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PATENT PLEDGES: WHY DO CORPORATIONS MAKE PATENTS AVAILABLE TO THE PUBLIC?

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Introduction

In June 2014, the CEO of Tesla, Elon Musk, announced on the company's website that "All Our Patent Are Belong To You."[1] In this blogpost, he declared that "Tesla will not initiate patent lawsuits against anyone who, in good faith, wants to use our technology." In response, in January 2015, Toyota Motors opened its patent license for its fuel cell vehicles, making it free of charge.[2] Such a pledge regarding the non-exercise of patent rights is called a "patent pledge" and has attracted considerable academic attention. In recent years, many companies have pledged patents to resolve Covid-19. In October 2020, Moderna, known for its mRNA vaccine, pledged patents related to novel coronaviruses while the pandemic continued.[3] The IBM has participated as a founding adopter of the Open Covid Pledge, which encourages organizations to commit toward making their intellectual property available for free to end the pandemic.[4] Patent pledges have been widely used in the field of technical standards and open-source software. In 2004, Novell pledged that it would not enforce its patents against the Linux OS. In 2005, IBM and Google declared that they would not enforce approximately 500 and 241 of their patents against OSS technologies, respectively.[5]

Patent pledges have attracted attention because, at first glance, by pledging patents, right holders seem to be choosing to give up their interests. Generally, firms spend a considerable amount of time and resources on R&D to obtain patents. As patent holders can recover their R&D costs by utilizing their exclusive monopoly rights, opening up patent rights appears to be a counterintuitive way of recouping R&D costs. The starting point of this study is the

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[1] All Our Patent Are Be long To You | Tesla
[2] Toyota Opens Its Fuel Cell Vehicle Patents for Free Use | Toyota Motor Corporation Official Global Website
[3] Statement by Moderna on Intellectual Property Matters during the COVID-19 Pandemic (modernatx.com)
[4] IBM Offering Free Access to Patent Portfolio to Combat COVID-19
[5] IPR Pledge Database – Program on Information Justice and Intellectual Property (pijip.org)

comprehensive research conducted by Contreras (2015). Contreras (2015) summarized the major industries in which patent pledges were adopted and discussed their motivations. However, his study did not fully discuss the impact of patent pledges on the market, which is of paramount importance for economics. Therefore, to fill this gap, this study focuses on the case of Tesla, which is frequently referenced in discussions on patent pledges. It examines the incentives that motivated Tesla to pledge patents and the resulting market effects.

The remainder of this paper is organized as follows. Section 2 surveys related studies on patent pledges. Section 3 develops the first model based on a discussion of strategic delegation, used in industrial organization theory. Section 4 takes a divergent approach from Section 3 to analyze Tesla's patent pledge incentives. It incorporates carbon credits that bolster Tesla's profit margins, and establishes an endogenous entry model. Finally, Section 5 concludes the paper. All the proofs are provided in the Appendix.

Related Literature

Contreras (2015)

Contreras (2015) was the first comprehensive study of patent pledges. Nevertheless, he did not provide a clear definition of patent pledges in his article, as the legal literature itself has subtle differences in its definitions. Ehrnsperger and Tietze (2019) have provided the following definition of patent pledges based on the legal literature:

> A patent pledge is a publicly announced intervention by patent owning entities (‘pledgers’) to out-license active patents to the restricted or unrestricted public free from or bound to certain conditions for a reasonable or no monetary compensation using standardized written or social contracts.

From the above definition, a patent pledge is a public announcement made by the patentee about a valid patent that may or may not have (1) limited users, (2) limited content of use, or (3) reasonable monetary considerations. Tesla's patent pledge can be interpreted as follows: (1) it does not limit users; (2) it has no restrictions on the content of use; and (3) it does not require monetary compensation. In contrast, although Toyota’s 2015 patent pledge did not require monetary compensation, it (1) restricted users to fuel cell-related companies and (2) had a fixed term of use.

Contreras compiled a database of patent pledges and identified four industries in which patent pledges were prevalent: (1) information and communication technology (ICT), (2) open-source software, (3) green/clean technology, and (4) life sciences.

In the ICT industry, it is necessary to maintain interconnections among many information devices. Technical standards play an important role in unifying the interfaces between terminals. Owing to the increasing complexity of technology, standard participants are sometimes required to patent their technology to manufacture their products. Patents associated with technology that must necessarily be used to produce goods in accordance with technical standards are called standard essential patents (SEP). SEPs are powerful patents, and rights holders have a strong incentive to set high license fees when licensing them. As setting high license fees hinders the diffusion of standard technology, the standard-setting organization requires SEP holders to set license fees in accordance with “Fair, Reasonable, And Non-Discriminatory” (FRAND) conditions or to make them royalty free (RF). FRAND conditions are treated as a patent pledge because they restrict pledgers from exercising their patent rights.

Open-source software is a typical example of a patent pledge in the software industry. The Open-Source Initiative has defined open-source software,[6] which requires developers to make the source code publicly available, allow redistribution, and not discriminate while licensing. Linux, the Android OS, and Firefox are common examples of open-source software packages. Open-source software is also an example of a patent pledge because to label their software as open source, software patent holders must publicly announce that they will not enforce their rights. In 2004, Nokia, Novell, and Sun Microsystems declared that they would not enforce their patents against Linux OS. In 2005, IBM and Google declared that they would not enforce approximately 500 and 241 of their patents against OSS, respectively.

The third category of patent pledges are observed in the environmental-technologies industry. As mentioned in Introduction, Tesla's pledge for electric vehicles falls under this category. The Eco-Patent Commons, established in 2008, is the most prominent patent pledge in the field of environmental technology. Companies participating in the Eco-Patent Commons pledge that they would not enforce certain patents against technologies that help solve environmental problems.

The fourth category of patent pledges is observed in the field of life sciences. In recent years, several companies have pledged to not enforce patents and other intellectual property rights to address Covid-19. For example, in October 2020, Moderna, best known for its mRNA vaccine, pledged to not enforce patents related to its Covid-19 vaccine during the pandemic. Another example of a pledge related to Covid-19 is the Open Covid Pledge, established in August 2020. Thirty companies participated in this pledge, including Amazon, AT&T, Facebook, Fujitsu, HP, IBM, Intel, Microsoft, and NASA.

[6] The Open-Source Definition (Annotated) – Open-Source Initiative

Companies require considerable time and money to obtain patent rights. Why patent holders allow other companies to use their technology without paying for the patent license is an important question. According to Contreras (2015), patent-rights holders have four motivations for making a patent pledge: (1) inducement, (2) collective action, (3) voluntary restraint, and (4) philanthropy.

Contreras (2015) elucidated that several patent pledges are aimed at inducing market participants to undertake specific actions. For instance, licensing SEPs with FRAND conditions motivates other organizations to adopt the standard by keeping the licensing fees reasonable. In the realm of Open-Source Software, the disclosure of source code encourages users to utilize and even modify the software to make further improvements. In the environmental technology and life sciences domains, licenses stimulate research and development efforts aimed at addressing pressing societal issues.

Moreover, patent pledges are taken to address complex problems, when each market participant recognizes the mutual benefit of taking a collective action yet is disinclined to incur the cost of executing it individually. For example, every company understands the social desirability of reducing environmental pollution to a certain extent; however, doing so requires expensive improvements in production technology and emission reduction facilities. In such cases, pledges such as Eco-Patent Commons incentivize companies to mitigate this problem collectively. Free access to various environmental improvement technologies will enable companies and individuals to develop production technologies with a lower environmental impact and provide cost-effective solutions to reduce emissions. Additionally, it fosters the creation of new technologies.

Patent pledges are also utilized in the context of competition law. For instance, in the field of technical standards, SEP agreements made on FRAND terms are meant to assure competition authorities that the patent holder does not intend to exclude potential entrants.

The last perspective on patent pledges regards them as an act of corporate philanthropy. However, providing examples of pledges created solely for philanthropic purposes is challenging. Nevertheless, the Open Covid Pledge and the Eco-Patent Commons may serve as instances of such pledges. As economics is premised on market actors' profit-maximizing behavior, it is difficult to consider patent pledges as entirely charitable.

Contreras (2015) identified inducement and collective action as significant motivations behind patent holders' decision to make patent pledges. From an economic standpoint, the presence of this "inducement" raises concerns. Economics asserts that incentives drive the behavior of economic actors, such as firms and individuals. The inducement motivation implies that by making a patent pledge, the right holder is incentivizing other companies to take a specific action. This assertion is almost axiomatic in economics if the patent holder derives no direct benefits from making a patent pledge.

However, discussing the incentives to make patent pledges comprehensively is challenging, as the range of industries is extensive, and the circumstances in which individual firms differ. This study focuses on the case of Tesla, which is often cited as a prime example in discussions of patent pledges, and examines the incentive structure that led Tesla to make its pledge.

Related Literature in Economics

This section discusses how patent rights are dealt with in the economic domain, before introducing the study's analytical model. Economics assumes that a patent holder can become a market monopolist as patent rights provide them with exclusive rights to use and profit from their patented product. In the absence of patent rights, market participants would behave competitively. In this case, a perfectly competitive market is achieved and social welfare–defined as the sum of the market participants' surpluses–is maximized. However, in a competitive market, suppliers do not have an incentive to develop new technology because the competition is too severe to recover their development costs. Although patent rights cause social welfare losses, they also provide developers with sufficient profits to cover development costs and encourage innovation. When considering patent pledges from an economic perspective, the question arises as to what benefits patent holders gain by giving up a large monopoly profit. In the following section, we discuss the benefits of giving up monopoly profits as captured by economics, while referring to existing studies.

Network Externality, Technology Standard and Open-Source Software

As mentioned above, patent pledges in the ICT industry involve a license agreement pertaining to standardization under FRAND conditions. Network externalities (Katz and Shapiro, 1985) are considered an economic incentive for firms to exercise patent rights at low or no cost. Network externality is the property whereby the greater the number of users of a product or service, the more favorable the outcome for users of the standard. Taking the USB standard as an example, if enough people use the USB, it will be easy for individuals to borrow a cable from a friend when their smartphone runs out of charge. Alternatively, they can also use the USB cables they have bought earlier. Moreover, many products are likely to be developed if there are many users.

Thus, the more widely the USB standard is established, the higher the utility this standard provides. By reducing the royalty for patents held by a company through the FRAND commitment, a company can (1) reduce the price of a product and encourage consumers to buy it, thereby achieving the network externality effect, and (2) lower the of participation for other companies to adopt the standard.

Lerner and Tirole (2015) provide a comprehensive model that includes the effects of FRAND conditions and the decision of right holders regarding the standards in which they should participate. If a participant's patents become SEPs, they have an incentive to charge high royalties after the standard is established. Lerner and Tirole (2015) consider the FRAND condition a loose commitment that would make it impossible to significantly change the royalty after the standard is set. They suggest that this improves market efficiency, and that the FRAND condition may not be adopted naturally under market competition.

Few studies have focused on SEPs. Firms' decision to participate in a standardization process by declaring their essential patents are motivated by three considerations. (1) Declaring a substantial number of essential patents can help firms enhance their role in the standardization process and ensure that they receive a greater share of the standard's benefits (Dewatripont and Legros, 2013). (2) Firms can establish their authority in the standardization, which would ensure that the standard is customized to suit the firm's technology (Lerner and Tirole, 2015). (3) By participating in the standardization process, firms can acquire the necessary information to convert their low-value patents to essential patents (Kang and Bekkers, 2015).

Lerner and Tirole (2003, 2005) pioneered economic analysis of open-source software. After examining individual programmers openly release the source code of their software, they concluded that it is a way for programmers to demonstrate their programming skills to others (e.g., potential employers, investors) and obtain their next job. Johnson (2002) discussed the benefits of programmers sharing their knowledge under OSS, and the programmer free-riding problem that arises simultaneously. Network externalities also exist in the software industry, and research has focused on the competition between OSS developers and commercial distributors. Mustonen (2005) found that in the presence of network externalities, open-source compatibility leads to a network effect for all firms, which in turn reduces the competitive effect.

August, Shin, and Tunca (2013) mentioned the effect of open-source code on collaboration with other firms in software development. They found that if a software company typically profits from the sale of software and related services, even if it loses some revenue from releasing its source code, this loss will not be substantial. This is because, releasing source codes fosters collaboration among software developers and induces a quality improvement effect, which eventually increases the number of consumers in the service sector. However, when OSS developers and commercial distributors compete, commercial distributors are forced to set lower prices to compete with OSS developers that will have lower prices in the future. Zhu and Zhou (2012) showed that such low prices are undesirable for commercial sales firms because they will provide consumers with an even lower consumer value.

Strategic Information Disclosure

Several studies have analyzed the economics of firms disclosing their technical information, such as by foregoing patent rights. For example, according to Milliou (2009), assuming that there is spillover knowledge between firms, if the spillover effect is large, it is preferable for firms to disclose information to each other to improve quality. De Fraja (1993) also explained the rationality of disclosing information to end the patent development competition early on if the firm can secure some profit, even if other firms succeed in developing their technology, as it would help the firm save R&D costs. Anton and Yao (2003) focused on the effect of information disclosure in the intermediate stages of research, which can signal other firms to disclose information about their own marginal costs. Similarly, they analyzed how a partner firm's entry and its success would be respectively affected by a firm's mid-stage information and knowledge disclosure (Gill, 2008), which would increase the degree of innovation required to obtain patent rights (Baker and Mezzetti, 2005; Ponce, 2011).

The analysis of patent pledges from an economic perspective presents two noteworthy considerations. First, the industrial sectors referenced in Contreras's (2015) work is excessively broad. The state of the market strongly influences the effectiveness of patent non-enforcement. For instance, the pharmaceutical industry, in which a single patent can produce a valuable good, presents a different scenario than the ICT industry, in which numerous patents and technical standards are required to produce a good. Similarly, a pledge would be perceived differently by software-only companies compared with those that generate revenue from both selling the software and providing software-support services. Hence, an effective examination of patent pledges requires an in-depth analysis of specific industries and markets. Second, Contreras's (2015) treatment of "philanthropic" motivation must be approached from an economic perspective. Existing studies have demonstrated that rights holders' decision regarding forgoing or exercising their patent rights is determined by a cost-benefit analysis, and therefore, are not truly motivated by philanthropy. Specifically, the monopoly profits that a company can generate by exercising their patent rights are substantial. Thus, from an economic perspective, companies must determine whether these the benefits that arise from foregoing these profits are sufficient.

Therefore, taking an economic perspective, we focus on the electric-vehicles industry and analyze the motivation behind Tesla's patent pledge, which is often viewed as a philanthropic act. To this end, this study delves into several scenarios to determine the underlying incentives that may have motivated Tesla's disclosure of its patents. When considering Tesla's patent pledge, the first thing to consider is the network externalities. By opening their patents, other suppliers can easily build charging platforms. With more charging platforms, the utilities for electric-vehicle users will increase because of network externalities, which will have a positive impact on Tesla's electric-vehicle sales. As there the benefits of network externalities is already established in the literature, this study focuses on other factors.

Strategic Delegation (Model 1)

Elon Musk, Tesla's CEO, has been interviewed about his patent pledges on various media platforms. In these interviews, he emphasized that he made the patent pledges solely to promote the spread of electric vehicles. At the Air Warfare Symposium in 2020, he stated:

> Yeah, actually, at Tesla, we just open-sourced our patents some years ago. So, anyone can use our patents. So, we have not even tried to protect intellectual property in that sense. We've tried to smooth the path because the overarching goal of Tesla is to accelerate the advent of sustainable energy. And so, if we created a patent portfolio that discouraged other companies from making electric cars, that would be inconsistent with our mission. So, we open-sourced all the patents.

However, we show how the company earns profits by strategically delegating output decisions to managers whose goal is to increase social welfare.

In the quantity competition model, which is widely used in economics, market prices depend on the total quantity produced in the market, and each company reasonably presumes the quantity produced by other companies. To determine the quantity that would yield the maximum profit, each firm first calculates its residual demand by subtracting the other firm's forecast total output from its demand. A firm can increase its profits by credibly committing to other firms that it would produce larger quantities so that other firms reduce their production quantities. In the field of industrial organization theory, firms have been shown to increase output by strategically delegating decision-making tasks to managers and publishing their wages as a commitment device (Fershtman and Judd, 1987; Sklivas, 1987; Vickers, 1985). Elon Musk's patent pledge can be viewed as a credible commitment to promote the widespread use of electric vehicles rather than earning corporate profit. This section analyzes Tesla's profit when the patent pledge acts as a commitment device, based on the strategic-delegation model.

Set-Up

In this model, there is no effect of open patent rights per se. We consider a duopoly market. The demand function is given by $p(Q) = a - bQ$ where $Q = q_1 + q_2$. For simplicity, we assume that all firms have the same marginal cost, c for simplicity. We also assume that a>c. Firm i^\primes profit function and social welfare function are expressed as

$$\pi_i(q_1, q_2) = (a - b(q_1 + q_2) - c)q_i$$

$$SW(q_1, q_2) = PS + CS + positive\ externality$$

$$= (a - b(q_1 + q_2) - c)(q_1 + q_2) + \frac{(q_1 + q_2)^2}{2} + \gamma(q_1 + q_2)$$

<See Figure 1>

Each firm produces environmentally friendly electric vehicles, and each electric vehicle has a positive externality. $\gamma(\gamma \geq 0)$ means the degree of positive externality. The owner of Firm 1 can delegate its output decision to the CEO[7]. If firm 1's owner sets the CEO salary (w) as

$$w = A + B[\alpha\pi_1 + (1 - \alpha)SW\ ]$$

A means the fix fee and B is the bonus rate. To increase his profits, the manager sets the quantity $q_1$to maximize $\alpha\pi_1 + (1 - \alpha)SW$. The model operates in the following stages:

Stage 1 : The owner of Firm 1 decides whether to delegate output decision to the manager. If firm 1 delegates manager, the owner decides α to maximize[8] π_1.

Stage 2 : Firm i decides quantity q_i simultaneously.

From the first-order condition, we obtain the best response functions as follows.

$$q_1 = \frac{a - c - q_2 + (1 - \alpha)\gamma}{1 + \alpha}$$

$$q_2 = \frac{a - c - q_1}{2}$$

Firm 1's best response function becomes that of the well-known Cournot competition when $\alpha = 1$. In equilibrium quantity is given by

---

[7] We adopt the basic setting of strategic delegation models, as described by Fershtman and Judd (1987), wherein the owner utilizes the wage profile of their manager to make other firms believe that the manager will set a quantity level greater than the firm's profit-maximizing level. In 2014, when Tesla made its patents public, Elon Musk received little or no executive compensation from Tesla. However, releasing the patent rights for free is tantamount to giving up the profit that the company would have earned and could signal that Elon Musk is trying to contribute toward solving environmental problems. In this case, the results obtained in our study conform with the expected results of the present model.

[8] The owner tries to maximize $\pi - w$ subject to the manager's participation constraint $w - R \geq 0$ where R is the reservation value of manager. In equilibrium, A and B will be adjusted so that this participation will bind. If we also assume that $R = 0$, the owner's objective function becomes $\pi - w = \pi - R = \pi$.

$$q_1(\alpha) = \frac{a - c + 2\gamma(1-\alpha)}{1 + 2\alpha}, q_2(\alpha) = \frac{\alpha(a-c) - \gamma(1-\alpha)}{1 + 2\alpha}.$$

Firm 1's quantity is a decreasing function of α, while the Firm 2's quantity is an increasing function of α. When α is small, the manager will be more focused on social welfare. We also assume that a positive externality exists in the production of electric vehicles. Then, Firm 1's manager has a strong incentive to increase quantity when α is small.

To consider the impact of the decision made by Firm 1's owner, we must obtain π_i. The equilibrium profit is given by

$$\pi_1(\alpha) = \frac{\left(a - c + 2\gamma(1-\alpha)\right)\left(\alpha(a-c) - \gamma(1-\alpha)\right)}{(1+2\alpha)^2}.$$

The owner sets α to maximize π_1. From the first-order condition, we can obtain the optimal α as

$$\alpha^* = \frac{a - c + 4\gamma}{2(a - c + 2\gamma)} < 1$$

We are now ready to obtain equilibrium outputs, prices, and profits. The next section summarizes the results.

Proposition 1 : Equilibrium outcomes are as follow.

$$q_1^* = \frac{a-c}{2}, q_2^* = \frac{a-c}{4}, \pi_1^* = \frac{(a-c)^2}{8}, \pi_2^* = \frac{(a-c)^2}{16}.$$

Firm 1's quantity is equal to that under Stackelberg competition. Firm 1's owner has an incentive to hire a manager because the profit from strategic delegation is larger than that from Cournot competition. This result is well-established in the strategic-delegation literature. The owner of Firm 1 can set the Stackelberg quantity by hiring a manager who can relatively maximize social welfare.

In various interviews, Musk stated that his goal was to promote sustainable energy. However, his statements alone do not constitute a credible commitment. As mentioned above, Tesla's patent pledge has no restrictions on users, nor does it specify any time limits, or require fees. Not exercising one's patent rights is tantamount to making the company fully competitive, which allows Musk to commit production volumes that maximize social welfare. The model in this section suggests that patent pledges act as a commitment device that may allow Tesla to increase its quantity and profit.

The next section considers economic incentives for Tesla's patent pledge using a different approach.

Carbon Credit (Model 2)

Most studies on patent pledges have focused on Tesla. However, until recently, much of Tesla's profits were not from the sale of electric vehicles, but from carbon credits set up by the government. table summarizes the financial information reported by Tesla.

<See Table 1>

Tesla has recently achieved profitability; however, notably, carbon credits have significantly improved its profit margins. These credits have already been factored into net income; without them, the deficit would have been much greater. However, what exactly are carbon credits and how do they support Tesla?

In 1998, the European Automobile Manufacturers' Association committed to reduce CO2 emissions to 140 g/km or less for new cars by 2008. In 2009, the EU established a target of 130 g/km by 2013 under Regulation (EC) 443/2009. If a vehicle exceeded this target by more than 3 g/km between 2012 and 2018, it would incur a penalty of approximately $(excess -$

3) × €95 per vehicle. Additionally, companies that produce vehicles emitting less than the emission standard are granted credits, which they can then sell to companies that exceed the emission standard.

<See Figure 2>

This chapter discusses Tesla's strategy regarding carbon credits. In what follows, we show that when carbon credits are considered, (1) Tesla has no incentive to drive gasoline cars out of the market altogether, and (2) reducing the CO2 emissions of gasoline cars through the patent pledge can improve its own profit margins.

Set-Up

We apply the framework of Etro (2006) that endogenized followers' decision of market entry. There are n firms in the market; one is the incumbent (firm L) that makes electric vehicles, and $n-1$ represents potential entrants (firm i) that make hybrid (or gas) cars. For simplicity, we assumed that electric vehicles do not emit CO_2, whereas hybrid cars do. The sequence of this game is as follows:

Stage 1 : Firm L decides whether to pledge their patent. If they pledge, they can decrease the amount of CO_2 emitted by Firm i.

Stage 2 : Firm L decides its production quantity q_L.

Stage 3 : Firm i decides whether to enter market. If they decide to enter, they also decide on their production quantity q_i.

This study assumes a homogeneous goods market. This implies that the value to the consumer is the same for electric vehicles and hybrid cars[9]. The market price is given by

[9] This is a strong assumption but even if we were to relax this assumption, the basic result would still be the same.

$$P = a - q_L - Q.$$

where a is the market size parameter. Q represents the sum of the potential entrants. Formally, $Q \equiv \sum_{i=1}^{n-1} q_i$. The profit functions of the companies are as follows:

$$\pi_L = (a - q_L - Q - c)q_L + r \times \min\{q_L A, QB\} \tag{1}$$

$$\pi_i = (a - q_L - Q - c)q_i - rBq_i - F \tag{2}$$

c is the marginal cost of products, which we assume is the same for each company. r is the carbon-credit price. A is the number of carbon credits per vehicle obtained from the electric vehicles produced by Firm L. B is the amount of CO_2 emissions from hybrid vehicles produced by potential entrants that exceed the standard value. F is the fixed entry cost for Firm i. Equation (1) shows Firm L's profit function. The first term represents the profit from electronic vehicles. The second term is the profit from carbon credit. When $q_L A > QB$, the total credit earned by Firm L exceeds the standard CO_2 emissions in the market. As only QB amount can be sold, the total amount of credits sold by Firm L is equal to $r \times QB$ when $q_L\, A > QB$. Equation (2) shows the potential entrants' profit function, which is the sum of the profit from goods, expenditure on carbon credit, and entry costs.

<See Figure 3>

This model can be solved through backward induction. First, we consider Firm i's quantity setting. We obtain the $n - 1$ first-order conditions as follows:

$$a - q_L - c - \sum_{k \neq 1}^{n-1} q_k - rB = 2q_1$$

$$\vdots$$

$$a - q_L - c - \sum_{k=1}^{n-2} q_k - rB = 2q_{n-1}$$

We calculate the equilibrium total output of the potential entrant using the classical n-firm Cournot model. The following equation is obtained by adding up all of the $n-1$ first-order conditions.

$$(n-1)(a-c-q_L-rB)-(n-2)Q=2Q$$

From this equation, we obtain the total amount of products produced by potential entrants.

$$Q=\frac{(n-1)(a-c-q_L-rB)}{n} \tag{3}$$

As we assume that the firms' production quantities are symmetrical, Firm i's quantity is given as

$$q_i=\frac{(a-c-q_L-rB)}{n} \tag{4}$$

The profits of potential entrants can be obtained by substituting (4) into (2).

$$\pi_i=(a-q_L-Q-c)x_i-rBq_i-F$$

$$=\left(\frac{a-c-q_L-rB}{n}\right)^2-F$$

Under the free-entry assumption, potential entrant i enters the market until their profit equals zero. The number of entrants to the market is

$$n=\frac{a-c-q_L-rB}{\sqrt{F}}. \tag{5}$$

Clearly, the number of entrants is a decreasing function of $F, q_L,$ and rB. From this equation, we obtain Firm i's equilibrium quantity.

$$q_i=\sqrt{F}$$

We are now ready to analyze the second stage. We consider Firm L's optimization problem based on the relationship between q_LA and QB.

（1） $q_L A > QB$： Firm L covers all CO_2 emissions.

In this context, Firm L's profit function is:

$$
\begin{aligned}
\pi_L &= (a - q_L - Q - c)q_L + rQB \\
&= \left(rB + \sqrt{F}\right)q_L + rB\left(a - c - qx_L - rB - \sqrt{F}\right) \\
&= \sqrt{F}q_L + rB\left(a - c - rB - \sqrt{F}\right)
\end{aligned}
\tag{6}
$$

The above equation clearly shows that Firm L's profit is an increasing function of q_L. The rationale for this is as follows: Firm L first determines its output, and the potential entrants are assumed to be free entrants. The potential entrant will continue to enter the market up to the level where its own profit is equal to zero, given that the output is determined by Firm L. Then, regardless of the level of Firm L's output, the market commodity price will be adjusted to a level exactly equal to the entry cost F by subtracting the marginal cost and carbon credits from it, and then multiplying by $\sqrt{F}$, the output of each firm. Thus, the market price is no longer dependent on q_L, and firm L faces a situation in which the more it produces, the higher its profit, as long as potential entrants are willing to enter the market.

In this context, we must consider the two constraints of q_L. First, the number of Firms n must be greater than two to ensure potential entrants. Second, $q_L A$ must be greater than QB. The constraints of q_L are given as

$$
\begin{cases}
n \geq 2 \Leftrightarrow q_L \leq a - c - rB - 2\sqrt{F} \\
q_L A > QB \Leftrightarrow q_L > \dfrac{B\left(a - c - rB - \sqrt{F}\right)}{A + B}
\end{cases}
\tag{7}
$$

To ensure the existence of q_L and satisfy Equation (7), the following equation must hold:

$$\frac{B\left(a-c-rB-\sqrt{F}\right)}{A+B}<a-c-rB-2\sqrt{F}$$

In this analysis, we assume $\sqrt{F}$ is not sufficiently large to ensure the existence of q_L. In general, we assume the following:

$$\sqrt{F}<\frac{A(a-c-rB)}{2A+B} \tag{8}$$

Firm L tries to increase its quantity to the upper bound because its profit function is an increasing function of q_L. Therefore, Firm L sets its quantity as

$$q_L=a-c-rB-2\sqrt{F}.$$

This quantity indicates that Firm L attempts to eliminate potential entrants from the market. We obtain the following equilibrium outcomes.

$$q_L^*=a-c-rB-2\sqrt{F}, Q^*=0,$$

$$p^*=c+rB+2\sqrt{F}$$

$$\pi_L^*=\left(rB+2\sqrt{F}\right)\left(a-c-rB-2\sqrt{F}\right)$$

（2） $q_L A\leq QB$: Firm L cannot cover all firms' CO_2 emissions.

In this context, Firm L's profit function is

$$\pi_L=(a-q_L-Q-c)q_L+rq_LA$$

$$=\left(rA+rB+\sqrt{F}\right)q_L \tag{9}$$

Firm L's profit is an increasing function. The rationale behind this result is the same as that in Equation (6). The constraints of q_L in this region are given by:

$$\begin{cases} n \geq 2 \Leftrightarrow q_L \leq a - c - rB - 2\sqrt{F} \\ q_L A \leq QB \Leftrightarrow q_L \leq \dfrac{B\left(a - c - rB - \sqrt{F}\right)}{A + B} \end{cases} \tag{10}$$

From Equation (10), constraints of q_L can be rewritten as

$$q_L \leq \frac{B\left(a - c - rB - \sqrt{F}\right)}{A + B}$$

We obtain the equilibrium outcomes as

$$q_L^{**} = \frac{B\left(a - c - rB - \sqrt{F}\right)}{A + B}, Q^* = \frac{A\left(a - c - rB - \sqrt{F}\right)}{A + B},$$

$$p^{**} = c + rB + \sqrt{F},$$

$$\pi_L^{**} = \left(rA + rB + \sqrt{F}\right)\frac{B\left(a - c - rB - \sqrt{F}\right)}{A + B}$$

Firm L allows potential entrants to enter the market. From these equations, we find that Firm L sets q_L^{**} to satisfy $q_L^{**}A = Q^*B$. This is because surplus carbon credits cannot be sold if they generate a credit amount that exceeds the market's CO_2 emissions, and vehicle prices will also fall. Figure 4 shows the relationship between Firm L's quantity and the sum of the potential entrant quantities Q.

<See Figure 4>

（３）Firm L's optimal strategy

We obtain Firm L's optimal strategy as follows. The next proposition shows what happens when Firm L attempts to exclude all potential entrants from the market.

Proposition 2: Firm L's optimal strategy is as follow

1. *When* $(2A+B)(a-c)/B(3A+2B) \leq r$ *or* $(2A+B)(a-c)/B(3A+2B) > r \geq (a-c)/2(A+B)$ *and* $A(a-c-rB)/(2A+B) > \sqrt{F} \geq ((2A+B)(a-c) - rB(3A+2B))/2(4A+3B)$ *, firm L sets* q_L *to allow market entry by potential entrant.*
2. *Otherwise, Firm L sets* q_L *to eliminate potential entrants from the market.*

The rationale behind this proposition is as follows. The strategy chosen by Firm L depends on the carbon-credit price r. When r is sufficiently large, profits from carbon credits increase. In this case, Firm L has a strong incentive to allow potential entrants to enter the market and emit CO_2. If r is small and the income from carbon credit is small, then the income from car sales becomes more important. The number of potential firms increases when F is small, because entry is easier. If Firm L allows potential competitors to enter the market, then its home production is smaller. This is undesirable if Firm L intends to increase profits from the sale of vehicles.

（4） Firm L's decision regarding patent pledge

Previously, we analyzed the condition in which Firm L has an incentive to drive potential entrants out of the market. Next, we examine whether Firm L has an incentive to pledge patents during the first stage. In our setting, we assume that Firm L can reduce the CO_2 emissions of potential entrants by creating a patent pledge that allows the technology to be used widely.

Therefore, Firm L is incentivized to make a patent pledge when its profit function in equilibrium is a decreasing function of B, the potential entrant's CO_2 emissions. The next proposition shows what happens when Firm L has an incentive to pledge its patents.

Proposition 2: When $\sqrt{F}$ and r is large enough, Firm L's profit function becomes a decreasing function of B.

Thus, the rationale behind this proposition is clear. Profit from the products is obtained by multiplying the "profit per product" by the "number of products sold." From the profit obtained by Firm L in each domain, the "profit per product" is an increasing function of $\sqrt{F}$ and rB, whereas "number of products sold" is a decreasing function of $\sqrt{F}$ and rB. If each variable can be controlled by Firm L, the degrees of $\sqrt{F}$ and rB would be at intermediate levels, neither too high nor too low, to maximize the value. However, $\sqrt{F}$ and r are parameters that are set independently of the intention of Firm L. If Firm L can lower B through its patent non-exercise pledge, it can adjust the effects of $\sqrt{F}$ and r, which are too high, by lowering B. Therefore, if (1) a carbon-credit market exists and (2) the carbon-credit price set by the government is high, Firm L can increase its own profit through a patent pledge.

（５）Government's objective function

Previously, we showed Firm L's potential to increase its profit through a patent pledge in the presence of a carbon-credit market. One question to consider is how would the government set its carbon- credit price? This section provides an extended interpretation of the model results.

If the negative externality from CO_2 and the entry cost F for potential entrants are large, the government would try to maximize social welfare by setting a moderate carbon-credit price at which Firm L could dominate the market on its own. If Firm L sets its production volume at a level that prevents potential entrants from entering the market, several positive effects on social welfare will emerge. The first is the reduction in CO_2 emissions, as there are no potential entrants in the market that make CO_2-emitting goods. If the government includes these environmental externalities in its welfare policy, it will have a significant positive effect. The second advantage is entry-cost savings. If an entrant wants to enter the market, it must pay an entry cost F, which is a social cost. If Firm L prevents entrants from entering the market, then the market has no entry costs, which is socially desirable.

If the social diffusion of environmental knowledge is part of the objective function, the government may set a higher r. If only Firm L remains in the market, as described above, the overall CO_2 emissions will certainly be reduced; however, because only Firm L has the technology to produce electronic vehicles, the potential for future technological development may be reduced. If the government sets r high, then based on the discussion in the previous section, Firm L will make a patent pledge to increase its profits and allow other firms to use its knowledge. One of the social benefits of a patent pledge is that subsequent firms can freely use knowledge, making it easier for them to conduct R&D that will lead to subsequent innovations. If governments consider short-term social benefits and the long-term development of new technologies, the implementation of patent pledges by prior firms at the time of setting high carbon-credit prices would have a positive effect.

Conclusion

This study examined the incentives for rights holders to make patent pledges and their impact on the market. Section 3 examined the potential of Elon Musk's patent pledge as a credible commitment device that motivates him to pursue actions geared toward maximizing social welfare (i.e., promoting electric vehicles) using a theoretical model. Section 4 introduced the carbon-credit market into the endogenous entry model, contending that Tesla may be incentivized to decrease the CO_2 emissions of other companies via its patent pledge. Both models demonstrate that Tesla had economic motives for pledging patents, from different perspectives.

The concluding remarks are presented below. First, this analysis dealt with the strategic delegation and endogenous entry models to demonstrate that factors other than network externalities that may cause Tesla to make patent pledges. However, this study could not clarify which factors actually caused Tesla to pledge its patents, nor has it considered the impact of each factor. Second, in this study, the endogenous-entry model was used for the performing a static analysis. However, the unit price of carbon credits and market entry cost for each company is anticipated to decrease over time. Notably, the European Union has set a target of 95 g/km g/km CO_2 emissions for cars by 2021, and an increasing number of companies are manufacturing electric vehicles. Therefore, a dynamic analysis of Tesla's strategy is required to account for any decrease in r and $\sqrt{F}$. In addition, the reason behind Tesla's declaration of indefinite non-exercise should be considered in future research.

Appendix

Proof of Proposition 2

Firm L's profit when it drives other firms out of the market π_L^* and the profit when it does not π_L^{**} are as follows.

$$\pi_L^* = \left(rB + 2\sqrt{F}\right)\left(a - c - rB - 2\sqrt{F}\right),$$

$$\pi_L^{**} = \left(rA + rB + \sqrt{F}\right)\frac{B\left(a - c - rB - \sqrt{F}\right)}{A + B}$$

The difference between these profit functions is calculated as follows.

$$\pi_L^{**} - \pi_L^* = \frac{F(4A + 3B) + rB\sqrt{F}(3A + 2B) - \sqrt{F}(2A + B)(a - c)}{A + B}.$$

The sign of this equation depends on the sign of the denominator, which we define in functional form as follows:

$$D\left(\sqrt{F}\right) \equiv F(4A + 3B) + rB\sqrt{F}(3A + 2B) - \sqrt{F}(2A + B)(a - c)$$

We can obtain the second derivative of this function as

$$\frac{\partial^2 D\left(\sqrt{F}\right)}{\partial \sqrt{F}^2} = 2(4A + 3B) > 0.$$

In addition, we can obtain $\sqrt{F}$, which makes $D\left(\sqrt{F}\right)$ zero.

$$D\left(\sqrt{F}\right) = 0 \; when \; \sqrt{F} = 0, \; \frac{(2A + B)(a - c) - rB(3A + 2B)}{2(4A + 3B)}$$

Because $D\left(\sqrt{F}\right)$ is a convex function, $D\left(\sqrt{F}\right)$ will is negative when $\sqrt{F}$ is in the range of 0 and $\frac{(2A+B)(a-c)-rB(3A+2B)}{2(4A+3B)}$.

Next, we check whether was larger 0 and $\frac{(2A+B)(a-c)-rB(3A+2B)}{2(4A+3B)}$. We obtain the following relationship:

$$\frac{(2A+B)(a-c)-rB(3A+2B)}{2(4A+3B)} \gtreqless 0 \rightleftarrows\Leftrightarrow \frac{(2A+B)(a-c)}{B(3A+2B)} \gtreqless r$$

When r is greater than $(2A+B)(a-c)/B(3A+2B)$, $\frac{(2A+B)(a-c)-rB(3A+2B)}{2(4A+3B)}$ becomes negative. In this setting, we assume that $\sqrt{F} \geq 0$. Thus, π_L^{**} is larger than π_L^{*} for all regions. When r is smaller than the limit, π_L^{**} is larger than π_L^{*} when $\sqrt{F} \geq \frac{(2A+B)(a-c)-rB(3A+2B)}{2(4A+3B)}$. From equation (8), we also assume that

$$\sqrt{F} < \frac{A(a-c-rB)}{2A+B} \tag{8}$$

Then, the condition becomes as

$$\frac{(2A+B)(a-c)-rB(3A+2B)}{2(4A+3B)} \leq \sqrt{F} < \frac{A(a-c-rB)}{2A+B}$$

To verify the existence of this region, we compared the upper and lower bounds of this limit. Proposition 2 is obtained from the following conditions.

$$\frac{A(a-c-rB)}{2A+B} \geq \frac{(2A+B)(a-c)-rB(3A+2B)}{2(4A+3B)} \Leftrightarrow r \geq \frac{a-c}{2(A+B)}.$$

Proof of Proposition 3

First, we consider when π_L^{*} becomes a decreasing function of B.

$$\pi_L^{*} = \left(rB + 2\sqrt{F}\right)\left(a - c - rB - 2\sqrt{F}\right),$$

We can obtain the following equations.

$$\frac{\partial \pi_L^*}{\partial B} = r\left(a - c - 2rB - 4\sqrt{F}\right) \tag{11}$$

The right-hand side of equation (11) is a decreasing function of r and $\sqrt{F}$. π_L^* becomes a decreasing function of B when.

$$r < \frac{(a-c)}{2(A+B)} \tag{12}$$

From the proof of Proposition 2, if firm L attempts to remove potential entrants from the market, then

$$\sqrt{F} < \frac{(2A+B)(a-c) - rB(3A+2B)}{2(4A+3B)} \tag{13}$$

We can easily show that if we substitute the upper bounds of r and $\sqrt{F}$, as shown in Equation (12) and (13), the right-hand side of Equation (11) becomes negative.

Similarly, we try to consider π_L^{**}.

$$\pi_L^{**} = \left(rA + rB + \sqrt{F}\right)\frac{B\left(a - c - rB - \sqrt{F}\right)}{A+B}$$

From this equation, we can obtain

$$\frac{\partial \pi_L^{**}}{\partial B} = -\frac{\left(AF + \sqrt{F}(Ac - Aa + 4ABr + A^2r + 2B^2r) - r(A+B)^2(a-c-2Br)\right)}{(A+B)^2} \tag{14}$$

The sign of (14) depends on the sign of the denominator, which we define in functional form as follows:

$$E(\sqrt{F},r) \equiv \left(AF + \sqrt{F}(Ac - Aa + 4ABr + A^2r + 2B^2r) - r(A+B)^2(a - c - 2Br)\right)$$

The following holds for the range of r and $\sqrt{F}$to the extent that Firm L does not drive out potential entrants:

$$\frac{\partial^2 E(\sqrt{F},r)}{\partial\sqrt{F}\partial r} > 0, \frac{\partial E(\sqrt{F},r)}{\partial\sqrt{F}} > 0, \frac{\partial E(\sqrt{F},r)}{\partial r} > 0$$

If we substitute the upper bounds of r and $\sqrt{F}$, $E(\sqrt{F},r)$ becomes positive. Therefore, when r and $\sqrt{F}$ are sufficiently large, Firm L's profit function becomes a decreasing function of B.

TABLES

Table 1

$ in millions	2016	2017	2018	2019	2020	2021
Net (loss) income	(675)	(1,962)	(976)	(862)	721	5519
Regulatory credits	302	360	419	594	1580	1465

FIGURES

Figure 1

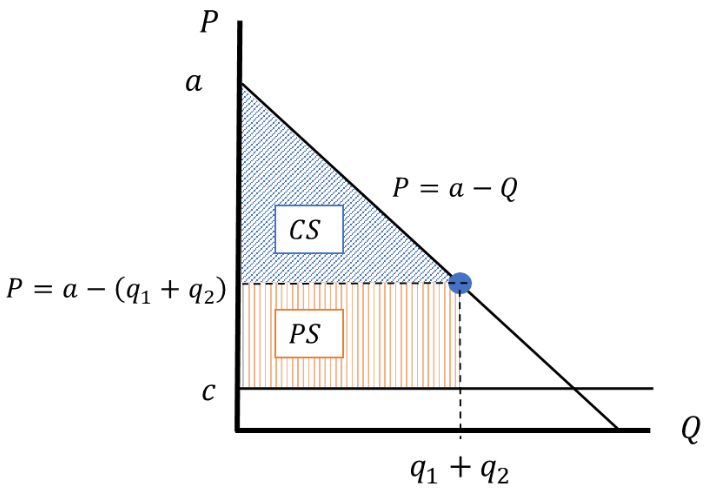


Figure 2

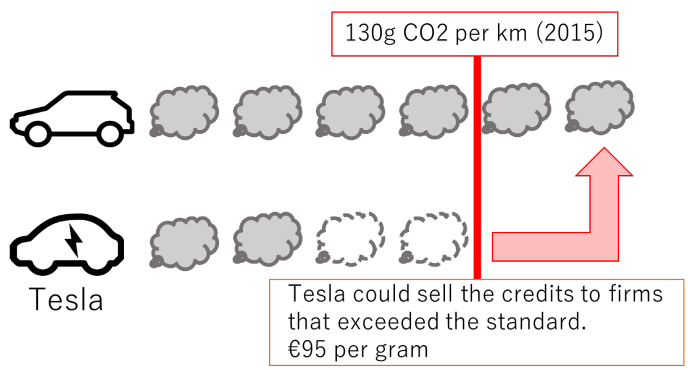


Figure 3

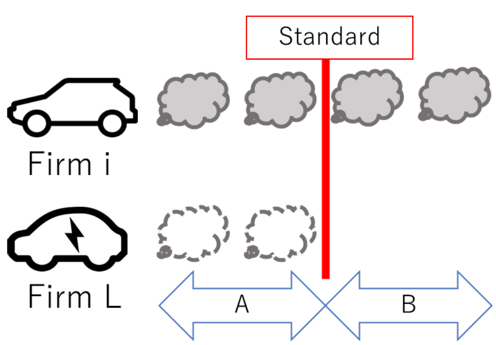
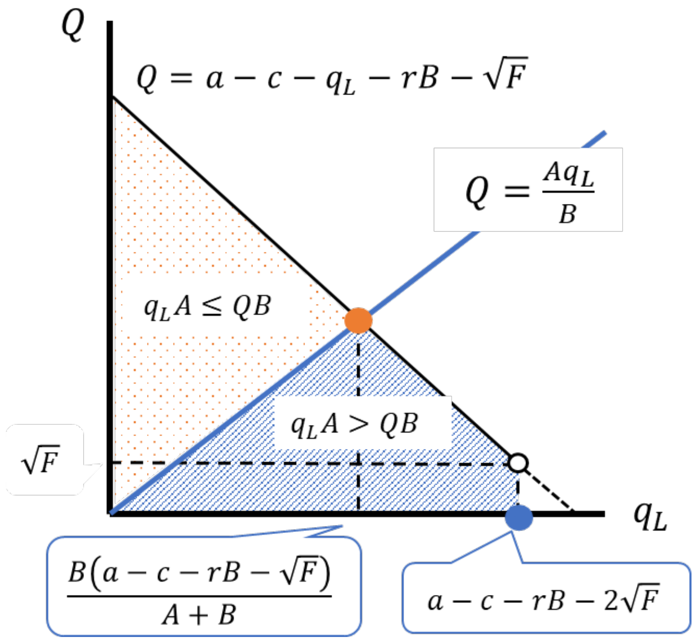


Figure 4



Q
$Q = a - c - q_L - rB - \sqrt{F}$
$Q = \frac{Aq_L}{B}$
$q_L A \leq QB$
$q_L A > QB$
$\sqrt{F}$
q_L
$\frac{B(a - c - rB - \sqrt{F})}{A + B}$
$a - c - rB - 2\sqrt{F}$

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