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The Optimal Patent Portfolio of The Technology Standards Alliances in Innovation Competition

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ABSTRACT

Unlike the dominant theories based on the rigid assumption that "technology standards must contain only essential patents", this paper discusses the standard alliances that are engaged in their cumulative innovation. Its focus is particularly on a more realistic setting that a standard alliance should contain both the essential and the non-essential patents. We use the essential-patent's ratio, which denotes the percentage of the essential patents in the total patents in a standard, as the cumulative innovation model's core variable. The mathematical analysis illustrates that the essential-patent's ratio performs an important role in the arguments' standards. There is an optimal portfolio that maximizes the alliances' efficiency in an innovation competition. It implies that the social welfare effects depend on the dynamic trade-off between the long-term technical gap caused by the technological upgrades' missing opportunities and the short-term welfare losses that consumers may suffer. The patents' and antitrust laws should tolerate a certain number of non-essential patents being contained by the technology standards.

KEYWORDS

Optimal patent portfolio; technology standards alliances; innovation competition; patent pools

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K21; L15

1. Introduction

The network industries' technology standards result from the competition between the formal or informal alliances sponsoring the different standards. The antitrust laws and economics both indicate that only perfect complementary (Lerner and Tirole 2004; Shapiro 2001) or essential patents (Quint 2014) can be included in a standards alliance or in a patent pool. These studies assume that the downstream products market is perfectly competitive, and that the patents as the final products are licensed directly to the users. Hence, only the competition in the technology market needs to be considered, and the patent's license price can accurately capture its welfare effects. What the existing literature actually reviews are the simplex patent pools. These are traditional patent pools where technology separates itself from the product: by overlooking that the adoption of the standards results from the competition in the end-product's markets. Following these research's suggestions, the patent pool policies in various countries have not sufficiently stimulated the formation of the new patent pools (Lerner and Tirole 2004).

However, unlike their traditional counterparts, the contemporary patent pools mainly exist in the network markets. Although they exist as research and development (R&D) and joint licensing organizations in the standards' development, they are the initial standardization of patents in the digital age. Only until a candidate standard can be accepted by the critical mass of users, can it become the "*de facto* standard"[1] in the end-product markets (Lou 2011). Therefore, the existing literature is

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inconsistent with the empirical findings, in that it simply considers the standards alliances as the traditional patent pools. Moreover, a contemporary patent pool is both a technological alliance and a product alliance. In the process of designing the technical schemes and commercialization, it is necessary to keep investing in R&D. This serves to improve the applied technologies that meet the diversified demands in the end-products markets. Therefore, the standards alliances engage in multi-stage and sequential innovation competition and are featured with having the patent's continual accumulation.

This paper investigates how the patent pool's composition impacts the performance of the standards alliances in the innovation competition. The standards alliances include not only the essential patents that form the initial framework of a standard, but also the non-essential patents, such as the subsequent and substitute patents.[2] The essential patents are that are technically inevitable and necessity to a standard, and may be complementary. As inevitable products of the sequential innovation competitions, the subsequent patents based on the pioneering ones may restrict the competition from their rivals. The research question is, "how does the patent's portfolio, that is the proportion of the essential patents and the non-essential patents, impact the efficiency of the standard alliance's cumulative innovation?" The papers' contribution is that it releases the strict assumption in the existing literature that a patent pool contains only the essential or the complementary patents. This is accomplished by using the rate of the essential patents in the total patents as the key variable in an improved cumulative innovation model to replace the original variable of the patent's license fee. We establish that including a certain proportion of non-essential patents will help the alliance to maintain a long-term competitive advantage.

The remaining parts of this paper is organized as follows. Section 2 will give a literature review, and in Section 3 we will elaborate on the cumulative innovation model. In Section 4 a case study on the development of 3G standards in China will be presented to indicate that diversifying the patent portfolio and creating a value chain based on the core technology will help the alliance to achieve success. And Section 5 will provide a conclusion.

2. Literature Discussion

The perfect complementary patent model by Shapiro (2001), based on the complementary supplement theory by Cournot (1838), is path-breaking research on the modern patent alliance. Cournot-Shapiro, Lerner and Tirole (2004) further develop this into a more practical LT model, where patents are situated between the perfect complementarity and perfect substitutivity. However, they still suggest that the stronger complementarity between the patents in the patent pools will create more social value. This correlation exists in situations where patents are of differing importance, even if one patent in the alliance is dominant. This further strengthens the traditional concept of the "necessity and complementarity." Gilbert (2004) reviews the representative patent pool litigation cases throughout over 100 years of the U.S.' history. He analyzes the reasons for the court ruling and the welfare effects of the "weak patent" in patent pools. He concludes that the patent pools that contain the competing patents or cross-licensing will cause threats of monopoly. Quint (2014) finds that some patents are essential for the production of each product. However, the non-essential patents are required only for a specific product. Those non-essential patents required by any two products are different. By establishing a patent's price competition model in a multi-product industry, he compares the welfare effects of the alliances with the different patent structures. Quint (2014) argues that in the multi-product industries, to improve the social welfare, the alliance should not be required to include all the complementary patents but only the essential patents.

Judging whether a patent pool promotes or restrains their competition depends on the relationship between the patents entering the pool. It also depends on the relationship between the pooled patents and the patents outside the pool. The two kinds of the most basic technical differences among the patents are: the complementary or mutual substitute patents, and the essential or non-essential patents. Currently, the regulations are based on the belief that only the alliance of the Standard

Essential Patents (SEPs), also called "no substitution inside and no complements outside," can promote competition and innovation (Zhan 2013, 16). The substitute patents are regarded as monopolistic behaviors in the antitrust economics and law studies that have a negative impact on the social welfare. This prevailing idea leads to the fear of anti-monopoly sanctions is one of the reasons why patentees are reluctant to initiate patent pools (Heller and Eisenberg 1998).

However, these harsh conditions for the formation of the alliances are difficult to attain (Lampe and Moser 2010). Even for the patent pools in the traditional markets, the effects of these regulations are not satisfactory. Antitrust agencies could also not accurately evaluate the relationships between the patents (Gilbert 2004; Lerner et al. 2007). Most of the technology valuations (TV) depend on the dominant experts' knowledge, so that their TV results could be subjective and flexible (Jun et al. 2015). Moreover, it is rare that a group of patents with the perfect complementarity are indispensable to the production of a given product. The relationship between the patents may vary with the license price's changes (Lerner and Tirole 2004). Due to the evolving demand and the dynamic nature of the networks' technology in the digital age, and the uncertainty of the protection scope of the patent itself (Klemperer 2007), the two types of patents are likely to be interchangeable. Some essential patents (core patents) may need to be removed, while some improved blocking patents obtained from the cumulative innovation must be submitted (Tang 2013, 58; Gao 2015, 108–111). Therefore, the technology standards will inevitably be combined with the non-essential patents of the competing relationships (Nelson 2007). The rigid preset is a particular patent market structure that only emphasizes the competition in the technology markets. The analysis based on it lacks universality (Du, Ma, and Bai 2009). In summary, it is an idealization to directly identify the perfect essential or complementary patents required by the antitrust laws and economics. However, it is not socially desirable nor practical to do so.

3. The Cumulative Innovation Model: The Role of the Essential-patent Ratio in an Innovation Competition

3.1. Hypothesis, Methods and Settings

3.1.1. Hypothesis

There is an optimal patent portfolio that maximizes an alliances' efficiency in an innovation competition. The inclusion of an appropriate proportion of the non-essential patents in the standards alliances will improve the innovation efficiency in a standards' competition. We will test this hypothesis through an equilibrium analysis of both the R&D intensity and the essential-patent rate.

3.1.2. Methods

We create a new variable called, "the essential-patent rate," that indicates the proportion of the essential patents in the total patents in a standard to replace the original variable of the patent's license rate in an improved progressive innovation model. The dynamic R&D incentives model by Dequiedt and Versaevel (2013) assumes that there is no mutual influence between the patents without an alliance. This makes their research fail to capture the "patent jungle" challenge in the innovation markets. Therefore, drawing on the modeling ideas of Du et al. (2011), we introduce the cumulative innovation model's patents' relationship by Llanes and Trento (2012) into Dequiedt and Versaevel's model framework (2013). The crucial improvement that we propose to make is to release the constraints by allowing the technology standards to include the non-essential patents. In addition, it would use the essential-patents rate as the core variable in the improved cumulative innovation model.

3.1.3. Settings

The standards alliances' subsequent R&D's competition involves the continuous, inter-temporal option investments. Firms can apply to join a standards alliance if they achieve the relevant patents. The patents granted are permanently effective.[3] The probability of a firm achieving success in an innovation competition only correlates with its R&D's intensity and investment in this period. We let

n ($n > 1$) denote the number of the symmetrical firms that compete with each other in an innovation competition.[4] The size of the alliance equals the number of the patents it includes and is denoted by s, $s < n$. In a certain phase, only one firm obtains one patent. Therefore, there is a one-to-one relationship between the firm, the patent, and the phase. The patents obtained in the different phases may be restricting each other, both in a one-way and in two-way forms. At each point in time, firms i can make an independent decision on the amount to invest in the R&D. $x_t^i,\ i \geq 1,\ x_t^i \geq 0$, t denotes the point in time when the firm makes the R&D investment. The above assumptions construct a sequential game of the R&D's speed competition, that is a Markov chain without an aftereffect.

One patent can deliver a value-added v in the end-product market. The discount rate $r > 0$, indicates the time costs in the waiting period. A risk-free return rate can be referenced from the interest rate of a government's bond. If being included in an alliance is not considered in the phase of k ($0 < k < n$), the net present value of the net cashflows generated by this patent is $\widetilde{V_k^i}(1) = \int_0^\infty v_e^{-rt} dt = {}^{v}\!/_{r}$. The time firm i expects to achieve success in the R&D's competition is determined by the instantaneous probability that is the Poisson jump process with a slope of x_t^i. Therefore, if the innovation's costs and the entrance fee to an alliance are not considered, the net present value of the expected return is $\widetilde{V_k^i}(0) = \int_0^\infty \left[x_t^i e^{-\left(x_t^i + r\right)t} \widetilde{V_k^i}(1)\right] dt = \frac{x_t^i}{x_t^i + r} \widetilde{V_k^i}(1)$ (Dequiedt and Versaevel 2013). Function $\widetilde{V_k^i}(0)$ describes the expected net present value of the patent k for the firm i at the beginning of the phase that patent $k - 1$ has arisen but when patent k has not. When patent k has been achieved, we let $\widetilde{V_k^i}(1)$ denote the net present value of patent k for the patentee at the end of the phase.

We suppose that $\prod = \widetilde{V_k^i}(1) - \widetilde{V_k^i}(0)$ is the option value of patent k for the firm$i$, and $\prod$ is a decreasing function of $\widetilde{V_k^i}(0)$. The flow cost function in the process of innovation is a simple quadratic nonlinear equation, that is $c\left(x_t^i\right) = \left(x_t^i\right)^2$. It satisfies the conditions that $c(0) = 0, c'\left(x_t^i\right) = 2x_t^i \geq 0, c'(0) = 0, c'(+\infty) = +\infty, c''\left(x_t^i\right) = 2 > 0$. Therefore, the optimal R&D's effort for the firm i is an interior-point solution that guarantees the existence of the Nash equilibrium in every phase (Lee and Wilde 1980). Concurrently, as $c'''\left(x_t^i\right) = 0$ satisfies the condition that $c''' \geq 0$, there is a unique solution to the Markov perfect equilibrium in the symmetric games.

The time for n firms to achieve their patents is different. The candidates must develop their R&D based on the pioneering patents owned by the existing alliance members. The pioneering patents can charge fees from its subsequent members. The patent's portfolio is denoted as the essential-patent rate β ($0 \leq \beta \leq 1$). Members must pay a linear license fee with a fixed unit of $l_p = \beta v$.[5] We then substitute the equation into the original model and rederive it. When $\beta = 1$, the equation would be equivalent to the original models, with the assumption of having perfect essential-patents.

3.2. Results

Lemma 1 The incentive compatibility condition: There are $n - s$ external candidates competing for the opportunity of being included in the standards alliances. In the subsequent innovation's competition (in the phase $s < k < n$) among these candidates, constant efforts are made to achieve a breakthrough. The optimal degree of their efforts is denoted by $\tilde{x}$ and the option value for a patent is $2\underline{\tilde{x}}$.

Proof: We suppose that after the alliance is formed, regardless of the phase at which external candidates achieve success, they can receive the net present value $\underline{\tilde{V}}(1) = (1 - \beta)\frac{v}{r}$ at the end of the period. For each participant, at the beginning of the period, the net present value $\underline{\tilde{V}}(0)$ of the expected return on the R&D's project in the best-case scenario satisfies:

$$r\,\underset{\sim}{V}(0) = \max_{\tilde{x}}\left\{\tilde{x}\left[\underset{\sim}{V}(1) - \underset{\sim}{V}(0)\right] - c(\tilde{x})\right\} \tag{1}$$

According to the first-order condition associated with the maximization of the right-hand side of the Equation (1), we obtain the optimal degree of the R&D effort for each participating firm

$$\underset{\sim}{x} = \frac{\underset{\sim}{V}(1) - \underset{\sim}{V}(0)}{2} \tag{2}$$

$$\underset{\sim}{V}(0) = \underset{\sim}{V}(1) - c'(\underset{\sim}{x}) = \frac{(1-\beta)v}{r} - 2\underset{\sim}{x} \tag{3}$$

By substituting (3) in the right-hand side of the Equation (1), we obtain the optimal constant R&D effort $\underset{\sim}{x}$, that meets the following condition:

$$\underset{\sim}{x}^2 + 2r\underset{\sim}{x} - (1-\beta)v = 0 \tag{4}$$

According to (2), the option value at this time is:

$$\prod = \underset{\sim}{V}(1) - \underset{\sim}{V}(0) = 2\underset{\sim}{x} \tag{5}$$

Lemma 1 is proved.

Corollary 1.1 The more the R&D investment is made by the alliance members in the subsequent innovation competition, the higher the option value of their patents. In addition, there will be more incentives to the potential participants who will develop more R&D efforts.

Corollary 1.2 The higher the option value, the more the participants, the more rapidly an alliance grows in size (in other words, in the number of patents it contains), and the higher the markets' expansion potential.

Lemma 2. Participation constraints: Before a candidate standards alliance becomes successful (in phase $k < n$), the condition for any firm that attempts to be included in the alliance, is to engage in the innovation competition: $\widetilde{V_{k+1}}(1) > \widetilde{V_k}(1) > \frac{v}{r} > \frac{v-\beta v}{r}$.[6]

Proof: First, when the number of the patents is close to the threshold of forming an alliance (phase $s-1 < k < s$), the net present value of patent s at the end of the phase is:

$$\widetilde{V_s}(1) = \frac{v}{r} + \frac{n-s}{s}\frac{\underset{\sim}{x}}{\underset{\sim}{x}+r}\frac{\beta v}{r} \tag{6}$$

(6) consists of two components. The first component is the present value of the return that the patentee s can receive after the alliance is formed. It achieves the commercialization in the downstream market. The second component is the expected licensing fee received from $n-s$, that is, the number of licensees that are distributed equally among s number of the alliance members. We assume that the R&D conducted by every potential participant (licensee) follows the Poisson jump and mixed diffusion process. Thereafter, the expected risks can be adjusted with a probability of a successful innovation and can be denoted as $\frac{\underset{\sim}{x}}{\underset{\sim}{x}+r}$. We let $l_p = \beta v$ define the licensing fee after it successfully obtains a patent.

Thereafter, taking (3) and (6) as the starting point of a reverse recursion, and considering the patent's competition in various phases before the alliance is formed ($k \leq s$), when the competition in the k phase begins, the value of the R&D project $\widetilde{V_k^i}(0)$ to the firm i satisfies:

$$r\widetilde{V_k^i}(0) = \max_{\tilde{x}_k^i}\left\{\tilde{x}_k^i\left[\widetilde{V_k^i}(1) - \widetilde{V_k^i}(0)\right] + \tilde{x}_k^j\left[\widetilde{V_{k+1}^i}(1) - \widetilde{V_k^i}(0)\right] - c\left(\tilde{x}_k^i\right)\right\} \tag{7}$$

In (7), $\widetilde{V_k^i}$ denotes the value of the R&D project for a firm i in the beginning of phase k. We let $\tilde{x}_k^i$ denote the R&D's effort of firm i in phase k, and $\tilde{x}_k^j$ is the total R&D effort of the remainder of the $n-k$ firms in phase k. $\tilde{x}_k^i\left[\widetilde{V_k^i}(1) - \widetilde{V_k^i}(0)\right]$ is the return of firm i that has been successfully granted a patent k. Concurrently, $\tilde{x}_k^j\left[\widetilde{V_{k+1}^i}(1) - \widetilde{V_k^i}(0)\right]$ indicates the return of the remainder of the $n-k$ number of firms that fail to achieve patent k.

According to the first-order condition associated with the maximization of the right-hand side of (6), the optimal R&D effort for firm i is $\tilde{x}_k^{i^*} = \frac{\widetilde{V_k^i}(1) - \widetilde{V_k^i}(0)}{2}$. From the assumption of symmetry, there is $\tilde{x}_k^{i^*} = \tilde{x}_k^*$, $\widetilde{V_k^i}(0) = \widetilde{V_k}(0)$, $\widetilde{V_k^i}(1) = \widetilde{V_k}(1)$, therefore:

$$\widetilde{V_k}(0) = \widetilde{V_k}(1) - c'\left(\tilde{x}_k^*\right) = \widetilde{V_k}(1) - 2\tilde{x}_k^* \tag{8}$$

From (7) and (8), the recursive equation of $\widetilde{V_k}(0)$ is

$$r\widetilde{V_k}(0) = \left(\tilde{x}_k^*\right)^2 + (n-k)\tilde{x}_k^*\left[\widetilde{V_{k+1}}(0) - \widetilde{V_k}(0)\right] \tag{9}$$

We assume that before the establishment of the alliance (phase $k \leq s$), the net present value of patent k at the end of the period is $\widetilde{V_k}(1)$. In the innovation competition at phase $k+1$, if all the $n-k$number of the firms fail in their R&D, then the patentee k can obtain a real net present value of $\frac{v}{r}$. This will occur at the end of the period at a probability of $\frac{r}{r+(n-k)\tilde{x}_{k+1}^*}$. If in phase $k+1$ an invention has been made, the only successful patentee k can expect is a net present value of $\widetilde{V_{k+1}}(1)$. This will occur at the end of the period at a probability of $\frac{(n-k)\tilde{x}_{k+1}^*}{r+(n-k)\tilde{x}_{k+1}^*}$. Therefore, the net present value of patent k at the end of the period is:

$$\widetilde{V_k}(1) = \frac{r\left(\frac{v}{r}\right) + (n-k)\tilde{x}_{k+1}^*\widetilde{V_{k+1}}(1)}{r + (n-k)\tilde{x}_{k+1}^*} \tag{10}$$

From (10), we know $\widetilde{V_k}(1)$ is a convex combination of $\frac{v}{r}$ and $\widetilde{V_{k+1}}(1)$, and $\widetilde{V_s}(1) > \frac{v}{r}$.

Corollary 2.1 We use the time when the alliance is formed as a benchmark, as the earlier the patents are obtained, the more the waiting time and the costs before the developers can reap a profit. Furthermore, the lower the option value and the less the incentives for the innovations.

Corollary 2.2 The patents' net present value held by an alliance's existing members at the period's end is always higher than that held by the external potential candidates.

Corollary 2.3 The standards alliances that have more subsequent innovations can cater for the diversified customers. They particularly have various preferences in the differentiated competition of the end products. This increases its market share more rapidly.

As mentioned above, the subsequent inventions that have the same origin can be considered as the differentiated overlapping patents. This is with the exception of those that may be counted as blocking patents. These differentiated substitute patents perform a significant role in increasing the alliance's share in the end-product market. Hence, it reaches the critical threshold of the installed base and improves its prospect of achieving its final success in the standards wars.

Proposition 1 In the range of $[0, 1]$, the higher the β, the higher the licensing fee l_p, and the less the investment in the subsequent innovation, and vice versa.

Proof: We set $\underline{\tilde{x}}$ as a parameter of β, from (4) and that of $\underline{\tilde{x}} \geq 0$. We then obtain:

$$\underline{\tilde{x}}(\beta) = \sqrt{r^2 + v(1-\beta)} - \mathrm{r} \tag{11}$$

According to (11), there is $\frac{d\tilde{x}}{d\beta} = -\frac{1}{2\sqrt{r^2+v(1-\beta)}} < 0$, and $\lim_{\beta\to 0} \underline{\tilde{x}} = \sqrt{r^2 + v} - r$. Thus, $\lim_{\beta\to 1} \underline{\tilde{x}} = 0$ holds.

Proposition 1 is proved.

Corollary 3.1 Without its complementary patents, the downstream firms cannot form any standards alliance.

Corollary 3.2 The higher (lower) the essential-patent ratio for an alliance, the higher (lower) the licensing fee $l_p = \beta v$. In addition, the less (more) the investment $\underline{\tilde{x}}$ in the subsequent innovations. The closer β is to one, the stricter the control strategy adopted by the alliances in the standards wars. This would thoroughly prohibit the subsequent innovations from the outside and any compatible technologies.

A perfectly complementary patents' alliance must result in 0 subsequent innovations. An alliance that is composed of perfectly substitutable patents will disintegrate. When the essential-patent ratio equals one, this alliance that is composed of all the perfectly complementary patents would not tolerate any substitute innovations. Heller and Eisenberg (1998) argued that "Moreover, the lack of substitutes for certain biomedical discoveries (such as patented genes or receptors) may increase the leverage of some patent holders, thereby aggravating holdout problems ." Without the competition between the differentiated substitute patents, it would incentivize either more outside patentees or the potential candidates to seek a higher price. This is because every complementary patent is insufficient in constituting a standard. However, due to the intense competition and the lack of connection, the perfect substitute patents cannot maintain cooperation.

Corollary 3.3 The perfectly complementary alliances required by the law is inefficient for both the society and the alliances. When $\beta = 1$, it means that all the profits in the end-product market will accrue to the licensors and thus disincentivize the investment in their subsequent innovations.

Proposition 2 In the range $[0, 1]$, there is only one optimal essential-patent ratio β^* that can maximize both the R&D investment before the alliance is formed $\tilde{x}_k^*(\beta^*)$. This includes the option value of the patents Π, held by its alliance members, and $k \leq s$.

Proof: From (8), we obtain:

$$\tilde{V}_k(\beta', 1) = \tilde{V}_k(\beta', 0) + 2\tilde{x}_k^*(\beta')$$

$$\tilde{V}_k(\beta'', 1) = \tilde{V}_k(\beta'', 0) + 2\tilde{x}_k^*(\beta'')$$

if $\tilde{V}_k(\beta', 1) > \tilde{V}_k(\beta'', 1)$, that implies that $\tilde{V}_k(\beta, 0)$ and $\tilde{x}_k^*(\beta)$ move in the same direction, and both are greater than 0. Therefore, there is $\tilde{V}_k(\beta', 0) > \tilde{V}_k(\beta'', 0)$ and $\tilde{x}_k^*(\beta') > \tilde{x}_k^*(\beta'')$. If $\beta^*$is the essential-patent ratio that can maximize $\tilde{V}_k(\beta^*, 1)$, it will also maximize $\tilde{x}_k^*(\beta^*)$. According to the Equation (10) and Lemma 2, if $\tilde{V}_{k+1}(\beta', 1) > \tilde{V}_{k+1}(\beta'', 1)$ and $\tilde{x}_{k+1}^*(\beta') > \tilde{x}_{k+1}^*(\beta'')$ are satisfied, then $\tilde{V}_k(\beta', 1) > \tilde{V}_k(\beta'', 1)$ holds. Through a backward induction, there must be $\tilde{x}_k^*(\beta') > \tilde{x}_k^*(\beta'')$. If there is only one β^*that will maximize $\tilde{V}_s(\beta^*, 1)$, then it must be the optimal essential-patent ratio that can also maximize $\tilde{V}_k(\beta^*, 1)$

and $\tilde{x}_k^*(\beta^*)$, as well as the option value $\prod$ according to (5). Further, it can be established that in the range of $[0, 1]$, the second-order conditions for the maximization can be satisfied.

Proposition 2 is proved as depicted in Figure 1.

Figure 1 demonstrates how the essential-patent ratio affects the subsequent R&D investments as indicated by Lemma 3 and Proposition 1. In addition, it depicts how it influences the patent pool's option value and its competitiveness. It also determines the choice of an optimal essential-patent ratio.

Corollary 4.1 $l_p^* = \beta^* v$ can be viewed as the ceiling of the licensing fee based on the rule of FRAND. A license fee that is higher than l_p^* would not increase the patents' option values held by the alliance members. However, as it disincentivizes the subsequent innovations, it will lower the alliance's efficiency in the standards wars.

4. Case Study: The Chinese 3G Mobile Communication Standards

There were three standards for 3G: CDMA2000, WCDMA and TD-SCDMA.[7] TD-SCDMA was the dominant 3G standard in China. Its upgraded version, 4G mobile communication standard (TD-LTE) has also achieved success in China and in its customers' acceptance in the foreign markets. There were three standards for 3G: CDMA2000, WCDMA and TD-SCDMA. The development process of TD-SCDMA can be divided into three stages:

4.1. Stage 1: The Patent Pool (1995-2000.05)

In this stage, the founding firms need to form a R&D alliance, conduct research on the essential patents, and develop the patents' portfolios and their technical framework. They also need to seek approval from the ITU, as one of the 3G standard candidate schemes. At first, the China Academy of Information and Communications Technology (CAICT), together with Cwill and other firms, set up Beijing Xinwei Communication Technology Group. Co., Ltd. This focuses on the initial development of the core technology of SCDMA. Thereafter, the three initiators formed a joint R&D Alliance, as depicted in Table 1 and gradually integrated members, such as Chongyou Xinke.

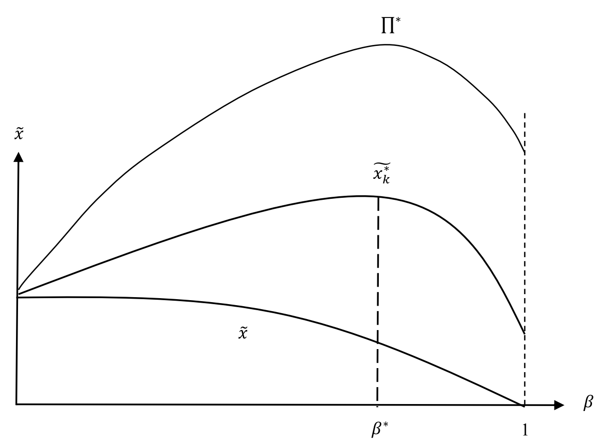

Figure 1. The moderate essential-patent ratio for an alliance.

Table 1. Sponsor's patent investment before the establishment of TD-SCDMA alliance.

	Datang Mobile	Siemens	Beijing Xinwei
1997	-	-	9
1998	3	1	2
1999	2	4	-
2000	11	4	-

Source: Official website, State Intellectual Property Office of China.

4.2. Stage 2: Industrialization (2001.03-2006.01)

The phase's strategic focus is to form an industrial alliance and to improve the value chain to prepare for entering the end market. As compared with Table 1, Table 2 indicates that the subsequent R&D and the eight new sponsors have delivered more patents than the three founding members. In addition, the alliance has absorbed the hardware and software suppliers with the product market's advantages and the production capacity. The examples of these are: Huawei, ZTE, Lenovo, and Putian. It thus covered the network equipment manufacturers, application service providers, and other segments. Thus, the basic industry chain had been founded. The alliance then went through the second expansion that integrated seven other firms.

4.3. Stage 3: The Commercialization Stage (2006.03-2014.06)

The phase's strategic focus is to foster the "installed base of users" (Shapiro and Varian 1999, 16). This serves to develop the marketing channels and increase the market share. In this phase, the alliance expanded for the third time, by adding six board members and ten companies, such as mobile operators. The subsequent commercial application technology development, for example, the High-Speed Downlink Packet Access (HSDPA), also made rapid progress. It continued to integrate 100 non-board members. Its testing network has extended to Korea, Romania, Canada, Hong Kong, Italy, Ghana, Myanmar, Taiwan, and so on. In summary, TD-SCDMA's success trajectory has the following features:

4.4. Feature 1

The standards may require the process of the patent's R&D, a basic version design, the subsequent innovation, a patent extension and a version upgrade. To gain the first-mover advantage, the TD-SCDMA adopts the mode of platform loading by first putting out the initial standard, and thereafter seeking the follow-up extension. It is guided by a basic standard framework, that is composed of the

Table 2. Industry alliance members and patent investment in industrialization stage of TD-SCDMA.

Sponsor	Patent input (Pieces)	Market Performance in 2002 (Sales revenue: 100 million RMB)	Major input
Datang	26	20.9	Technology R&D, Terminal Chips, Solutions, Production of Key Equipment
Huali	12	0.1	R&D of Terminal Equipment, Terminal Chip
Huawei	2135	221	Base Station, R&D of antenna, Solutions, R&D and Production of Terminal Equipment
Lenovo	635	202.3	R&D and Production of Terminal Equipment
ZTE	666	110	Solutions, Terminal Equipment Suppliers
China Putian	-	602	Base Station, Solutions, Network Access and Terminal Products
Southern High Tech.	1	21	R&D and Production of Terminal Products
China Elec.	2	-	Terminal Products and Equipment Suppliers

Source: Annual Report of the above Companies.

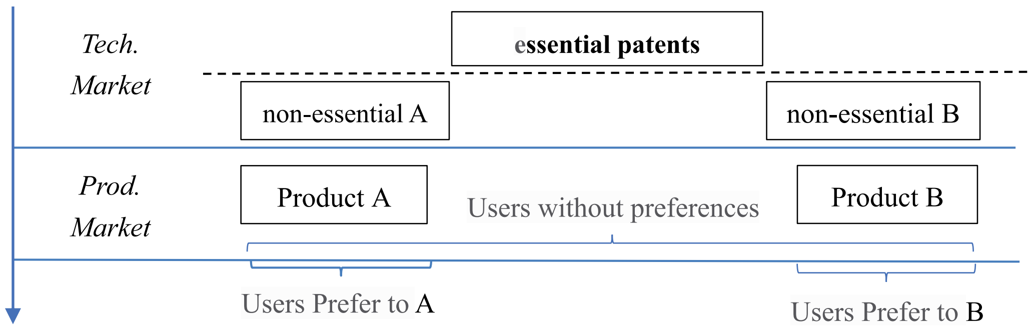

Figure 2. The process of innovational competition of technology standards alliances.

technical cores. This encourages the external and internal participants to follow up on improved research and facilitates the expansion and upgrade of the standards alliances.

4.5. Feature 2

Catering for the end-users' diverse needs, the standards need to dynamically extend their patents' scopes. At the industrialization and commercialization stages, the TD-SCDMA extends to the application system suppliers (Xinwei and Datang). It also extends to the terminal service suppliers (for example, China Mobile), and the terminal equipment suppliers. Examples of these are Siemens, Huawei, ZTE and others that provide instruments, antennas, RF chips, and so on). It thereby facilitated the accumulation of the application-oriented technical knowledge, the software copyright, and even the trademarks and brands. It demonstrates that developing the Patent Jungle is conducive to protecting the essential patents.

4.6. Feature 3

The standards wars between the industry value chains are much deeper, wider, and fiercer than the patent pools' competition in the technology markets. At first, the TD-SCDMA was weaker than WAPI, a failed Chinese standard. It encounters a strong counter-network (Gao 2007). A large installed base may cause a technological lock-in, but TD-SCDMA has a much smaller installed base than its rival standards, such as CDMA2000 and WCDMA. Also, its technology maturity has not been tested in a market environment. However, due to the value chain collaboration, the TD-SCDMA has finally been grasped. The innovation competition's process of the technology standards' alliances can be depicted as per Figure 2.

5. Conclusion

Based on the sequential innovations model raised by Llanes and Trento (2012, 703–725), the accumulation of the patents generates an increasing number of claims. In addition, based on the dynamic R&D incentives model by Dequiedt and Versaevel (2013), we develop this model with the essential-patent rate as the key variable. This paper demonstrates that accommodating an appropriate proportion of the non-essential patents will incentivize the subsequent innovation efforts. It will also increase the patent pools' option values and will further improve the alliances' prospects in the standards wars. An appropriate essential-patent rate may act as an incentive mechanism to prevent the opportunistic behaviors that undermine the cooperation in an innovation. It has the "function of *ex-ante* member selecting" to prevent adverse selection. Conversely, it has the "*ex-post* incentive function" to discard the moral hazard. Unfortunately, due to the limited data, this paper fails to provide empirical evidence.

The paper's theoretical contribution is a more inclusive framework for the patent pool's composition that includes the simplex and perfect composition in the existing literature as a special case. Harsh requirements on the patent's types are very likely to reduce the number of the patent pools that will be formed. They can also lessen the competition and cause greater risks of the monopolies. Diversifying the patents' portfolios by releasing the restrictions helps to encourage the innovation's competition. It also helps to facilitate a technology standard to reach the users' critical mass, and to gain a competitive advantage. Furthermore, expanding a product's extensive margin can also raise the protective barrier and value of the IPRs (Wei and Lian 2020). By being confronted with the disruptive technology changes in the digital economy, perhaps it is more socially desirable to seize the opportunity of the iterative innovation than to protect the consumers' welfare from the threat of monopoly. The antitrust agency must make a trade-off between the long-term technological gap caused by missing the upgradation opportunity and the short-term welfare losses that consumers may suffer.

The policy suggestion for the antitrust body is to accept the essential-patent rate as an alliance rule. Allowing the technology standards alliances to absorb the non-essential patents, especially in the context of the cruel standards wars, will improve the conditions for SEP licensing to appropriately perform its role.

Notes

1. The French phrase means the "factual standard". It is the technical norm spontaneously formed by the market, and the standards of the network industries are the technology systems that win in the market competition. In contrast to that, the traditional standard is a legal formal standard enforced by the government (Anderson and Tushman 1990).
2. The relationship between the patents can be grouped by the degree of their interdependence: Substitution, one-way blocking, mutual blocking and complementarity. As mentioned, the substitute patents are regarded as a group of patents with differentiated competing relationships among several blocking patents produced at the same stage. This idea is inspired by the case of the TD-SCDMA, which is the very successful 3G standard in China.
3. A patent comprises of many detailed claims on rights. An application to extend the life of patents is a widely used business strategy that adds new claims or revises some original claims to extend the original patent term or renew the patent. However, it may be irrelevant with the technology standards in the alliance. Therefore, this assumption is based on reality. For studies on patents' claims, see Gao (2015).
4. Their business and profit structures are the same. They are either firms that focus on the R&D in the upstream and we term them "pure patent holder." They could also be vertically integrated firms that are involved in both the upstream R&D and the downstream manufacturing, that may be termed "mixed patent holders."
5. It is irrelevant to the size of alliances, and only relates with the number of the licensees and their profit margin. Consistent with the international prevailing practices, the licensing fee must be collected in a package by the alliance according to the fair, reasonable, and non-discriminatory ("FRAND") terms (Lemley and Shapiro 2013, 1135). It must then be distributed among the alliance members. The alliance's licensing rules include the grant-back clauses, requiring the licensees to transfer newly developed, and correlated patents to the alliance without any compensation. This makes it impossible for the outside firms to obstruct the alliance by using their subsequent patents. They thus cannot charge a license fee from the alliance for their patents. This also enables them to become members of the alliance and thus expands the scale of the alliance.
6. A technology standard can be considered as being successful only when it has been accepted by the critical mass of the end-users and it becomes the dominant standard.
7. The case's essential information originates from the website: http://www.tdia.cn/about.asp?id=11. More information on the development of the Chinese standards can be found in Ernst (2017) and in the Appendix of this paper.

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