"Questionable Patent" and Contract Design of Patent Insurance

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Abstract: "Questionable patent" is one of the most serious problems facing the patent system. This paper suggests that the existing patent system can't build relationship well between patent right and patent value, and causes the imbalance of patent holder's rights and obligations, and then result in "questionable patent". This paper has come up with the idea of contract of patent insurance on the premise that patent's validity is uncertain, analyzed the strategic choice of all the participants through a sequential game model, and designed the optimal patent insurance contract on this basis. The results show that if the patent insurance premium and patent infringement compensation can be reasonably designed and the patent authorization behavior of innovative manufacturer can be properly intervened, the regulator could regulate the whole market through innovative manufacturer, and then achieve objectives such as compensating R&D cost of innovative manufacturer, minimizing the monopoly manufacturers' profit and maximizing social welfare.

1. Introduction

Questionable patent, also called "probability patent" or "weak patent", refers to a patent that is improperly granted, including one that does not comply with authorization condition that the provisions of current patent law, and one that may be granted a patent, but the scope of claim is too broad. With the continuous advancement of technology and society, the complexity and diversity of inventions and creations are increasing, and the number of questionable patents is increasing rapidly.

The existence of questionable patents will bring great harm to society. Questionable patents can hinder innovation or increase the cost of innovation; To increase the formation of patent jungles, resulting in new difficulties in patent licensing; To increase the uncertainty of patent prospects; To use of questionable patents for royalties, or the threaten of litigation will defeat existing or potential manufacturers competition; To waste of patent application and review resources, and high litigation costs brought by subsequent court decisions etc.

In view of the various social and economic problems caused by "questionable patents", economists have done a lot of research on this issue. The causes of questionable patents include internal factors and external factors. The internal factor means that the patent right is not a fully enforceable right [1], and the patent holder has the right to fight for exclusive rights in court [2]. However, due to the uncertainty of litigation outcome, the validity of patent right cannot be determined accordingly, this uncertainty is the root cause of questionable patent. The external factors mean that the sharp increase in the number of patent applications, the insufficient quality of examiners, the limited time for examination, the insufficient of authorization and retrieval conditions, and the deficiencies of related policies etc. In addition, the "pro-patent" policy adopted by governments in order to promote innovation is also an important reason for the emergence of questionable patents.

Lemley [3] discussed the questionable patent earlier. He pointed out that since patent quality is uncertain, the regulator will be vaguer on the evaluation of patent quality, so there may be fewer valuable patents in the market. If patent simply accept the scrutiny of regulator, it will reduce the average quality of patent inevitably. However, because patent litigation is often accompanied by high

litigation costs, patent litigation usually revolves around truly valuable patents that will be screened out in court. However, Jaffe and Lerner [4] disapprove of Lemley's statement. They suggest that while the litigation cost can be tolerated under the current inefficient scrutiny, the intangible costs caused by the generally low quality of patents is much higher than the patent litigation costs. The uncertainty of the litigation outcome is an unquantifiable cost to all parties. Any manufacturer attempting to commercialize a new technology will complain about uncertainty of patent quality, which undermines the enthusiasm of manufacturers to develop new technologies.

Farrell and Shapiro [5] suggested that in many cases, if the validity of patent is not thoroughly examined, then the patent is a "probability patent". They further analyzed the impact of "probability patents" on social welfare, and pointed out that a thorough review of the validity of patents prior to patent approval would benefit social welfare. Encaonu and Lefouili [6] studied the issue of the authorization of "weak patents" under the "shadow of litigation". Based on the models of Farrell and Shapiro, they relaxed two basic assumptions: On the one hand, they suggested that questionable patents are not necessarily involved small innovations, some violent innovations can also lead to questionable patents; On the other hand, they relax the restriction that the license contract provided by the patent holder must be accepted by all downstream manufacturers. They pointed out that according to changes in the market environment, patent holders may block or trigger patent litigation. In order to improve the efficiency of patent examination department, some patent applications can be "reasonably ignored", and increased resources investment for the judicial system and encouraged third parties to participate in the supervision of "weak patents".

Choi [7] pointed out that due to the lack of a rigorous scrutiny process, many suspicious patent applications are authorized, and the result is often hindered rather than promoted innovation. In view of the lack of innovation incentives for questionable patent holders, the existing patent system should be reformed by strengthening third-party supervision and replacing costly and time-consuming patent litigation with post-licensing scrutiny. Lemley and Shapiro [2] suggested that patent rights are uncertain, and the patent system gives patentee exclusive monopoly rights for a certain period of time. In order to solve the uncertainty of patent value and build a better patent system, resources should be inclined to patent applications with greater commercial value. Teece, Sherry and Grindley [8] argued that the primary goal of patent system reform is improve patent quality, and that it is vital to stimulate manufacturers' incentives for invention and innovation. Questionable patent seriously affected the quality of patent, Love [9] pointed out that although the Patent Office tried its best to improve the scrutiny process, questionable patents are actually granted. They need to adjust the cost to reduce the number of patents granted, which increased the cost of maintaining patent and reduced the application fee for administrative litigation after authorization. Lei and Wright [10] also believed that the reason for the questionable patent is that the examiners' scrutiny of the patent application is insufficient, and patent examiners ignores the objective validity of the patent. Questionable patents increase the social costs associated with abuse of litigation, but reduce the social benefits of innovation incentives.

2. Statement of Question

The above literature analyzed the impact of questionable patents on innovation and social welfare from different perspectives, and most of them advocated the governance of questionable patents by strengthening the scrutiny process or increasing judicial input. However, few scholars have examined the patent system from the most essential level.

This paper believes that the existing patent system can't build relationship well between patent right and patent value, and causes the imbalance between rights and obligations of patent holders and the emergence of "questionable patent", which is embodied in the following two aspects:

Firstly, the existing patent system does not link patent rights to patent prices. The patent system can grant the owner an exclusive right to produce and sell patent-related inventions, essentially by compensating the innovator's R&D costs through the marketization of innovation. However, the existing patent systems often separate innovative technological factors from market factors. The

patent scrutiny department only pays attention to the novelty, practicability and non-obviousness of innovation, and on this basis grants patents to innovators. When patents have problems in the market, the department that solves these problems is usually the court. Therefore, the existing patent system is actually an ex post mechanism, that is the specific price of the patent is not determined when the patent is granted, and the price is determined in court until the patent is infringed. This ex post mechanism provides huge rent-seeking space for patent holder.

Secondly, the existing patent system does not better coordinate the rights and obligations of patent holders. The primary rights of patent holders include the right to enforce their own patents, the right to license or prohibit others from enforcing their patents, and the right to seek protection. The primary obligation includes the obligation to pay fees and the obligation to implement and promote their inventions. However, due to the pro-patent policies of governments, such as subsidies or incentives for the costs incurred in the process of patent application, authorization and maintenance, the payment obligations of patentee are largely attenuated. At the same time, for the patentee, it is both a right and an obligation to implement and promote his invention. Therefore, the patentee usually exercises it as a right, which further weakens the obligations of the patentee.

This paper suggests that in order to curb the abuse of patent rights and the emergence of questionable patents, the patent system should be reformed from the most essential level, which is composed of the following two aspects:

On the one hand, we must closely contact patent rights with patent prices. Since the purpose of the patent system is to stimulate innovation through the market, it is impossible to bypass the market when granting patent rights, and the functions of the patent examination department and the court in the patent system should change accordingly. On a practical level, we can design a patent system based on patent insurance. Under the patent system, the patent examination department should determine the price of the patent while granting the patent right, which is expressed as the patent insurance premium and the corresponding infringement compensation amount. The main task of the court is to finalize the validity of patent when the patent dispute arises, doesn't determine the relevant amount of infringement compensation, which is determined by the amount of infringement compensation previously determined by the patent examination authority.

On the other hand, we must strike a balance between the rights and obligations of patentee. First, we should weaken the rights of patentee. The more straightforward method is to abandon the existing patent infringement compensation mechanisms and replace them with the cost-compensation doctrine. In the patent insurance contract designed in this paper, the patent price is determined by the R&D cost of the patentee, and the profit obtained by the patentee in the process of implementing the patent right is mainly used to compensate its R&D investment costs. If the patentee initiates a patent litigation on the premise that the R&D costs have been compensated, it will not gain any benefits from patent litigation. Therefore, the mechanism can effectively restrain the rights of innovative manufacturers while maintaining their innovation incentives. This mechanism does not mean that the patentee can arbitrarily encroach on patent rights after the R&D costs have been compensated. Since knowledge is a pure public good, the more it is used, the more social benefits it generates. In order to improve the efficiency of resource utilization, manufacturers should be encouraged to actively develop the existing knowledge. For infringing manufacturers, we still use the cost-compensation mechanism to regulate them, that is, to punish their income beyond the cost, so that their final profit is zero. In the patent insurance contract designed in this paper, the regulator can achieve this goal by designing the appropriate infringement amount.

Since patent rights are granted to innovators, they have the obligation to promote new knowledge and technology in the market for benefit the society. Since the patent right is a monopoly right, the income obtained by the patentee is often higher than the R&D cost, and these excess parts can be regarded as a kind of monopoly rent. In the patent insurance contract designed in this paper, regulator can levy the monopoly rent by designing appropriate patent insurance premium, so that final profit of the patentee is zero.

Section 3 is the model hypothesis. Section 4 analyzes the behavior of the innovation and downstream manufacturers. In section 5, we design the optimal patent insurance contract of regulator. Section 6 is the conclusion and enlightenment.

3. The Model Hypothesis

Construct a vertical structure market, which consist of upstream manufacturer P and several homogeneous potential entry manufacturers $i\,(i=1,2,...,n)$ in the downstream market. Suppose that manufacturer P develops a new product and applies for patent protection. Its R&D cost is C, and the product's inverse demand function is $p=a-q$. To simplify the analysis, assume that the marginal cost and fixed cost of manufacturer P are both zero, and the competition in the product market is Cournot competition.

It is worth noting that if manufacturer P obtains a patent, the patent may be valid or invalid, and whether it is indeed valid as the private information of manufacturer P. Other participants can only observe the patent quality ρ, $\rho\in[0,1]$. The larger the value of ρ, the higher the probability that the patent is valid. This parameter also indicates the probability that the patent is recognized as valid by the court after the occurrence of patent litigation.

In this paper, the participants in this game are regulators, manufacturer P and manufacturers i, and assuming all participants are risk neutral. The game consists of four phases, as shown in Figure 1.

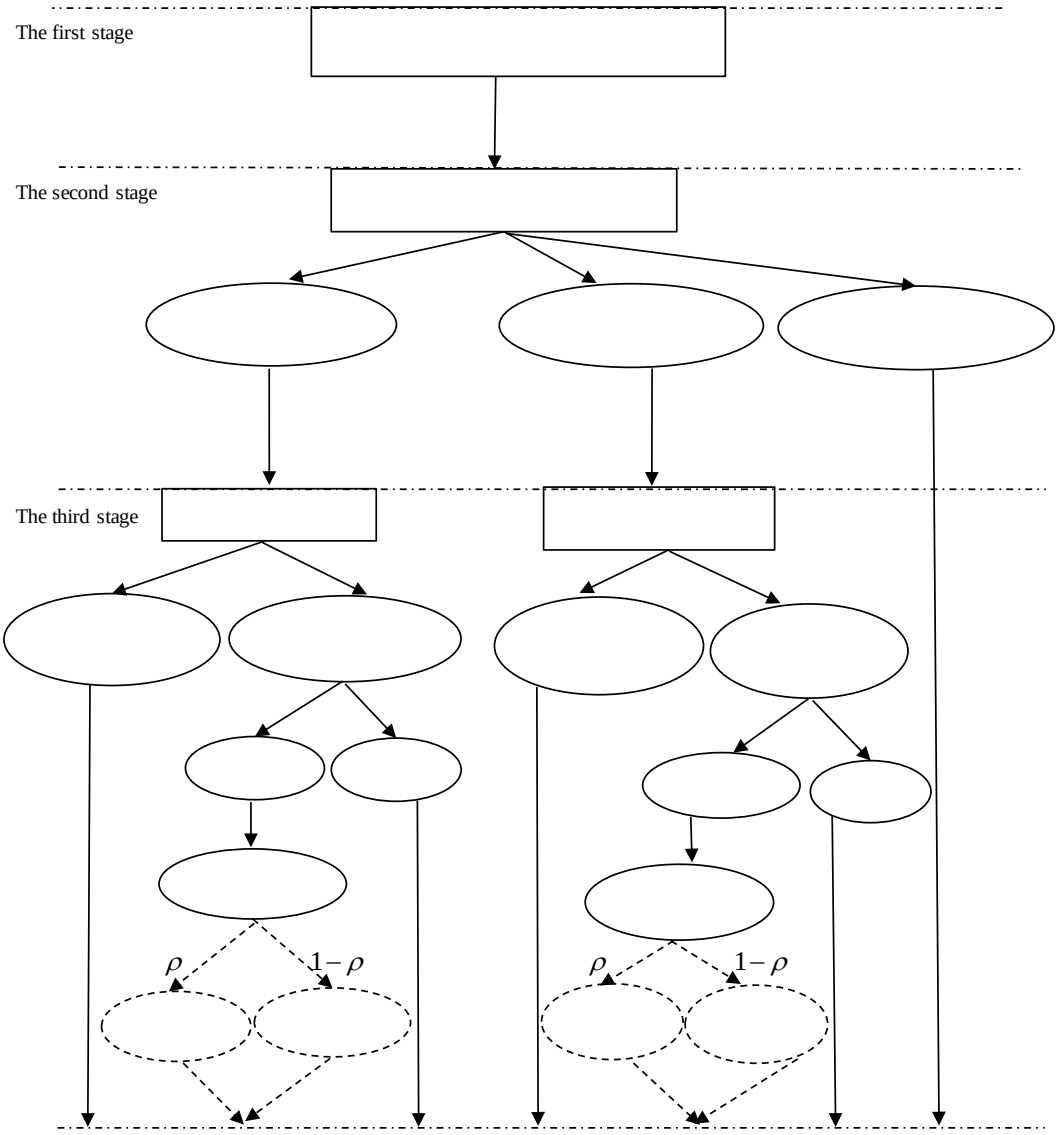

Fig. 1 Tripartite game tree.

The first stage: After receiving the patent application from manufacturer P, the regulator establishes a patent insurance contract based on the patent quality ρ and other relevant information. The contract is mainly composed of patent insurance premium T and patent infringement compensation S. S indicates that the compensation amount of infringer's payment to patentee when the court confirms that the patent is valid, after the occurrence of potential entry manufacturers' infringement.

The primary goal of regulators is to stimulate innovation, that is, to compensate the R&D costs of innovation manufacturer. Under the premise of meeting the primary goal, the regulator needs to maximize social welfare. Under the premise of meeting the above two objectives, the regulator must minimize the excess profits obtained by the innovators.

The second stage: manufacturer P action. If manufacturer P accepts the patent insurance contract (S,T), manufacturer P can obtain the patent right after paying patent insurance premium T, and then start to formulate patent license contract (r,F), which r and F respectively indicates unit usage fee and fixed use fee paid by the manufacturer i when using the patent. If manufacturer P

doesn't accept patent insurance contract (S,T), its products can't be patented. At this stage, manufacturer P also decides whether to enter the downstream market.

The third stage: potential entry into manufacturer i actions. If manufacturer P is granted a patent, manufacturer i has three alternative strategies: accepting contract of manufacturer P, infringing production, and not entering the market. If manufacturer i doesn't accept the patent license contract of manufacturer P and enters the market, the two parties will initiate a patent litigation. If the court confirms that the patent is indeed valid, manufacturer i must pay manufacturer P a certain amount of compensation S. If the court confirms that the patent is invalid, manufacturer i doesn't have to pay any fees.

At this stage, manufacture P can also reject the patent insurance contract of regulator, at this time its new product is not protected by patent. Since both marginal and fixed costs are zero, manufacturer i are bound to enter the market.

The fourth stage: According to the behavior of participants in the game, the following seven situations may occur:

Situation A: Manufacturer P accepts the patent insurance contract (S,T) and enters the downstream market, while manufacturer i accepts the patent license contract (r,F) of manufacturer P.

Situation B: Manufacturer P accepts the patent insurance contract (S,T) and enters the downstream market, but manufacturer i doesn't accept the patent license contract (r,F) of manufacturer P and chooses the infringing production.

Situation C: Manufacturer P accepts the patent insurance contract (S,T) and enters the downstream market, while manufacturer i doesn't enter the market.

Situation D: Manufacturer P accepts the patent insurance contract (S,T) but doesn't enter the downstream market, and manufacturer i accepts the patent license contract (r,F) of manufacturer P.

Situation E: Manufacturer P accepts the patent insurance contract (S,T) but doesn't enter the downstream market, but manufacturer i doesn't accept the patent license contract (r,F) of manufacturer P and chooses the infringing production.

Situation F: Manufacturer P accepts the patent insurance contract (S,T) but doesn't enter the downstream market, and manufacturer i doesn't enter the market.

Situation G: Manufacturer P doesn't accept patent insurance contracts (S,T) and enters the downstream market, while manufacturer i enter the market.

4. Manufacturer Behavior Analysis

In this paper, the inverse inductive method is used to solve the sub-game perfect Nash equilibrium, which is first analyzed from the fourth stage of the game.

4.1. The Fourth Stage of the Game: Earnings Analysis of Each Manufacturer.

Situation A: Manufacturer P accepts the patent insurance contract (S,T) and enters the downstream market, while manufacturer i accepts the patent license contract (r^A,F^A) of manufacturer P. It is assumed that the output of each manufacturer is q_P^A and $q_i^A(i=1,2,...,n)$, and the profit function of each manufacturer can be obtained by combining the hypothesis in this paper, as shown in the following formula (1):

$$\begin{cases} \pi_P^A = (a - q_P^A - \sum_{i=1}^{n} q_i^A) q_P^A + r^A \sum_{i=1}^{n} q_i^A + nF^A - T - C \\ \pi_1^A = (a - q_P^A - \sum_{i=1}^{n} q_i^A) q_1^A - r^A q_1^A - F^A \\ ..... \\ \pi_n^A = (a - q_P^A - \sum_{i=1}^{n} q_i^A) q_n^A - r^A q_n^A - F^A \end{cases} \tag{1}$$

According to formula (1), Nash equilibrium solution of each manufacturer under Cournot competition can be obtained, as shown in the following formula (2):

$$\begin{cases} q_P^{A*} = \dfrac{a + nr}{2 + n} \\ q_1^{A*} = q_2^{A*} = ... = q_n^{A*} = \dfrac{a - 2r}{2 + n} \end{cases} \tag{2}$$

By combining equations (1) and (2), the optimal price and profit of each manufacturer can be obtained, as shown in the following formula (3):

$$\begin{cases} p_P^{A*} = p_D^{A*} = \dfrac{a + r^A}{n + 2} \\ \pi_P^{A*} = \dfrac{(a + nr^A)^2}{(2 + n)^2} + \dfrac{nr^A(a - 2r^A)}{2 + n} + nF^A - T - C \\ \pi_1^{A*} = \pi_2^{A*} = ... = \pi_n^{A*} = \dfrac{(a - 2r^A)^2}{(2 + n)^2} - F^A \end{cases} \tag{3}$$

Situation B: Manufacturer P accepts the patent insurance contract (S,T) and enters the downstream market, but manufacturer i doesn't accept the patent license contract of manufacturer P and chooses the infringing production. At this time, a patent litigation will be generated between manufacturer P and the downstream manufacturer i. If manufacturer P wins the litigation, each downstream manufacturer i must pay the infringement compensation S to manufacturer P. If manufacturer P loses, manufacture i doesn't have to pay any fees. Since the probability of manufacturer P winning is ρ, the expected profit function of each manufacturer as shown in the following formula (4):

$$\begin{cases} E(\pi_P^B) = (a - q_P^B - \sum_{i=1}^{n} q_i^B) q_P^B + n\rho S - T - C \\ E(\pi_1^B) = (a - q_P^B - \sum_{i=1}^{n} q_i^B) q_1^B - \rho S \\ ..... \\ E(\pi_n^B) = (a - q_P^B - \sum_{i=1}^{n} q_i^B) q_n^B - \rho S \end{cases} \tag{4}$$

According to the above formula, the optimal output, price and profit of each manufacturer under situation B can be obtained, as shown in the following formula (5):

$$\begin{cases} q_P^{B*} = q_i^{B*} = \dfrac{a}{2 + n}; p_P^{B*} = p_i^{B*} = \dfrac{a}{2 + n} \\ E(\pi_P^{B*}) = \dfrac{a^2}{(2 + n)^2} + n\rho S - T - C; \quad E(\pi_i^{B*}) = \dfrac{a^2}{(2 + n)^2} - \rho S \end{cases} \tag{5}$$

The product price and manufacturer profit of situation C to G are shown in the following Table 1 below:

Table 1. Product price and manufacturer profit of situation C to G.

	p_P	p_i	π_P	π_i
Situation C	$\frac{a}{2}$	∞	$\frac{a^2}{4}-T-C$	**0**
Situation D	∞	$\frac{a+nr^D}{n+1}$	$n(\frac{a-r^D}{n+1})r^D+nF^D-T-C$	$\frac{(a-r^D)^2}{(n+1)^2}-F^D$
Situation E	∞	$\frac{a}{n+1}$	$n\rho S-T-C$	$\frac{a^2}{(n+1)^2}-\rho S$
Situation F	∞	∞	$-C-T$	**0**
Situation G	$\frac{a}{2+n}$	$\frac{a}{2+n}$	$\frac{a^2}{(2+n)^2}-C$	$\frac{a^2}{(2+n)^2}$

4.2. The Third Stage of the Game: The Behavior Analysis of Manufacturer i.

The third stage of the game is manufacturer i action, and the goal is to choose the suitable strategy at this stage to maximize benefits of the fourth stage. However, by comparing the gains of manufacturers i in the fourth stage, it is difficult to get a more intuitive conclusion because the patent license contract (r, F) of manufacturer P is not determined. Therefore, the second stage's analysis of the game must be carried out.

4.3. The Second Stage of the Game: The Behavior Analysis of Manufacturer P.

In the second stage of the game, manufacturer P has three strategic choices. Since the result of situation G is relatively straightforward, we mainly analyze the behavior of manufacturer P after accepting the patent insurance contract.

4.3.1. Manufacturer P Obtains the Patent Rights and Enters the Downstream Market.

If manufacturer P obtains the patent right and enters the downstream market, there may be three situations: situation A, situation B and situation C. The main problem facing the manufacturer is how to design a suitable patent license contract to maximize the benefits of manufacturer P in the fourth stage.

In the third stage, manufacturer i must choose the strategy to maximize its own revenue, so we must compare the benefits of the manufacturer under different situations. Since parameters are exogenous variables, such as ρ, S, T and C etc., while $\pi_i^{C^*}=0$ and $E(\pi_i^{B^*})=a^2/(2+n)^2-\rho S$, so the benefits of manufacturers i under situation B and situation C can be regarded as exogenous given.

If $E(\pi_i^{B^*})\geq\pi_i^{C^*}$, that is $a^2/(2+n)^2\geq\rho S$, manufacturer i can only choose either situation A or situation B. At this time, if manufacturer P expects the final result to be situation A, the manufacturer must maximize its own profit while designing the patent license contract, and the profit of manufacturer i is not lower than $E(\pi_i^{B^*})$, as shown in the following formula (6):

$$\begin{aligned} Max \quad & \pi_P^{A*} = \frac{(a+nr^A)^2}{(2+n)^2} + \frac{nr^A(a-2r^A)}{2+n} + nF^A - T - C \\ s.t. \quad & \frac{(a-2r^A)^2}{(2+n)^2} - F^A \geq \frac{a^2}{(2+n)^2} - \rho S \end{aligned} \tag{6}$$

The optimal patent license contract designed by manufacturer P and the final income of each manufacturer can be obtained through formula (6), as shown in the following formula (7):

$$\begin{cases} r^{A*} = \frac{a}{2}, \quad F^{A*} = -(\frac{a^2}{(2+n)^2} - \rho S) \\ \pi_P^{A**} = \frac{a^2}{4} - n(\frac{a^2}{(2+n)^2} - \rho S) - T - C \\ \pi_i^{A**} = \frac{a^2}{(2+n)^2} - \rho S \end{cases} \tag{7}$$

It can be known from formula (7) that the optimal patent license contract of manufacturer P is that the patent royalty charged for each unit of product is equal to the monopoly price, and manufacturer i is charged a negative fixed fee, which is obtained by manufacturer i in the situation B, the benefits are equal. At this time, no any potential entrants will enter the market. The entire market is completely monopolized by manufacturer P, and the product price is the monopoly price. The reason for this phenomenon is that competition will always reduce the joint profits of manufacturers. By purchasing the potential entrants and preventing them from entering the market, thereby manufacturer P obtains monopoly profits and maximizes profits without jeopardizing the interests of potential entrants.

Note that the expected return of manufacturer P under situation B is $E(\pi_P^{B*}) = \frac{a^2}{(2+n)^2} + n\rho S - T - C$, that the value is strictly less than π_P^{A**}. Therefore, situation A is a situation with higher returns for manufacturer P.

If $E(\pi_i^{B*}) < \pi_i^{C*}$, that is $a^2/(2+n)^2 < \rho S$, manufacturer i can only choose situation A or situation C. Using the same analysis process, it is easy to know that the optimal patent license contract of manufacturer P is that the patent royalty charged for each unit of product is equal to the monopoly price, and the fixed fee is zero. At this time, no potential entrants enter the market. The reason for this phenomenon is that the punishment of patent infringement is relatively strong, and any entry into the market of potential entrant is unprofitable, so that manufacturer P can monopolize the entire market.

Based on the above analysis, the following proposition 1 can be obtained:

Proposition 1: If manufacturer P accepts the patent insurance contract and enters the downstream market, its optimal patent license contract is $((r = a/2, F = \min\{-(a^2/(2+n)^2 - \rho S), 0\})$, at this time, manufacturer P monopolizes the entire market, and the income of all potential entrants is $\max\{a^2/(2+n)^2 - \rho S, 0\}$.

4.3.2. Manufacturer P Obtains Patent Rights but Doesn't Enter the Downstream Market.

If manufacturer P obtains the patent right and enters the downstream market, there may be three situations: situation D, situation E and situation F. It is noted that the final profit of manufacturer P under situation F is negative and the profit of manufacturer i is zero. No manufacturer wants this situation to happen, so we only need to analyze situation D and situation E. If manufacturer P wants situation D to occur eventually, the manufacturer must maximize its own profit when designing the patent license contract, and make the profit of manufacturer i not less than $E(\pi_i^{E*})$. By comparing the profits of situation D and situation E in table 1, the following equation (8) can be obtained:

$$\begin{aligned} Max \quad & \pi_P^{D*} = \frac{nr^D(a-r^D)}{1+n} + nF^D - T - C \\ s.t. \quad & \frac{(a-r^D)^2}{(1+n)^2} - F^D \geq \frac{a^2}{(1+n)^2} - \rho S \end{aligned} \tag{8}$$

The optimal patent license contract of manufacturer P and the final profit of each manufacturer can be obtained through formula (8), as shown in the following formula (9):

$$\begin{cases} r^{D*} = \dfrac{(n-1)a}{2n}, \quad F^{D*} = \dfrac{(1+2n-3n^2)a^2}{4n^2(1+n)^2} + \rho S \\ \pi_P^{D**} = \dfrac{(n-1)a^2}{4(1+n)^2} + n\rho S - T - C \\ \pi_i^{D**} = \dfrac{a^2}{(1+n)^2} - \rho S \end{cases} \tag{9}$$

According to formula (9), the product price in situation D is $p^{D*} = a/2$, and the price is monopoly price. When manufacturer P doesn't enter the downstream market, its optimal choice is to set the appropriate unit usage fee r^{D*}, resulting in the product price as a monopoly price, thereby achieving the joint profit maximization of all downstream manufacturers. On this basis, manufacturer P maximizes the profits of other manufacturers by setting appropriate fixed usage fee F^{D*}, and ultimately maximizes its own profits.

By comparing the profit of manufacturer P in different situations, we can get $\pi_P^{A**} > \pi_P^{D**}$, $\pi_P^{B*} > \pi_P^{E*}$ and $\pi_P^{C*} > \pi_P^{F*}$. Therefore, if manufacturer P accepts the patent insurance contract, the profit obtained by the manufacturer when entering the downstream market is always higher than when not entering the downstream market. The following proposition 2 can be obtained:

Proposition 2: If manufacturer P accepts the patent insurance contract provided by the regulator and the manufacturer is free to design its patent license contract, entering the downstream market is a strict dominant strategy of manufacturer P.

5. The Regulator's Contract Design of Patent Insurance

The regulator design patent insurance contracts in the first stage of the game, with the goal of maximizing social welfare while compensating the R&D costs of innovative manufacturer. Since the inverse demand function of the market is $p = a - q$, the social welfare function as shown in the following formula (10):

$$w = \int_0^q (a-q)dq = aq - \frac{q^2}{2} \tag{10}$$

It is easy to know $\partial w / \partial p = -(a-p)$ from formula (12), so social welfare decreases with the increase of product price. If regulators want to maximize social welfare, they must minimize the market price of products. According to the analysis in the third part of this paper, under situation B and situation G, the product price is the lowest, and the social welfare is at the highest level under these two situations.

However, combined with Proposition 1 and Proposition 2, if the regulator simply stipulates patent premium T and infringement compensation S, the situation B can't occur. Therefore, the problem faced by regulators is how to design patent insurance contract in order to compensate the R&D costs of innovative manufacturers and maximize social welfare?

Proposition 3: According to the change of innovation manufacturer's R&D cost, the regulator's optimal patent insurance contract also needs to change accordingly. Therefore, the regulator's optimal patent insurance contract should be a discretionary choice mechanism, as follows:

(1) When $C < a^2/(2+n)^2$, the regulator's optimal patent insurance contract is any combination (S,T) that was satisfied with $T > (4n+n^2)a^2/4(2+n)^2$, and the regulator doesn't need to interfere with manufacturer's behavior. At this time, situation G is the only sub-game perfect Nash equilibrium, that is manufacturer P will reject the regulator's patent insurance contract and enter the downstream market, and its R&D costs will be compensated in the market, and social welfare will reach the optimal level.

(2) When $a^2/(2+n)^2 \le C \le (1+n)a^2/(2+n)^2$, the regulator's optimal patent insurance contract is $T = [(1+n)a^2/(2+n)^2] - C$ and $S = a^2/[\rho(2+n)^2]$, at the same time, prohibiting manufacturer P from collecting the patent unit usage fee, that is $r^{w*} = 0$. At this time, situation A is the only sub-game perfect Nash equilibrium, that is manufacturer P will accept the patent insurance contract of the regulator and enter the downstream market, and all potential entrants will accept the patent license contract of manufacturer P, and the final profit of all manufacturers is zero, while social welfare will reach the optimal level.

(3) When $(1+n)a^2/(2+n)^2 < C \le a^2/4$, the regulator's optimal patent insurance contract is $T = (a^2/4) - C$ and $S = a^2/[\rho(2+n)^2]$, the regulator doesn't need to interfere with manufacturer's behavior. At this time, situation A is the only sub-game perfect Nash equilibrium, that is manufacturer P will accept the patent insurance contract of the regulator and enter the downstream market, but no potential entrant will enter the market, and the R&D cost of manufacturer P will be compensated in the market. But social welfare can't reach the optimal level.

(4) When $C > a^2/4$, the R&D cost of manufacturer P couldn't be compensated by the market. At this time, the regulator may have to consider subsidizing innovation manufacturer.

Prove:

(1) When $C < a^2/(2+n)^2$, through the analysis of proposition 1, it can be known that if the regulator doesn't interfere with the behavior of manufacturer, the highest profit is $\pi_P^{C*} = (a^2/4) - T - C$ that can be obtained after manufacturer P obtains the patent right. By comparing π_P^{C*} and π_P^{G*}, when $T > (4n+n^2)/4(2+n)^2$, there was $\pi_P^{C*} < \pi_P^{G*}$. At this time, because the regulator sets the patent insurance premium too high, the profit of manufacturer P would decline after obtaining the patent right. Therefore, the latter's best choice is to reject the patent insurance contract and directly enter the downstream market. At this time, situation G is unique sub-game perfect Nash equilibrium. The R&D cost of manufacturer P will be compensated in the market, and social welfare will reach the optimal level.

However, under the patent insurance contract, if $C \ge a^2/(2+n)^2$, manufacturer P is unable to compensate its R&D costs in the downstream market, it will damage its innovation incentives. At this time, the patent insurance contract doesn't apply to the situation of $C \ge a^2/(2+n)^2$, we must re-examine the situation.

(2) When $a^2/(2+n)^2 \le C \le (1+n)a^2/(2+n)^2$, if the regulator doesn't interfere with the behavior of innovative manufacturer, either the latter' s R&D costs can't be compensated, or social welfare can't be maximized, the regulator must constrain the behavior of innovative manufacturer. If the behavior of manufacturer P is constrained, it will change the manufacturer's decision in the second stage of the game, and then affect the final result of the game, so the entire game needs to be re-examined.

Note that the product price is $p_P^{A*} = p_D^{A*} = (a + r^A)/(n+2)$ under situation A, if the regulator stipulates that manufacturer P is not allowed to charge any unit usage fee in the patent insurance contract, then situation A can maximize social welfare. At this time, the problem faced by the regulator is how to design (S,T), and the outcome of leading the game is situation A.

When the regulator stipulates that manufacturer, P is not allowed to charge any unit usage fee, if manufacturer P wants potential entrant to accept the patent license, the objective function must satisfy the following formula (11):

$$\begin{aligned} &Max \quad \pi_P^{Aw} = \frac{a^2}{(2+n)^2} + nF^{Aw} - T - C \\ &s.t. \quad \frac{a^2}{(2+n)^2} - \rho S \geq 0 \qquad (D1) \\ &\qquad \frac{a^2}{(2+n)^2} - F^{Aw} \geq \frac{a^2}{(2+n)^2} - \rho S \qquad (D2) \end{aligned} \tag{11}$$

In the above formula, the constraint condition (D1) ensures that potential entrants will enter the market, and (D2) ensures that potential entrants will not infringe. It can be know $F^{Aw} \leq \rho S$ from (D1), the optimal choice of manufacturer P is $F^{Aw*} = \rho S$ for the sake of profit maximization, and the final profit of different manufacturers as shown in the following formula (12):

$$\begin{cases} \pi_P^{Aw*} = \dfrac{a^2}{(2+n)^2} + n\rho S - T - C \\ \pi_i^{Aw*} = \dfrac{a^2}{(2+n)^2} - \rho S \end{cases} \tag{12}$$

By using the same analysis process, it is easy to find that the final profit is π_P^{Dw*} when manufacturer P doesn't charge any unit usage fee under situation D, which is known $\pi_P^{Aw*} > \pi_P^{Dw*}$ by comparison. Therefore, after manufacturer P obtains the patent right, even if the manufacturer isn't allowed to charge any unit usage fee, entering the downstream market is its strict dominant strategy.

When $r^A = 0$, the social welfare has reached the optimal level. At this time, the regulator must compensate the manufacturer's R&D costs, that is $\pi_P^{Aw*} \geq 0$, in combination with formula (14) can be obtained the following formula (13):

$$T \leq \frac{a^2}{(2+n)^2} + n\rho S - C \tag{13}$$

Since the regulator must also minimize the excess profits of all manufacturers, that is make π_P^{Aw*} and π_i^{Aw*} approaches zero, and the optimal insurance premium and infringement compensation can be obtained by combining formula (12) and (13), as shown in the following formula (14):

$$\begin{cases} S^{w*} = \dfrac{a^2}{\rho(2+n)^2} \\ T^{w*} = (1+n)(\dfrac{a}{2+n})^2 - C \end{cases} \tag{14}$$

The inherent logic of this patent insurance contract is that because the regulator prohibits manufacturer P from collecting the unit usage fee, it eliminates the conspiracy in the downstream market, minimizes the product price, and encourages potential entrants to enter the market by setting appropriate infringement compensation S. Then, manufacturer P will extract all the profits of potential entrant through charged fixed fee F, and the final profit obtained by manufacturer P is just equal to the patent insurance premium T set by the regulator in advance. Therefore, under this patent insurance contract, the R&D costs of the innovator manufacturers can be compensated, the social welfare can be optimized, and the excess profits of all manufacturers are levied by regulators through the patent insurance contract.

(3) Using the similar analysis process, it is easy to know that when $(1+n)(\frac{a}{2+n})^2 < C \le a^2/4$, the optimal insurance premium and infringement compensation are $S^{w*} = \frac{a^2}{\rho(2+n)^2}$ and $T^{w*} = \frac{a^2}{4} - C$ respectively.

(4) If $C > a^2/4$, the R&D cost of manufacturer P can't be compensated by the market, the regulator may consider subsidizing the innovation manufacturer.

6. Conclusion

The emergence of questionable patents indicates that the existing patent system has major deficiencies. This paper proposes a concept of patent insurance contract, and analyzes the strategic choices of each participant in the market under the contract through a sequential game model, and designs the optimal patent insurance contract on this basis. The results show that if patent insurance premiums and patent infringement compensations can be reasonably designed and patent licensing behaviors of innovative manufacturer are appropriate intervention, regulators can regulate the entire market through innovative manufacturers. The purpose of compensating the R&D costs of innovation manufacturer, minimizing the monopoly profits of all manufacturers and maximizing social welfare are achieved. Therefore, the patent insurance contract proposed in this paper is feasible theoretically, and the main conclusions of this paper are as follows:

First, when reviewing an innovation, regulators must consider not only the technical aspects, but also push the innovation's patent rights and its market value closer. The patent examination department should pay more attention to the market, such as market size, market structure and R&D costs etc.

Second, the rights and obligations of patent holder need to be equal. Since we have granted patents to innovators, they are obligated to promote new knowledge and technologies in the market for benefit the society. However, the emergence of "questionable patents" indicates that the existing patent system is difficult to do this, because the "loss of profits" rule upheld by the courts greatly expands the rights of patent holder, resulting in the imbalance between rights and obligations. Therefore, we can limit the rights of patent holder through the "cost compensation" rules, and guide potential entrants into the market by setting up reasonable patent insurance contracts, to maximize social welfare.

Third, the regulator should set certain stipulations and restrictions on the patent licensing behaviors of patent holder. Amir, Encaoua and Lefouili [1] analyzed the licensing mechanism of weak patent holders and pointed out that the negative impact of weak patents on social welfare is largely due to the litigation costs caused by patent disputes. Patent holder can avoid these disputes by designing reasonable patent licensing mechanism, but this doesn't optimize social welfare. The results of this paper show that if this behavior can be restricted, it will help to improve social welfare.

Fourth, the reform of patent system is imperative. In the past 100 years, the basic structure of the patent system has not undergone any fundamental changes. However, in today's increasingly complex and diverse of inventions and creations, the antiquated patent system appears to be incapable, leading to a series of problems such as "questionable patents", patent trolls, and excessive workload of examiners. Therefore, it is necessary for us to reform the existing patent system, and the direction of reform may be as pointed out by Burk and Lemley [11] that "……The inventions of all kinds are radically different in nature. Different industries have different forms of invention and creation, the patent process should also be different accordingly". In other words, they suggested that different patent systems should be designed according to different industries.

However, considering the large number of industries in the real world and the emergence of emerging industries, the patent system reform plan proposed by them is undoubtedly a huge and

complicated project. A simpler alternative is to design different patent insurance contracts based on the way of manufacturers compete and the types of innovation. For example, this paper assumes that the competition among manufacturers is Cournot competition, and if Bertrand competes, patent insurance contracts may change. At the same time, this paper assumes that the innovation of manufacturer P is product innovation, but there are many production technology innovations or technologies process innovations, such as reducing the cost of existing products or improving product quality etc. How should we response this type of innovation? All of these are further extensions of this paper, and indicate that the patent system should be a more flexible and diverse system.

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