Strategic Declaration of Standard Essential Patents *

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Abstract

We examine how the ex-post assessment of standard essential patents (SEPs) affects the patent holder's strategic incentive to declare SEPs. While declaration guarantees inclusion in the standard, it requires commitment to license under fair, reasonable, and non-discriminatory (FRAND) terms. We consider two forms of essentiality assessment: (i) by an independent organization and (ii) by the courts during a patent dispute or challenge initiated by a standard implementer. Assessment by an independent organization can eliminate declared patents whose essentiality is low. Assessment through a dispute can decrease the number of both declared and non-declared (i.e., non-FRAND-encumbered) patents and these different trade-offs affect the rights holder's strategic declaration incentive. We obtain the following results. First, there is less declaration when there is ex-post assessment of either type compared with no assessment. Second, there is less declaration with assessment by an independent organization than with assessment through disputes. We also show that a rights holder with high essentiality patents sets a higher declaration rate than one with low essentiality patents.

Keywords: Standard; Standard Essential Patents; R&D
JEL Classification: O38; L15

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1 Introduction

When a new technology is invented, the inventor needs to consider how to obtain revenue from the invention. Standardization is often necessary for the new technology to be adopted widely. A standard is "a document, established by consensus and approved by a recognized body, that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context"(ISO/IEC Guide 2:2004, definition 3.2). DVD or WiFi are examples of such standards. Further, some standards are not set by a recognized body and are instead produced by a private firm, such as the Windows OS and QWERTY keyboard. For example, Biddle et al. [2010] show that at least 251 interoperability standards are included in a modern laptop. Standardization thus plays an important role in our lives.

With technology becoming more and more complicated, there are more instances in which standard implementers need to use patented technology. A patent that protects an essential technology of a standard is called a standard essential patent (SEP). Under SEPs, not only is the technology required but also no substitute technologies exist. By definition, the SEP holder has strong bargaining power when it comes to agreeing licensing contracts. To avoid problems and negative consequences, the SEP holder must "declare"(i.e., make public) that the essential patented technology is an SEP and commit to fair, reasonable, and non-discriminatory (FRAND) terms of licensing for standard setting organizations to include it in the standard.

Despite the growing importance of SEPs, analysis of a patent holder's strategic incentive to declare SEPs is scarce. The literature on SEPs can be divided into two categories: analysis of the characteristics of SEPs and analysis of the strategic behavior to obtain SEPs. For example, Rysman and Simcoe [2008] show that patents declared as SEPs receive more citations than other patents in the same technology field. They also argue that high value patents tend to be declared as SEPs. Pohlmann et al. [2016] focus on the relationship between SEPs and the SEP holder's financial performance. They find an inverted U-shaped relationship between the number of SEPs and a firm's ROA. Lemley and Shapiro [2013] and Lerner and Tirole [2015], using a general framework, show that ex-ante price commitments such as a FRAND terms improve efficiency.

The second category of the literature focuses on the strategic behavior to invent and patent SEPs. Leiponen [2008] shows that firms can increase their contributions to the development of the new tehnical specification in the standard by joining the industry consortia. Bekkers et al. [2011] show that participation in the standardization process plays an important role in determining essential patent claims. Kang and Bekkers [2015] discuss the "just-in-time patenting strategy," a practice where rights holders apply for low value patents just before a standardization meeting and try to include these patented technologies into the standard.

These studies implicitly assume that SEPs are essential to the standard and overlook

SEP declaration as a strategic behavior. However, the essentiality of patents is not controlled by anyone. Firms can declare if they themselves judge the technology to be essential. Declaration does not involve any assessment of the actual essentiality of the patented technology. A firm can also choose not to declare a technology that is actually essential.

Several studies conclude that fewer than 30% of patent families declared "essential "are actually essential in the telecommunication industry (Goodman and Myers, 2005; Fairfield Resources International 2008, 2009). The rise in the number of declared SEPs increases the costs of reaching a licensing agreement. In addition, efforts to disguise inessential patents as SEPs results in a social cost. Therefore, policymakers such as the European Patent Office pay attention to the declaration issue.

To the best of our knowledge, the only work that examines the strategic incentive to declare is Dewatripont and Legros [2013]. They focus on the over-declaration of SEPs and show that the rights holder has an incentive to over-declare to increase its profit share from the standard. They assume that the rights holder focuses on the royalty benefit from SEPs. However, according to a survey of patent owners conducted by Blind et al. [2011], rights holders' most important reason for obtaining essential IPRs is to secure their freedom to operate (FTO), not generate license revenue. Dewatripont and Legros [2013] assume that inessential patents do not benefit the holder at all, even though they can be profitable since they are not restricted by FRAND terms. In our research, we take into account these factors not considered in Dewartripont and Legros' analysis. Regibeau et al. [2016] suggest two approaches to mitigate the over-declaration of SEPs. One approach is to make SEP declaration costly. The other is a random assessment of the essentiality of declared patents. However, they do not go into detail on how these approaches affect the rights holder's incentives. In this research, we analyze an effective policy for reducing the over-declaration of SEPs.

The remainder of the paper is organized as follows. Section 2 sets up the basic model and analyzes the two assessment approaches. Some extensions are presented in Section 3. Section 4 concludes. All proofs are given in the Appendix.

2 Model

Our model features a rights holder (firm 1) and a standard implementer (firm 2). Firm 1 obtains profits from its patented technology. We assume that the number of firm 1's patents is F. The rights holder can decide how many patents are declared as SEPs by setting the declaration rate $e \in [0, 1]$ to maximize its profit. We capture the essentiality of the rights holder's F patents by assuming they are distributed according to"essentiality". By essentiality, we mean the probability that a patent passes the ex-post assessment. If the rights holder sets the declaration level e, the lowest probability of positive assessment (i.e., it is essential) of its declared patent is equal to $1 - p(e)$. We assume that the probability that the patent is determined to be non-essential is $p(e)$, and it satisfies the following conditions:

$$p(0) = 0, p(1) = 1, \frac{dp(e)}{de} > 0 \tag{1}$$

If the rights holder increases the declaration rate e, it needs to disguise the patents whose essentiality is relatively low as SEPs. Then, $p(e)$ is an increasing function of e. If there is no ex-post assessment of SEPs' essentiality, the number of declared patents is $D_n = e \times F$.

The rights holder's payoff π_1 is given by

$$\pi_1 = R_F + R_H - C_D - C_O.$$

The rights holder must commit to the FRAND licensing terms if it declares its patent as an SEP. The profit from the FRAND royalty is given by R_F, which is assumed to be the function of the declaration rate e and number of inessential patents F:

$$R_F = D \times r_L.$$

D is the number of patents declared by firm 1 and r_L is equal to the FRAND royalty rate per patent. We assume that the profit from non-declared patents is R_H. If the rights holder does not declare its patents as SEPs, it can set a higher royalty rate than the FRAND condition or rely on profit from selling products including its inessential patents. Revenue from non-declared patents, R_H, is given by

$$R_H = N \times r_H,$$

N is the number of non-declared patents. r_H is the royalty rate per patent, which is larger than the FRAND royalty rate r_L. N is given by

$$N = F \times (1 - e).$$

We assume that a firm incurs declaration costs C_D, including the cost of disguising inessential patents as SEPs. C_D is given by the following:

$$C_D = \alpha \times F \times e.$$

The declaration cost depends on the number of declared patents and cost parameter α.

The rights holder also has an incentive to secure its FTO by declaring SEPs. To take this incentive into account, we introduce the operation cost C_O. If the number of declared patents increases, the rights holder can avoid the risk of being infringed. Therefore, we assume that C_O is

$$C_O = (A - D)\, c_O,$$

where A and c_O are positive constants. We consider two types of ex-post assessments: assessment by an independent organization (including a government) and assessment by patent disputes or challenges initiated by a standard implementer. The timing of the game is summarized as follows:

1. Firm 1 obtains the number of patents F.
2. Firm 1 decides the degree of over-declaration.
3. The number of patents decreases because of disputes or ex-post assessments.

Ex-post assessment is either by an independent organization or through a dispute. In the next section, we consider the benchmark case that no ex-post assessment exists.

2.1 Benchmark

First, we consider the case of no ex-post assessment. We can rewrite the firm's profit as follows:

$$\pi_1 = eFr_L + F(1-e)r_H - \alpha Fe - (A - eF)\, c_O. \tag{2}$$

Firm 1 chooses the declaration rate e to maximize its profit. From this equation, we can obtain the following lemma.

Lemma 1. *When there is no ex-post assessment, firm 1 sets the optimal declaration rate* e^* *as follows:*
(i) If $r_L + c_O - \alpha > r_H$*, firm 1 declares all its inessential patents as SEPs* $(e^* = 1)$*.*
(ii) Otherwise, firm 1 does not declare at all $(e^* = 0)$*.*

Proof. See the Appendix. □

When the firm increases the declaration rate, it can increase the benefits from the FRAND royalty r_L and securing FTO c_O. On the contrary, it needs to pay the declaration cost and give up the high royalty rate r_H. When $r_L + c_O - \alpha$ is larger than r_H, the benefit of declaration is sufficiently large. Then, the firm has a strong incentive to declare its inessential patents as SEPs. If the declaration cost α is too large or revenue from the FRAND royalty and FTO is small, the firm has no incentive to lie.

2.2 Ex-post assessment by an independent organization

We next consider ex-post essentiality assessment by an independent organization. If the independent organization assesses the declared SEPs, it can eliminate the SEPs

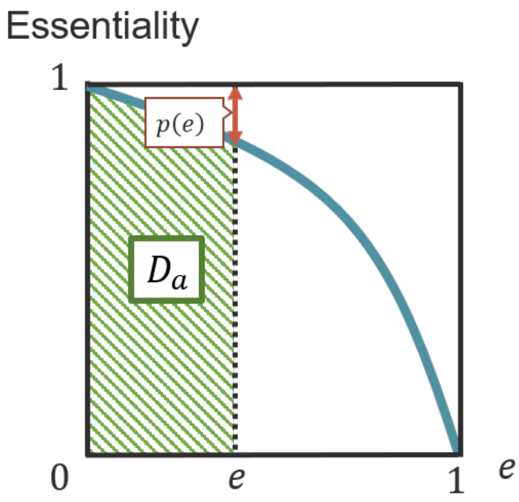

Figure 1: Expected number of SEPs with assessment

that do not pass the assessment. A firm's expected number of SEPs decreases because of the assessment. If the firm sets the declaration rate e, the number of declared patents without assessment is eF. When we take into account the ex-post assessment, the number of expected declared patents D_a is given by

$$D_a = F \times \int_0^e (1 - p(t))dt. \tag{3}$$

The shaded area in Figure 1 is equal to D_a.

Firm 1's profit with assessment is given by

$$\pi_1 = r_L F \times \int_0^e (1 - p(t))dt + r_H F(1 - e) - \alpha F e - \left(A - F \times \int_0^e (1 - p(t))dt \right) c_O. \tag{4}$$

From this equation, we can obtain the following lemma.

Lemma 2. *When there is ex-post assessment by an independent organization, firm 1 sets the optimal declaration rate e_A^* as follows:*

(i) If $r_L + c_O - \alpha > r_H$, firm 1 sets $0 < e_A^* < 1$ that satisfies

$$p\left(e_A^*\right) = \frac{r_L + c_O - \alpha - r_H}{r_L + c_O}.$$

(ii) Otherwise, firm 1 does not declare at all $(e_A^* = 0)$.

Proof. See the Appendix. □

When the declaration cost is sufficiently large, the declaration rate is equal to zero in the same manner as Lemma 1. The ex-post assessment decreases the marginal revenue of declaration since the number of declared patents decreases. We assume that the

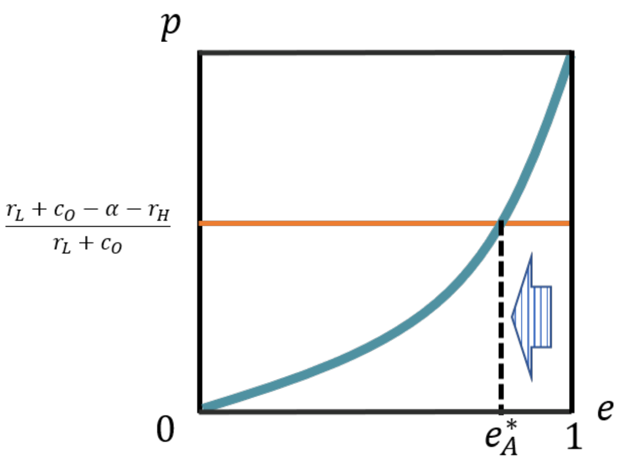

Figure 2: Optimal declaration rate with assessment

declaration cost is a quadratic form. The next proposition compares the declaration rate in the benchmark with that in the ex-post assessment.

Proposition 1. *A firm's declaration rate decreases when there is ex-post assessment by an independent organization.*

Proof. See the Appendix. □

The intuition of this proposition is shown in Figure 2. Because of the ex-post assessment, the expected number of declared SEPs decreases. Then, the firm will decrease its declaration rate since the marginal revenue of declaration decreases. The next corollary shows the comparative statics of the optimal declaration rate with ex-post assessment.

Corollary 1. *If $r_L + c_O - \alpha \geq r_H$, the optimal e_A^* depends on each parameter as follows:*

$$\frac{\partial e_A^*}{\partial r_L} \geq 0, \frac{\partial e_A^*}{\partial c_O} \geq 0, \frac{\partial e_A^*}{\partial \alpha} \leq 0, \frac{\partial e_A^*}{\partial r_H} \leq 0$$

Proof. See the Appendix. □

When the benefit from the declaration (FRAND royalty and FTO) increases, the optimal declaration rate also increases. Figure 2 shows the intuition of this corollary. If the declaration becomes costly or the non-FRAND royalty becomes large, the firm loses its incentive to declare. When the firm increases the declaration rate, it can increase the benefit from the FRAND royalty r_L and securing FTO c_O. On the contrary, it needs to pay the declaration cost and give up the high royalty rate r_H. When $r_L + c_O - \alpha$ is larger than r_H, the benefit of declaration is sufficiently large. Then, the firm has a strong incentive to declare its inessential patents as SEPs. If the declaration cost α is too large or revenue from the FRAND royalty and FTO is small, the firm has no incentive to lie. In the intermediate range, the firm sets e^* to solve this trade-off problem.

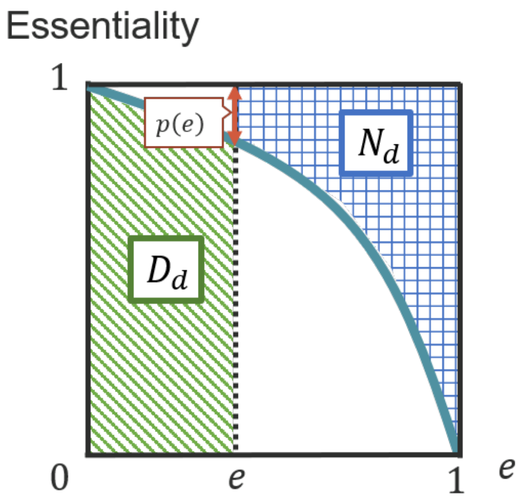

Figure 3: The expected number of patents with dispute

2.3 Ex-post assessment through disputes

The implementer can also decrease the number of declared patents by disputes or challenges in court. The implementer can reduce not only the number of declared patents but also the number of non-declared patents. An inessential patent has a risk of not being able to set a high royalty rate since its intentional failure to declare may be unfair competition because of firm 2's dispute. Thus, we assume that the expected number of patents that can obtain the non-FRAND royalty N_d depends on $p(e)$, namely the probability of the patent being considered to be inessential.

N_d is given by

$$N_d = F \times \int_e^1 p(t)dt$$

and is where in Figure 3.

We can obtain the number of declared patents with assessment through disputes from equation (3). If the dispute fee C_{DI} is sufficiently low, the implementer will decrease the number of both declared and non-declared patents to save the royalty payment. If the implementer resorts to disputes, firm 1's profit is given by

$$\pi_1 = r_L F \times \int_0^e (1-p(t))dt + r_H F \times \int_e^1 p(t)dt. - \alpha F e - \left(A - F \times \int_0^e (1-p(t))dt \right) c_O. \quad (5)$$

From this equation, we can obtain the following lemma.

Lemma 3. *When there is ex-post assessment through disputes, firm 1 sets the optimal declaration rate e_D^* as follows:*

(i) If $r_L + c_O - \alpha > 0$, firm 1 sets $0 < e_D^* < 1$ that satisfies

$$p\left(e_D^*\right) = \frac{r_L + c_O - \alpha}{r_L + c_O + r_H}.$$

(ii) Otherwise, firm 1 does not declare at all $(e_D^* = 0)$.

Proof. See the Appendix. □

This result can be interpreted in the same manner as Lemma 2. The implementer's challenge can defeat declared patents whose essentiality is low and non-declared patents whose essentiality is high. Hence, firm 1 sets the declaration rate by taking into account both eliminations. The next proposition compares the declaration rate in the benchmark case with that in the case of assessment through disputes.

Proposition 2. *When the profit from inessential patents is small, the rights holder's declaration rate decreases in the number of implementer's disputes. Otherwise, disputes increase the declaration rate.*

Proof. See the Appendix. □

The intuition of this proposition is clear. When the royalty rate from inessential patents, r_H, is high, the rights holder has a strong incentive not to declare in the benchmark case. If we take into account the implementer's dispute, the number of non-declared patents decreases. This effect increases the incentive to declare to obtain the profit from declared patents. When r_H is small, the rights holder will set $e = 1$ to enjoy the profit from inessential patents. The dispute decreases the marginal revenue of declaration by eliminating the number of declared patents. Then, the optimal declaration rate becomes smaller than in the benchmark case. The next corollary shows the comparative statics of the optimal declaration rate with disputes.

Corollary 2. *If* $r_L + c_O - \alpha \geq 0$, *the optimal* e_D^* *depends on each parameter as follows:*

$$\frac{\partial e_D^*}{\partial r_L} \geq 0, \frac{\partial e_D^*}{\partial c_O} \geq 0, \frac{\partial e_D^*}{\partial \alpha} \leq 0, \frac{\partial e_D^*}{\partial r_H} \leq 0.$$

Proof. See the Appendix. □

2.4 Comparison

We are now ready to compare disputes with ex-post assessment. The next proposition compares the optimal declaration rate under both schemes.

Proposition 3. *The declaration rate with assessment through disputes is larger than that with assessment by an independent organization.*

Proof. See the Appendix. □

The interpretation of this proposition is straightforward. The reduction in the number of declared patents decreases the marginal revenue of declaration. With the independent organization assessment, the rights holder's profit from inessential patents becomes relatively large since the assessment only decreases the number of declared patents. Therefore, the optimal declaration rate with ex-post assessment decreases considerably. When we consider assessment through disputes, the implementer can decrease both declared and non-declared patents. This reduces the profit from inessential patents. Compared with assessment by independent organizations, the rights holder sets a higher declaration rate since the profit from inessential patents decreases.

3 Extensions

The preceding section compared the two assessment schemes from the viewpoint of the declaration rate. In this section, two extensions of this model are considered: essentiality of patents and welfare analysis.

3.1 Essentiality of patents

In the real world, the essentiality of firms' patents is distributed in various ways. In this subsection, we consider how the distribution of essentiality affects the rights holder's strategy. We analyze two cases, namely when the essentiality of patents is high and when it is low. When essentiality is relatively high, we assume that $p(e)$ satisfies the following conditions:

$$\frac{d^2p\left(e\right)}{de^2} > 0, \lim_{e\to 0}\frac{dp(e)}{de} = 0, \lim_{e\to 1}\frac{dp(e)}{de} = \infty. \tag{6}$$

If equation (6) is satisfied, $p(e)$ is illustrated as in Figure 3. When essentiality is relatively low, $p(e)$ needs to satisfy

$$\frac{d^2p\left(e\right)}{de^2} < 0, \lim_{e\to 0}\frac{dp(e)}{de} = \infty, \lim_{e\to 1}\frac{dp(e)}{de} = 0. \tag{7}$$

If equation (7) is satisfied, $p(e)$ is illustrated as in Figure 4.

From Lemmas 3 and 2, we know that the optimal declaration rate depends on the characteristics of $p(e)$. The next proposition shows how the distribution of essentiality affects the firm's declaration strategy.

Proposition 4. *The optimal declaration rate of a firm whose essentiality is low e_L^* is smaller than those with high essentiality e_H^*.*

Proof. See the Appendix. □

The intuition of this proposition is shown in Figure 5.

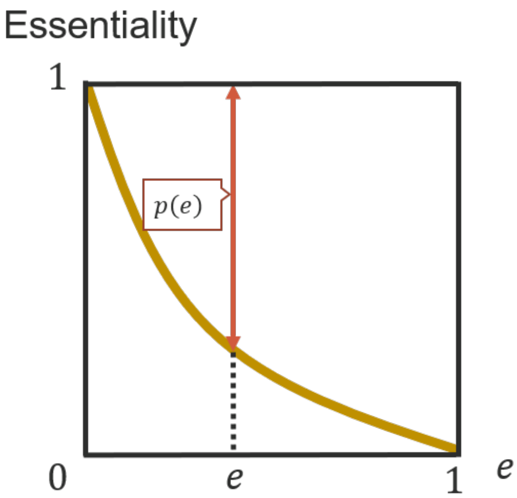

Figure 4: Essentiality of patents is relatively low

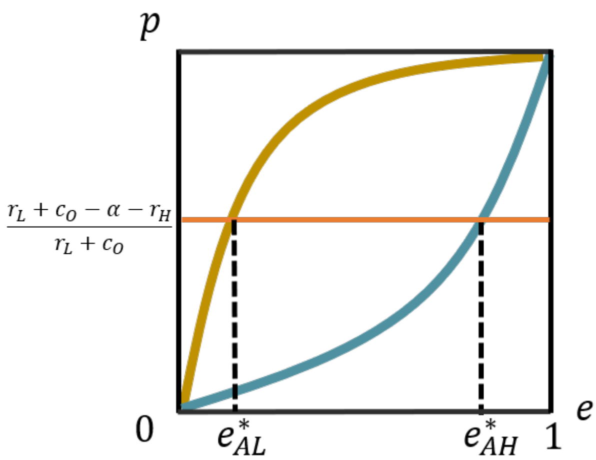

Figure 5: Comparison of the optimal declaration rate

When essentiality is low, the risk of not being able to set a high royalty rate is also low since the firm's patents are less involved in the standard. Then, the rights holder can easily obtain a high royalty by decreasing the declaration rate.

3.2 Welfare analysis

The existing literature does not pay attention to the welfare implications of the over-declaration of SEPs. In this subsection, we consider how the over-declaration of SEPs affects social welfare. To calculate social welfare, we shed light on the standard implementer's profit. For simplification, only one standard implementer, firm 2, can make standard products by using firm 1's patents and sell them to consumers[1]. The timing of the game is summarized as follows. First, the rights holder (firm 1) decides the degree of the over-declaration of SEPs. After that, firm 2 chooses the quantity of standard products. Firm 2's profit function is as follows:

$$\pi_2 = q \times (p - Dr_L - Nr_H) - \gamma D,$$

where q is the quantity of standard products. We assume that firm 2 needs to pay a license fee $Dr_L + Nr_H$ per product to the rights holder. The last term means that firm 2's transaction cost is an increasing function of the number of declared patents D[2]. We assume that the marginal cost of standard products is equal to zero. The inverse demand function is $p = T - q$. Firm 2 tries to maximize its profit by controlling the quantity of products. From the first-order condition, firm 2's optimal quantity q^* is given by

$$q^* = \frac{T - Nr_H - Dr_L}{2}.$$

To focus on social welfare, we must redefine the rights holder's profit function as follows:

$$\pi_1 = q \times (Dr_L + Nr_H) - \alpha D - (A - D)c_O.$$

The first term is the benefit from the royalty, the second term is the cost of over-declaration, and the last term is the operation cost. If we consider the case that no ex-post assessment exists, the number of declared patents D is eF. Firm 1 tries to maximize the following equation by controlling the declaration rate e:

[1]The results remain essentially unchanged if there are a number of producers of standard products in the market and they are engaged in price competition.

[2]Blind et al. [2011] quote from two interviewees. "For anyone wishing to adopt a standard, it is a daunting task to analyze all the claims and come up with an opinion which patents are truly essential" and "There is a very large amount of uncertainty; nobody really knows what is actually essential or not. . . ."It is thus clear that a rise in the number of declared patents increases the transaction cost of standard implementers.

$$\pi_1(e) = \left(\frac{T-(1-e)Fr_H - eFr_L}{2}\right) \times ((1-e)Fr_H + eFr_L) - \alpha eF - (A-eF)c_O.$$

From the first-order condition of this equation, we can obtain firm 1's optimal declaration rate e^* as follows:

$$e^* = 1 - \frac{(r_H - r_L)(T - 2r_LF) - 2(c_O - \alpha)}{2F(r_H - r_L)^2}. \tag{8}$$

If firm 1 declares its inessential patents as SEPs, it has to give up the high royalty rate r_H. On the contrary, it can increase the quantity of standard products q^* by decreasing its royalty. In addition, firm 1 can obtain the benefit of FTO. To satisfy $0 < e^* < 1$, the following condition is satisfied:

$$\frac{(r_H - r_L)(T - 2r_LF)}{2} - 2F(r_H - r_L)^2 < c_O - \alpha < \frac{(r_H - r_L)(T - 2r_LF)}{2}.$$

We are now ready to consider the socially optimal declaration rate. The social planner desires to maximize social welfare, which is the sum of $\pi_1 + \pi_2$ and consumer surplus CS. To maximize social welfare, we can obtain the socially optimal declaration rate e^{**} as follows:

$$e^{**} = 1 - \frac{4\gamma - 4(c_O - \alpha) - (r_H - r_L)(T + r_LF)}{F(r_H - r_L)^2}. \tag{9}$$

From equations (8) and (9), we can obtain the following proposition.

Proposition 5. *The social over-declaration of SEPs occurs when γ is larger than $(3T(r_H - r_L) + 6(c_O - \alpha))/8$. Otherwise, the social under-declaration of SEPs occurs.*

Proof. See the Appendix. □

The intuition of this proposition is clear. From the view of society, the declaration of SEPs has two welfare-enhancing effects. First, the declaration of SEPs decreases the total royalty payment of the standard implementer since the royalty rate of declared patents needs to be reasonable. Therefore, the over-declaration of SEPs decreases the price of standard products and increases the consumer surplus. Second, firm 1 can save the operation cost by increasing the number of declared SEPs. The declaration of SEPs also has two welfare-reducing effects. If the number of declared SEPs increases, the standard implementer needs to pay the transaction cost γD. Firm 1 needs to pay the declaration cost αD to disguise inessential patents as SEPs. Firm 1 does not internalize the standard implementer's transaction cost. Then, if γ is sufficiently large, the declaration rate set by firm 1 becomes larger than that set by the government. In this case, the mitigation of the problem of the over-declaration of SEPs by using ex-post assessment is socially beneficial. This proposition also indicates when social over-declaration tends to happen. We can obtain the following corollary.

Corollary 3. *Social over-declaration tends to happen when*

1. The downstream market is small (T is small).

2. The difference between the FRAND royalty and non-FRAND royalty is small ($r_H - r_L$ is small).

3. The declaration cost is large (α is large).

The intuition of this corollary is clear. If the downstream market is small or the royalty difference is small, firm 1 cannot obtain sufficient revenue from non-declared patents. Then, it has an incentive to declare SEPs to enjoy the benefit from FTO. When the declaration cost is large, the social planner's incentive to over-declare decreases. In addition, the social planner must take into account the standard implementer's transaction cost. Then, the socially optimal declaration rate tends to be smaller than the private optimal rate. These results show the conditions under which ex-post assessment that decreases the declaration rate becomes socially desirable. As we noted before, Regibeau et al. [2016] suggest a random assessment of the essentiality of declared patents to mitigate over-declaration. However, when the downstream market is large and the rights holder can set a higher royalty rate for its inessential patents, ex-post assessment may harm social welfare.

4 Conclusion

We discussed how ex-post assessment affects the rights holder's declaration incentive. We considered two types of ex-post assessment: one that does not affect non-declared patents (independent organization) and one that does (through disputes). We discussed the over-declaration of SEPs in a model wherein (1) the rights holder controls the declaration rate to maximize its expected profit by incurring certain costs and (2) the rights holder can enjoy a FRAND royalty and FTO from the declared patents and a high royalty from non-declared patents. We obtained the following results. First, the level of declaration is lower under ex-post assessment, which eliminates those patents whose essentiality is low. Consequently, ex-post assessment decreases the marginal benefit of declaration. Second, the level of declaration with ex-post assessment by an independent organization is smaller than that with assessment through disputes by an implementer. Assessment through disputes decreases the total number of patents. Then, the rights holder will place greater weight on non-declared patents with assessment by an independent organization compared with assessment through disputes. We also showed that a rights holder with high essentiality patents sets a higher declaration rate than one with low essentiality patents. Our analysis thus suggests that changes should be made to the direction of modern standardization policy.

We close with thoughts on future extensions of this model. First, we need to consider the welfare analysis carefully. In this model, we focused on how to mitigate the over-declaration of SEPs. However, it is not clear which assessments are socially desirable, by disputes or by an independent organization. Second, in our setting, the number of patents, F, is exogenously given. The R&D incentive is, of course, affected by ex-post assessment. A framework within which firms make R&D decisions is therefore necessary to analyze how assessment policy affects the R&D incentive.

5 Proof

Proof of Lemma 1

We can easily show that the declaration rate affects the rights holder's profit from equation (2) as follows:

$$\frac{\partial \pi_1}{\partial e} = F(r_L + c_O - \alpha - r_H). \tag{10}$$

When the profit from inessential patents is large $(r_L + c_O - \alpha < r_H)$, the rights holder does not declare at all. Otherwise, it chooses full declaration $(e = 1)$.

Proof of Lemma 2

Firm chooses the declaration rate e to maximize its profit. We can obtain the first-order condition from equation (4) as follows:

$$\frac{\partial \pi_1}{\partial e} = F(r_L + c_O - \alpha - r_H) - Fp\,(e)\,(r_L + c_O) = 0. \tag{11}$$

We can easily show that the second-order condition is satisfied as Follows:

$$\frac{\partial^2 \pi_1}{\partial e^2} = -Fp'\,(e)\,(r_L + c_O) \leq 0.$$

From equation (11), the optimal declaration rate e_A^* needs to satisfy

$$p(e_A^*) = \frac{r_L + c_O - \alpha - r_H}{r_L + c_O}. \tag{12}$$

Proof of Proposition 1

From (12), it is clear that $p(e_A^*)$ is smaller than 1 when $r_L + c_O - \alpha + r_H$ is positive.

Proof of Corollary 1

We assume that $p(e)$ is an increasing function of e. If the right-hand side of (12) increases, the declaration rate also increases. From (12), we can obtain the following results:

$$\frac{\partial p(e_A^*)}{\partial r_L} \geq 0, \frac{\partial p(e_A^*)}{\partial c_O} \geq 0, \frac{\partial p(e_A^*)}{\partial \alpha} \leq 0, \frac{\partial p(e_A^*)}{\partial r_H} \leq 0.$$

Proof of Lemma 3

The firm chooses the declaration rate e to maximize its profit. We can obtain the first-order condition from equation (5) as follows:

$$\frac{\partial \pi_1}{\partial e} = F(r_L + c_O - \alpha) - Fp\,(e)\,(r_L + c_O + r_H) = 0. \tag{13}$$

We can easily show that the second-order condition is satisfied as Follows:

$$\frac{\partial^2 \pi_1}{\partial e^2} = -Fp'\,(e)\,(r_L + c_O + r_H) \leq 0.$$

From equation (13), the optimal declaration rate e_D^* needs to satisfy

$$p(e_D^*) = \frac{r_L + c_O - \alpha}{r_L + c_O + r_H}. \tag{14}$$

Proof of Proposition 2

From (14), it is clear that $p(e_D^*)$ is smaller than 1 when $r_L + c_O - \alpha$ is positive. When $0 < r_L + c_O - \alpha < r_H$, we find that $e_D^* > e^* = 0$.

Proof of Corollary 2

We assume that $p(e)$ is an increasing function of e. If the right-hand side of (14) increases, the declaration rate also increases. From (14), we can obtain the following results:

$$\frac{\partial p(e_D^*)}{\partial r_L} \geq 0, \frac{\partial p(e_D^*)}{\partial c_O} \geq 0, \frac{\partial p(e_D^*)}{\partial \alpha} \leq 0, \frac{\partial p(e_D^*)}{\partial r_H} \leq 0.$$

Proof of Proposition 3

From (12) and (14), it is clear that $e_D^* > e_A^*$ when $r_L + c_O - \alpha > r_H$. When $0 < r_L + c_O - \alpha < r_H$, we find that $e_D^* > e_A^* = 0$.

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