Data and Sample

IETF IPR disclosure data. We use IPR disclosures made by patent owners before the end of 2017. There are three kinds of IPR disclosures: 1) generic IPR disclosures, which describes an organization's general IPR policy relating to IETF standards; 2) specific IPR disclosures, which declares a patent holders' ownership of potential IPR relating to some specific RFC standards or proposals (i.e. internet-draft) and possible license terms; 3) specific third-party IPR disclosures, which are submitted by a third party to warn potential IPR existence relating to some specific RFC standards or proposals. We only use specific IPR disclosures in this study as patents cannot be identified from Generic IPR disclosures and licensing terms cannot be identified from third-party IPR disclosures. In total, we got 2530 disclosures. However, among these disclosures, there are duplicates entries for the same information or invalid inputs such

as “test”. We only use the disclosures with valid IPR holder, patents numbers, and RFC/internet-draft information, which resulted in 1,901 valid disclosures.

Matching IPR disclosure data with patent data. To create technical scope, legal scope and other patent level indicators, we need to match the disclosure information with patent data. The IETF does not have a standard format requirement for submitting patent numbers, thus firms may provide patent grant number, application numbers, or publication numbers in free text format. We parsed the text and retrieved any kind of patent number, together with patent authority (i.e. country) information and tried to identify the types of these number according to the patterns and ranges. Since the patterns are country specific, and some patent indicators are only comparable within a patent authority, we limit our sample to U.S. patents only. Among 6012 patent numbers identified, 4,436 are from USPTO. A manual sampling check of the remaining 1,576 patent numbers of other authorities are mainly of the same patent family with those filed in USPTO.

We then matched the 4,436 patent numbers and publication kind (application number, serial number or grant number) to PATSTAT 2017b patent database and identified 1,005 unique patents as many patents are disclosed with different kinds of patent numbers multiple times. Thus, we are able to retrieve patent bibliometric information from PATSTAT database, including number of claims, filing date and patent family size. The data is further matched to PatentsView US patent database (USPTO) to retrieve disambiguated assignee information and citation information.

Matching IPR disclosure data with IETF working group data. IETF’s standards proposal and setting are organized under different technical areas. Currently, there are seven areas: Applications and Real-Time Area (art), General Area (gen), Internet Area (int), Operations and

Management Area (ops), Routing Area (rtg), Security Area (sec), and Transport Area (tsv).[2] Under each technical area, many working groups are formed to tackle special technical problems and propose internet-draft, some of which will be finally approved as RFC. To map each disclosure to its technical area, we utilize this working group information and the title of internet-draft. As defined by IETF standards, the abbreviation of the working group should be used in the file name (also as a unique id) of internet-draft. Thus, for specific disclosures with internet-draft id, we can identify the working group and further technical area. For disclosures with RFC number, we first trace its original internet-draft id from RFC documentary history, and then apply the same routing to identify the technical areas.

Coding license terms. As described in Table 1, IETF explicitly provides six SEP declaration options for SEP owners to select, including "no license," "royalty-free," "royalty-bearing," "provided later," "unwilling to commit," and a free formatted "see below" option. Table 1 lists some examples of the license terms. Over 60% of disclosures are made under the option of "see below," along with customized licensing declarations. Also, the selection of options and the detailed license terms may be conflict. For example, a patent holder may select "royalty-bearing" but declare that free license may be provided under reciprocity. Thus, we codify license terms by text mining of detailed license declaration text and manual check. We classify "no license required," "royalty-free (no matter reciprocity required or not)" as royalty-free license, and other types of license terms as royalty-bearing (i.e. non-free). As shown in Table 1, IPR holders may include a reciprocal (grant back) licensing requirement for either royalty-free or royalty-bearing contract. This can either be indicated by some key phrases such as "subject to reciprocity" as illustrated in Telefonaktiebolaget LM Ericsson's license

[2] A detailed introduction of the technical areas can be found at IETF website: https://www.ietf.org/topics/areas/

terms in Line 2 of Table 1, or in the form of defensive suspension clauses "(the licensor) will retain the right to retain the right to terminate the license and assert its patents against any licensee who assert any patent right against (the licensor) …" as illustrated in KDDI's license term in Line 6 of Table 1. Thus, we also codify a dummy variable, *reciprocity*, to indicate whether the patent holder requests reciprocal licensing. We match the license term using some regex expressions, including "recipro.*" and "provided that the licensee provides a.*" , as a first step to identify reciprocal license requirement and do manual check for more complex text patterns of license terms.

4.2 Estimation Models

To empirically investigate the determinants of license terms of SEPs, and test the hypotheses, we define two variables to capture the key conditions of license terms: free and reciprocal., reflecting generic and specific leveraging strategy, respectively. The definitions are as follows.

free: a dummy variable equals 1 if the license term either requires no license or the patent holder claims not to assert any right against potential users or commit to grant a royalty-free license; equals 0 otherwise.

reciprocal: a dummy variable equals 1 if the SEP is offered for licensing with a reciprocal licensing-back term; equals 0 otherwise.

The two variables are coded for each declared license term, they can not be treated as independently determined variables. Therefore, we need to estimate simultaneous equations specified as follows.

$$\begin{cases} free = \alpha_1 \cdot reciprocal + \beta_1 \cdot X_1 + \gamma_1 \cdot X_3 + C_1 \\ reciprocal = \alpha_2 \cdot free + \beta_2 \cdot X_2 + \gamma_2 \cdot X_3 + C_2 \end{cases}$$

Where X_1 and X_2 are explanatory variables for the free and reciprocal respectively but is not explanatory variable for the other. X_3 are explanatory variables for both. The equations can be estimated using Three-stage Least Squares(3SLS) estimation model (Zellner and Theil

1992). The key point in estimation of the simultaneous functions is to find appropriate X_1 and X_2, which serve as "instrumental variables" for *free* and *reciprocal*. In our estimation, we define two variables, *claim_scope* and *duration* as the instrumental variable for *free* and *reciprocal*. The variable *claim_scope* is the inverse of word count of primary independent claim in unit of thousands, measuring the breadth of the focal SEP's claim scope (Dang and Motohashi 2015; Marco, Sarnoff, and deGrazia 2019) . The variable *duration* is the remaining years of the patent at the time of declaration in unit of years. The relationship between the dependent variables and two instruments are discussed as follows.

A key factor that shapes the strategic choice of a direct and indirect leverage strategy depends on is the strength of patent rights—whether the declared patents is "essential" enough to potential licensees to enter a royalty-bearing license contract. In an extreme case, a declared SEP may be essential for enabling all the proposed candidate standards, thus empower its holder strong exclusionary rights and bargaining power. As a more general rule, it is harder for the implementers to invent around patents with a broader claim scope. Therefore, SEPs holder are more likely to capture direct rents from those patents. Empirical studies also show that patent claim scope is closely related to the probability that a patent is litigated (Lanjouw & Schankerman, 1997).Thus, A SEP with a broader legal scope is likely to be licensed for royalty.

In an indirect leverage strategy, the importance of claim scope can be purpose dependent. For instance, strong patents are required to get greater acceptance or influence in standard setting process (Shapiro & Variance, 1999). However, in a defensive use of SEPs by inclusion of a reciprocal term, the SEPs holders generally does not need to do an *ex-ante* selection based on the strength of their declared SEPs, because the reciprocal term becomes effective only if the implementation of the standards is already constrained by the focal patent's claim scope. Therefore, the claim scope, which is a proxy of the *ex-ante* probability of infringement, should have no impact on the effectiveness of reciprocal terms.

An important nature of a reciprocal term is that it serves as a real option for the SEP holders to mitigate potential risk of being sued. Meanwhile, reciprocal terms decrease the attractiveness of the SEP for potential licensees with large patent portfolios or patents covering the focal firm's business. In other words, the option carries a cost. The SEPs holders are more likely to set a reciprocal term for SEPs with high option value. According to real option theory, the value of an option decreases as it approaches to expiration. In the U.S. and most patent laws nowadays, the term of a granted utility patent is twenty years from the earliest filing date of the application. The duration (remaining life) of a SEP on the date of IPR policy declaration is positively correlated with the option value of a reciprocal term and motivates inclusion of such term in licensing. Thus, A SEP with a longer legal duration is likely to be licensed with a reciprocal licensing clause.

However, the relationship between the duration of SEP and free/royalty-bearing licensing commitment is more subtle. In a general view, refusing to commit free licensing at the beginning does not prevent patent holders from negotiating a free license in the future. In other words, holding the royalty-bearing licensing option brought value for patent holders. However, in the case of IPR declaration for SEPs, the patent holders are constrained by the standard setting process as the free/royalty-bearing licensing policy for SEPs can be a key factor in the evaluation of alternatives for standards. Different from the reciprocal term which takes effects only when the SEP holder is sued by its licensees for patent infringement in the future, the effect of a royalty-bearing license term will take effect as soon as the relevant standard is enacted. Whatever the duration of the focal SEP is, a free-license commitment's merit to attract supporters can be exploited best in the selection of standards candidates. Therefore, the option value of postponing commitment of free license for long-duration SEPs can be considered as trivial. This is an important difference between SEP license commitment and other generic

license activities, which facilitates decoupling licensors' decision on royalty charging and reciprocal term inclusion.

The common explanatory variables appeared in both equations are as follows.

npe: dummy variable equals 1 if the SEP holder is a non-practicing entity or technology provider ; 0 otherwise.

rfc_cited: dummy variable equals 1 if the focal RFC or its draft has been cited in the declared SEPs, 0 otherwise.

self_citation: the number of backward citations made by its own.

non_self_citation : the number of backward citations made by other parties

family: the number of countries for which the same invention is patented.

We also include 6 technical area dummies and year period dummies to control for technical and year effects.

4.3 Descriptive Statistics

Table 2 shows the frequency of observations categorized by the two dependent variables—*free* and *reciprocal*. A reciprocal license is three times more likely to be requested if the patent holder commit free license of SEPs.

(TABLE 2 HERE)

(TABLE 3 HERE)

Table 3 presents descriptive statistics of major explanatory and control variables. In average, 34.8% of patents in the sample has cited the focal RFC or its drafts related to the IPR declaration. The average duration of 15.80 years also shows that the patents are in the early years of their life at the time of IPR disclosure. Generally, the SEPs has an international patent family covering major patent authorities.

(TABLE 4 HERE)

Table 4 presents the correlations among independent variables. All the correlation coefficients are less than 0.3, indicating no obvious multicollinear problem.

•5. RESULTS

We firstly conduct benchmark estimations using OLS regression models, with *free* and *reciprocal* as two dependent variables separately.

(TABLE 5 HERE)

Table 5 reports the estimation result with *free* as dependent variable. First, the results of instrument variables for identification of 3LSL are consistent to our prediction (*claim_scope* with statistically significant coefficients and *duration* with not). As for the key explanatory variables, the coefficient to *npe* is negative, but not statistically significant. The coefficients to *rfc_cited* and *self_citation* are positive and statistically significant.

(TABLE 6 HERE)

Table 6 reports the estimation result with *reciprocal* as dependent variable. The result shows that the coefficient to *duration* is negative and statistically significant, while claim_scope does not have statistically significant coefficients (consistent with our predictions as well). The coefficient to *npe* is negative and statistically significant. The coefficient to *family* is negative and statistically significant as predicted in Hypothesis 2b. The coefficients to *rfc_cited* and *self_citation* are positive and statistically significant.

(TABLE 7 HERE)

Since the free/royalty-bearing license policy setting and inclusion of a reciprocal term are simultaneously determined, a more robust estimation of the factors affecting the decisions is to estimate simultaneous equation specified in Section 4.3. Table 7 reports the results of 3SLS estimation. In the 3SLS estimation, *claim_scope* is treated as an instrumental variable for *free* while duration is treated as an instrumental variable for *reciprocal*. This specification allows

us to decouple the two decisions and get a robust estimation of the determining factors behind each decision.

Table 7 shows that the coefficient of *npe* in the equation with *free* as dependent variable is positive but not significant, which does support Hypothesis 1a; in the equation with *reciprocal* as dependent variable, it is negative and significant, thus supporting Hypothesis 1b. The estimated coefficient of *rfc_cited* also shows that citation to standard increases the likelihood of free license, while no statistically significant results are obtained with regards to reciprocal terms. Therefore, hypothesis 2a are supported, while hypothesis 2b are not supported. The estimated coefficients of *self_citation* in both equations are positive and significant, in support of Hypothesis 3a and 3b.

In sum, we find that non-practicing entities (or technology provider) are less likely to include reciprocal terms in IPR declarations for their SEPs as predicted by the asymmetric holdup theory. However, we did not find significant difference between non-practicing entities and practicing entities in exploiting a free-license strategy. For the other two factors, citation to standard and backward self citation are affecting the leveraging strategy as is hypothesized, except for the relationship between citation to standard and reciprocal terms.

6. DISCUSSION AND CONCLUSION

Our paper to examines SEP holders' decision-making about the declared RAND terms in their licensing commitments from a perspective of patent leverage strategy. In existing literature on standards setting and SEP licensing, the major focus is on direct rent capturing by licensing, generally under a widely adopted RAND rule. Although there are some disputes on the vague nature of "reasonable royalty rate", the implicit assumption is that the licensing deals are likely to be royalty-bearing. However, in the IPR declaration of some SSOs, such as the case of IETF, many SEP holders declares "generous" free-license terms for their SEPs, thus abandon direct profiting opportunities. Meanwhile, SEP holders actively include some kinds

of reciprocal licensing-back terms in their declared IPR polices, which cannot fully be explained by the common benefits of attracting partners in standard promotion and enjoying network effects. It is closer to the defensive use of patents, though based on the barging power conferred by exclusivity of SEPs enabling implementation of the focal standards.

To incorporate both the direct profiting strategy by licensing and the defensive use of SEPs in IPR declarations, we use the integrative patent strategy framework proposed by Somaya (2012) to analyze the licensing term setting decision of SEP holders. In essence, the SEP licensing term reflects a leverage strategy of firms. According to Somaya's theory, an asymmetric holdup will enable parties less held up to leverage patents more effectively. A typical example is non-practicing entities, which take a more aggressive leverage strategy in appropriating rents from royalty revenue and infringement damages.

In this paper, we propose that asymmetric holdup will motivate directly leveraging SEPs to capture revenues by setting royalty-bearing licensing terms while symmetric holdup motivate indirectly leveraging SEPs for defense purpose.

Using IPR declaration data of IETF, this paper investigates both firm-level and patent-level factors in shaping the license terms based on three-stage estimation of structural equations. We find that we find that non-practicing entities and practicing entities differs in the defensive usage of SEPs as predicted by the asymmetric holdup theory. However, we find no significant difference between the two types of SEP holders in setting royalty-free or royalty-bearing license terms. The findings provide suggest that non-practicing entities may leverage SEPs for other benefits beyond royalty revenue and advantages in defense.

We develop further on the factors affecting the holdup status and proposes that the unequal market dependence or technology dependence can also result in asymmetric holdup, which further result in differentiated leverage strategies. Our empirical results shows that larger patent

family size and lower dependence on prior technologies motivates more active use of direct leverage of SEPs characterized by royalty-bearing and non-reciprocal license terms.

Our study contributes to the literature in both standard setting (Bekkers et al., 2017; Chiao et al., 2007; Farrell & Saloner, 1985; Farrell & Simcoe, 2012; Kang et al., 2014; Layne-Farrar et al., 2007; Lerner et al., 2016; Rysman & Simcoe, 2008; Simcoe, 2012) and Patent Strategy (Somaya, 2012; Reitzig, Henkel, & Heath, 2007). First, the investigation on IETF is critical to the SSO literature especially those highlight IPR policy on RAND terms at SSOs (Bekkers et al., 2017; Layne-Farrar et al., 2007), given its relevantly weak focus on IPR policy in standardization owing to its origin that built upon a tradition of freedom, the spirit of Internet. In such a unique context, we find weak associations of technical and legal characteristics of a SEP with its holder's decision on licensing for free but strong associations with a reciprocal licensing term. Second, prior studies on leveraging patent strategies generally focus on the directly leveraging patents for license revenues (Arora 2003). We contribute to this line of research by investigating the selection of direct and indirect (defensive) leverage strategy from the perspective of asymmetric holdup. Further, our study provides a more reliable empirical base as the novel sample is collected from *real* licensing commitments at IETF, thereby extending the relevant studies that relied on nothing but self-reported survey data of license which may be biased (Arora & Fosfuri, 2003; Gambardella et al., 2007; Motohashi, 2008).

Nevertheless, the current paper has several limitations. First, we use the IPR declaration of participants of IETF only and are yet unclear whether the large shares of royalty-free licensing terms and the active usage of reciprocal licensing clauses are common practices in other standard setting organizations. It is yet unclear whether these clauses (or other defensive suspension clauses) conflict with the *non-discriminatory* principle of RAND, or perhaps there are different policy criterions across SSOs that focuses on distinct industries or technologies. Future research may work toward this direction to reach a better understanding on this

important issue. Secondly, and finally, we have not incorporating the interactions of multiple IPR holders regarding to a single RFC or internet-draft. It is likely that licensing terms of the pioneering disclosure may affect the decisions of other following IPR holders. Furthermore, there should be substantial strategic interactions between competitors among technology standard making process (Future studies may apply a dynamic model to shedding light on the chaining disclosure strategies).

REFERENCES

Arora, Ashish, and Andrea Fosfuri. 2003. "Licensing the Market for Technology." *Journal of Economic Behavior & Organization* 52 (2): 277–95. https://doi.org/10.1016/S0167-2681(03)00002-7.

Bekkers, Rudi, Geert Duysters, and Bart Verspagen. 2002. "Intellectual Property Rights, Strategic Technology Agreements and Market Structure." *Research Policy* 31: 1141–61. https://doi.org/10.1016/S0048-7333(01)00189-5.

Bradner, Scott, and Jorge Contreras. 2017. "RFC 8179 - Intellectual Property Rights in IETF Technology." 2017. https://datatracker.ietf.org/doc/rfc8179/.

Chiao, Benjamin, Josh Lerner, and Jean Tirole. 2007. "The Rules of Standard-Setting Organizations: An Empirical Analysis." *The RAND Journal of Economics* 38 (4): 905–30.

Dang, Jianwei, and Kazuyuki Motohashi. 2015. "Patent Statistics: A Good Indicator for Innovation in China? Patent Subsidy Program Impacts on Patent Quality." *China Economic Review* 35: 137–55. https://doi.org/10.1016/j.chieco.2015.03.012.

Farrell, Joseph, and Timothy Simcoe. 2012. "Choosing the Rules for Consensus Standardization." *The RAND Journal of Economics* 43 (2): 235–52.

Geradin, Damien. 2013. "The Meaning of Fair and Reasonable in the Context of Third-Party Determination of Frand Terms." *Geo. Mason L. Rev.* 21: 919.

Kang, Byeongwoo, Dong Huo, and Kazuyuki Motohashi. 2014. "Comparison of Chinese and Korean Companies in ICT Global Standardization: Essential Patent Analysis." *Telecommunications Policy* 38 (10): 902–13.

Lemley, Mark A. 2002. "Intellectual Property Rights and Standard-Setting Organizations." *Calif. L. Rev.* 90: 1889.

Lemley, Mark A., and Carl Shapiro. 2006. "Patent Holdup and Royalty Stacking." *Texas Law Review* 85: 1991.

Lerner, Josh, Haris Tabakovic, and Jean Tirole. 2016. "Patent Disclosures and Standard-Setting." National Bureau of Economic Research.

Marco, Alan C., Joshua D. Sarnoff, and Charles A. W. deGrazia. 2019. "Patent Claims and Patent Scope." *Research Policy* 48 (9): 103790. https://doi.org/10.1016/j.respol.2019.04.014.

Nagaoka, Sadao, Kazuyuki Motohashi, and Akira Goto. 2010. "Patent Statistics as an Innovation Indicator." In *Handbook of the Economics of Innovation*, 1st ed., 2:1083–

1127. Nathan Rosenberg: Elsevier B.V. http://dx.doi.org/10.1016/S0169-7218(10)02009-5.

Pénin, Julien, and Daniel Neicu. 2018. “Patents and Open Innovation: Bad Fences Do Not Make Good Neighbors.” *Journal of Innovation Economics & Management*, no. 25 (January): 57–85. https://doi.org/10.3917/jie.025.0057.

Reitzig, Markus, Joachim Henkel, and Christopher Heath. 2007. “On Sharks, Trolls, and Their Patent Prey—Unrealistic Damage Awards and Firms’ Strategies of ‘Being Infringed.’” *Research Policy* 36 (1): 134–54. https://doi.org/10.1016/j.respol.2006.10.003.

Rivera, Kevin G., and D. Kline. 2000. “Discovering New Value in Intellectual Property.” *Harvard Business Review* 55: 1–14.

Shapiro, Carl. 2000. “Navigating the Patent Thicket: Cross Licenses, Patent Pools, and Standard Setting.” *Innovation Policy and the Economy* 1 (January): 119–50. https://doi.org/10.1086/ipe.1.25056143.

Shapiro, Carl, and Hal R. Varian. 1998. *Information Rules: A Strategic Guide to the Network Economy*. Harvard Business Press.

Simcoe, Timothy. 2012. “Standard Setting Committees: Consensus Governance for Shared Technology Platforms.” *The American Economic Review* 102 (1): 305–36.

Somaya, Deepak. 2012. “Patent Strategy and Management: An Integrative Review and Research Agenda.” *Journal of Management* 38 (4): 1084–1114. https://doi.org/10.1177/0149206312444447.

Zellner, Arnold, and Henri Theil. 1992. “Three-Stage Least Squares: Simultaneous Estimation of Simultaneous Equations.” In *Henri Theil’s Contributions to Economics and Econometrics*, 147–78. Springer.

Ziedonis, Rosemarie Ham. 2004. “Don’t Fence Me In: Fragmented Markets for Technology and the Patent Acquisition Strategies of Firms.” *Management Science* 50 (6): 804–20. https://doi.org/10.1287/mnsc.1040.0208.

Table 1. The RAND terms in licensing commitments at IETF

Types of RAND terms	Examples of RAND terms
No license	No license required for implementers.
Royalty-free	AIST (National Institute of Advanced Industrial Science and Technology) is prepared to grant a license under a contract with reasonable terms, conditions and royalty. But, if this document (RFC 6628, draft-shin-tls-augpake-xx) is adopted as an IETF standards track RFC, AIST is prepared to grant a non-exclusive royalty-free license for any conforming implementations of the adopted version (as an IETF standards track RFC) of this document (RFC 6628, draft-shin-tls-augpake-xx). Needless to say, this does not mean that all the claims and the contents in the patent application PCT/JP2009/062578 are covered with the non-exclusive royalty-free license.
Royalty-bearing	In case a license to a patent in the patent family above or a patent issued/granted on an application for a patent on the invention above should be necessary for implementing any standards-track IETF document , Telefonaktiebolaget LM Ericsson is willing to grant to anybody a license to such patent on fair, reasonable and non-discriminatory conditions for the implementation of the standards-track document, subject to reciprocity.
Provided later	Licensing declaration to be provided later.
Unwilling to commit	No information submitted
Defensive suspension (e.g. no license or royalty-free upon reciprocity, else royalty-bearing upon non-reciprocity; termination right upon non-reciprocity)	No License Required for Implementers. KDDI Corporation will retain the right to terminate the license and assert its patents (including the right to claim past royalties) against any licensee that asserts or whose affiliate asserts any patent (either directly or indirectly) against KDDI Corporation or any of KDDI Corporation's affiliates or successors in title.

Nokia agrees not to assert those claims in Nokia above mentioned patents that apply to the RFC3588 and are technically necessary to implement this IETF standard specification against any other party in respect of its implementation of the specification, provided that the party relying on this commitment does not assert its patents against Nokia.

Table 2. Category of license terms

	reciprocal		
free	0	1	Total
1	112	433	545
0	230	230	460
Total	342	663	1,005
Pearson	chi2(1) =	96.3691	Pr = 0.000

Table 3. Descriptive statistics of independent variables

Variables	N	Mean	SE	Min	Max
claim_scope	1,005	-0.191	0.096	-0.802	-0.028
duration	1,005	15.796	3.408	2.677	20
npe	1,005	0.116	0.321	0	1
family	1,005	3.463	3.305	1	33
self_citation	1,005	1.971	4.021	0	33
non_self_citation	1,005	15.449	33.947	0	423
backward	1,005	17.420	35.961	0	423
self_ratio	927	0.151	0.249	0	1
rfc_cited	1,005	0.348	0.477	0	1

Table 4. Correlation matrix of independent variables

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
claim_scope	1.00								
duration	-0.18	1.00							
npe	0.08	-0.06	1.00						
family	0.10	-0.01	0.29	1.00					
self_citation	-0.03	0.09	0.12	-0.05	1.00				
non_self_citation	0.08	-0.06	0.13	0.05	0.45	1.00			
backward	0.07	-0.04	0.14	0.04	0.53	1.00	1.00		
self_ratio	-0.10	0.16	-0.06	-0.12	0.37	-0.13	-0.08	1.00	
rfc_cited	-0.12	0.21	-0.24	-0.11	0.13	0.08	0.09	0.08	1.00

Table 5. Benchmark OLS regression on determinants of *free*

	(1) free		(2) free		(3) free		(4) free		(5) free		(6) free	
free												
claim_scope	-0.000377**	(-2.36)	-0.000419***	(-2.59)	-0.000377**	(-2.36)	-0.000455***	(-2.73)	-0.000389**	(-2.35)	-0.000310*	(-1.95)
duration	0.00487	(0.86)	0.00448	(0.78)	0.00486	(0.86)	0.00316	(0.55)	0.000701	(0.12)	0.00211	(0.37)
npe	-0.0153	(-0.31)	-0.00810	(-0.16)	-0.0153	(-0.31)	0.00570	(0.11)	-0.00930	(-0.18)	-0.0253	(-0.51)
family	-0.0354***	(-7.44)	-0.0389***	(-8.06)	-0.0354***	(-7.39)	-0.0336***	(-6.90)	-0.0345***	(-7.14)	-0.0363***	(-7.64)
self_citation	0.0244***	(6.53)			0.0244***	(5.66)					0.0226***	(5.27)
non_self_citation			0.00244***	(3.20)	0.00000576	(0.01)					-0.0000659	(-0.08)
backward							0.000950**	(2.29)	0.000690*	(1.66)		
self_ratio							0.397***	(6.29)	0.372***	(5.92)		
rfc_cited									0.151***	(4.28)	0.145***	(4.31)
gen	0	(.)	0	(.)	0	(.)	0	(.)	0	(.)	0	(.)
art	-0.136***	(-2.63)	-0.155***	(-2.95)	-0.136***	(-2.62)	-0.117**	(-2.20)	-0.0679	(-1.25)	-0.0875*	(-1.66)
int	-0.0476	(-0.74)	-0.0476	(-0.73)	-0.0476	(-0.74)	-0.00497	(-0.07)	0.0304	(0.45)	-0.00777	(-0.12)
ops	-0.227***	(-3.53)	-0.233***	(-3.57)	-0.227***	(-3.52)	-0.250***	(-3.80)	-0.201***	(-3.03)	-0.179***	(-2.77)
rtg	0.0158	(0.40)	0.0133	(0.34)	0.0158	(0.40)	0.0663	(1.63)	0.0919**	(2.25)	0.0424	(1.08)
sec	0.126*	(1.88)	0.0817	(1.21)	0.125*	(1.87)	0.122*	(1.78)	0.166**	(2.42)	0.170**	(2.53)
tsv	0.0508	(0.92)	0.0800	(1.43)	0.0508	(0.92)	0.0936*	(1.70)	0.102*	(1.87)	0.0618	(1.13)
y01_05	0.142***	(2.64)	0.152***	(2.77)	0.142***	(2.64)	0.151***	(2.76)	0.142***	(2.60)	0.136**	(2.54)
y06_10	0.122**	(2.05)	0.139**	(2.29)	0.122**	(2.04)	0.150**	(2.45)	0.131**	(2.16)	0.110*	(1.86)
y11_16	0.177**	(2.55)	0.177**	(2.50)	0.177**	(2.54)	0.182**	(2.50)	0.152**	(2.10)	0.153**	(2.21)
Constant	0.357***	(4.14)	0.401***	(4.56)	0.357***	(4.11)	0.306***	(3.47)	0.317***	(3.62)	0.363***	(4.21)
Observations	1005		1005		1005		927		927		1005	
r2	0.164		0.137		0.164		0.178		0.194		0.179	
r2_a	0.152		0.125		0.151		0.164		0.180		0.166	

Table 6. Benchmark OLS regression on determinants of *reciprocal*

	(1) reciprocal		(2) reciprocal		(3) reciprocal		(4) reciprocal		(5) reciprocal		(6) reciprocal	
reciprocal												
claim_scope	0.000181	(1.23)	0.000174	(1.19)	0.000200	(1.37)	0.000128	(0.84)	0.000163	(1.07)	0.000241*	(1.65)
duration	0.0139***	(2.68)	0.0147***	(2.82)	0.0149***	(2.88)	0.0142***	(2.67)	0.0129**	(2.42)	0.0132**	(2.55)
npe	-0.335***	(-7.32)	-0.319***	(-6.92)	-0.323***	(-7.06)	-0.344***	(-7.28)	-0.352***	(-7.45)	-0.329***	(-7.21)
family	-0.0230***	(-5.26)	-0.0236***	(-5.40)	-0.0215***	(-4.90)	-0.0204***	(-4.58)	-0.0209***	(-4.69)	-0.0220***	(-5.04)
self_citation	0.00883**	(2.57)			0.0148***	(3.76)					0.0138***	(3.49)
non_self_citation			-0.000942	(-1.36)	-0.00242***	(-3.06)					-0.00247***	(-3.13)
backward							0.000215	(0.57)	0.0000776	(0.20)		
self_ratio							0.207***	(3.58)	0.194***	(3.35)		
rfc_cited									0.0793**	(2.44)	0.0885***	(2.87)
gen	0	(.)	0	(.)	0	(.)	0	(.)	0	(.)	0	(.)
art	-0.175***	(-3.69)	-0.175***	(-3.67)	-0.163***	(-3.44)	-0.187***	(-3.81)	-0.160***	(-3.21)	-0.134***	(-2.76)
int	0.0566	(0.96)	0.0542	(0.91)	0.0542	(0.92)	0.0484	(0.78)	0.0670	(1.08)	0.0786	(1.32)
ops	-0.335***	(-5.67)	-0.336***	(-5.68)	-0.332***	(-5.65)	-0.348***	(-5.76)	-0.322***	(-5.26)	-0.303***	(-5.09)
rtg	0.0402	(1.12)	0.0400	(1.11)	0.0415	(1.16)	0.0660*	(1.77)	0.0795**	(2.11)	0.0578	(1.60)
sec	-0.0430	(-0.70)	-0.0481	(-0.78)	-0.0214	(-0.35)	-0.0483	(-0.77)	-0.0250	(-0.39)	0.00608	(0.10)
tsv	-0.263***	(-5.20)	-0.235***	(-4.64)	-0.253***	(-5.01)	-0.247***	(-4.90)	-0.242***	(-4.82)	-0.246***	(-4.89)
y01_05	0.0489	(0.99)	0.0507	(1.02)	0.0452	(0.92)	0.0511	(1.02)	0.0460	(0.92)	0.0413	(0.84)
y06_10	0.0127	(0.23)	0.0294	(0.54)	0.0193	(0.35)	0.0214	(0.38)	0.0117	(0.21)	0.0120	(0.22)
y11_16	0.0280	(0.44)	0.0373	(0.58)	0.0374	(0.59)	0.0125	(0.19)	-0.00334	(-0.05)	0.0227	(0.36)
Constant	0.604***	(7.62)	0.601***	(7.54)	0.574***	(7.22)	0.561***	(6.93)	0.566***	(7.02)	0.577***	(7.29)
Observations	1005		1005		1005		927		927		1005	
r2	0.219		0.215		0.226		0.242		0.247		0.233	
r2_a	0.208		0.204		0.215		0.230		0.234		0.220	

t statistics in parentheses

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

Table 7. 3SLS regression on determinants of *free* and *reciprocal*

	(1)		(2)		(3)		(4)	
free								
reciprocal	0.326	(0.89)	0.223	(0.56)	0.159	(0.39)	0.0545	(0.12)
claim_scope	-0.000442***	(-2.61)	-0.000484***	(-2.86)	-0.000348*	(-1.90)	-0.000398**	(-2.23)
npe	0.0900	(0.68)	0.0825	(0.55)	0.0271	(0.18)	0.00989	(0.06)
self_citation	0.0195***	(2.88)			0.0204***	(2.93)		
non_self_citation	0.000795	(0.68)			0.000327	(0.26)		
backward			0.000902**	(2.19)			0.000686*	(1.68)
self_ratio			0.351***	(3.39)			0.361***	(3.41)
rfc_cited					0.131**	(2.53)	0.146***	(2.84)
family	-0.0284***	(-3.17)	-0.0291***	(-3.16)	-0.0328***	(-3.26)	-0.0333***	(-3.27)
Constant	0.170	(0.61)	0.181	(0.62)	0.271	(0.89)	0.286	(0.90)
reciprocal								
free	-0.531	(-1.09)	-0.282	(-0.77)	-0.780	(-1.15)	-0.419	(-0.91)
duration	0.0175**	(2.51)	0.0150**	(2.53)	0.0149*	(1.95)	0.0132**	(2.12)
npe	-0.332***	(-5.67)	-0.343***	(-6.62)	-0.349***	(-5.10)	-0.356***	(-6.42)
self_citation	0.0278**	(2.12)			0.0314*	(1.89)		
non_self_citation	-0.00242**	(-2.43)			-0.00252**	(-2.21)		
backward			0.000483	(0.90)			0.000367	(0.68)
self_ratio			0.319**	(2.00)			0.350*	(1.90)
rfc_cited					0.201*	(1.80)	0.142*	(1.74)
family	-0.0403**	(-2.20)	-0.0299**	(-2.21)	-0.0503*	(-1.96)	-0.0353**	(-2.09)
Constant	0.763***	(3.39)	0.647***	(3.95)	0.860***	(2.86)	0.699***	(3.56)
_								
Year fixed effects	Yes		Yes		Yes		Yes	
Technology fixed effect	Yes		Yes		Yes		Yes	
Observations	1005		927		1005		927	
chi2_1	208.7		209.4		230.5		227.2	
chi2_2	181.7		242.5		144.2		219.5	

t statistics in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$