Effects of catch-up and incumbent firms' SEP strategic manoeuvres

Abstract

This paper investigates the effects of standard-essential patents (SEPs) to identify strategic differences between firms in advanced countries and those in latecomer countries. By comparing the SEP data-sets of incumbent and catch-up groups of the top 10 SEP firms, this paper has discovered the following four main findings. First, SEP strategic manoeuvres work as an effective way of expanding the sphere of catch-up firms' influence. Particularly after passing a certain threshold, catch-up firms' technological influence increases in an exponential manner. Second, for incumbent firms, SEP strategic manoeuvres serve as a catalyst to deepen the development of self-reliant trajectories embodied in the history and future of standards. Third, catch-up firms have specialised in short cycle technologies for self-reinforcing capability. Fourth, the effects of SEP strategic manoeuvres and international protection size on the likelihood of SEP litigation are greater for catch-up firms than for incumbent firms. These findings highlight the dual role of standards-setting organisations (SSOs) for catch-up firms (i.e., knowledge-learning and knowledge-diffusion spaces). For incumbent firms, these findings stress the importance of establishing reinforcing mechanisms to align long-standing self-reliant knowledge paths with the direction of anticipatory standardisation. This discovery provides strategic insights within the context of post catch-up strategy.

1. Introduction

The term *catch-up* refers to closing the gap between forerunning and latecomer firms in terms of their market share and technological capabilities (Lee & Lim, 2001). The rapid rise of South Korean and Chinese firms has been a canonical example of industrial policy-based economic success, catching up with incumbent US and European firms (Amsden, 1989; Lin, Cai, & Li, 1996). Accordingly, the catch-up strategies of leading South Korean and Chinese firms (e.g., Samsung and Huawei) have been under the global spotlight and have become a research focus (Joo & Lee, 2010; Joo, Oh, & Lee, 2016).

Proactive involvement in standardisation is a well-known secret behind catch-up firms' success (Lee & Oh, 2006; Lee, Lim, & Song, 2005). Standardisation facilitates the emergence of a new technological paradigm, which opens a window of opportunity for latecomers to catch up (Kim, Lee, & Kwak, 2017; Perez & Soete, 1988). Particularly in the high-tech industries where compatibility standards integrate heterogeneous legacy systems into a system of systems (David & Steinmueller, 1994), participation in standards-setting organisations (SSOs) plays a crucial role in accessing the accumulated knowledge base and controlling the direction of technological trajectories (Mattli & Büthe, 2003; Pfeffer, 1981).

In these industries of complex technological systems (e.g., telecommunications and information technology (IT)), competitive advantages are conferred on the firms which manage to control standards while simultaneously protecting their technologies via patents (Kim & Hart, 2002). These patents, essential to the implementation of standards, are called standards-essential patents (SEPs). The growing importance of SEPs' strategic value has drawn several researchers' attention (e.g., Bekkers, Bongard, & Nuvolari, 2011; Kang & Bekkers, 2015). In addition, practitioners have begun to comprehend the strategic importance of SEPs even in industries other than telecommunications and IT. For instance, BBC News recently reported that a group of car makers urged a regulator to take action against Qualcomm's practices of leveraging SEPs (Russon, 2020).

These two streams of academic literature (i.e., catch-up and SEPs) have been expanding their own knowledge foundation. Yet as far as the author is aware, there are only a few studies in the literature located at the intersection of the two knowledge bases. That intersection represents a cross-cutting aspect of the important phenomenon where incumbent and catch-up firms strategically employ SEPs to amplify technological capabilities in parallel with a series of standardisation activities. For instance, Lee (2013) conducted a set of well-structured analyses, relying on patent data, to compare the differences of incumbent and catch-up firms' strategies. Kang, Huo, and Motohashi (2014) stressed the strategic role of SEPs for East Asian catch-up firms (e.g., Samsung, LG, Huawei and ZTE) and compared the SEP portfolios of South Korean and Chinese firms. Despite their significant findings, these studies have not fully explored differences in the effects of SEPs on technological capabilities between incumbent and catch-up firms. Understanding these effects on the aspects of technological capabilities (e.g., technological influence and self-reinforcing capability) offers valuable insights for catch-up firms in terms of post catch-up strategy.

Moreover, the international patent race of SEPs between incumbent and catch-up firms has become more intense, where firms competitively conduct R&D activities to invent new technologies that are close substitutes. In this setting, a standard creates a monopoly in a market, which incentivises firms to race to develop substitute technologies that are in line with the selected standard (Jensen & Thursby, 1996). As shown in some cases (e.g., Apple vs Samsung), a firm strategically uses SEPs to block other firms' implementation of technological standards and influences the competitive dynamics of forerunners and followers. This indicates that SEPs serve as strategic assets that influence firms' knowledge position and bargaining powers (Bekkers, Verspagen, & Smits, 2002). The strategic importance of SEPs incentivises firms to make strategic moves to include their patented technologies in a series of standardisation projects. Considering the different knowledge positions where incumbent and catch-up firms are placed in the competitive field of standardisation, the effects of SEP strategic manoeuvres are likely to be different between incumbent and catch-up firms. This backdrop contextualises the following research question in this paper: *how are the effects of SEP strategic manoeuvres different between incumbent and catch-up firms in terms of technological influence, self-reinforcing capability and patent litigation?* Drawing on a set of statistical analyses of SEP data, this paper examines the above research question with the aim of contributing to the literature of catch-up and SEP studies within the context of post catch-up strategy.

2. Literature Review and Hypothesis Development

2.1. Patent citations and SEP strategic manoeuvres

Patents have been considered as a useful proxy for the output of firms' innovative activities (Griliches, 1990). Patent counts weighted by citations are a particularly good indicator of the value of innovation (Trajtenberg, 1990). The social value of innovation is grounded on the spillover effects of patent citations on firms' subsequent activities of knowledge generation. As a reference to the prior art, a patent citation is used to evaluate the novelty of patent claims under the assumption that the underlying knowledge of an invention originates from cited patents (Criscuolo & Verspagen, 2008). This assumption justifies patent citations as a valid index for the probability of useful knowledge flow, which captures an aspect of technological influence (Jaffe, Trajtenberg, & Fogarty, 2002). A patent citation is often employed as a measure for technological progress (e.g., Von Wartburg, Teichert, & Rost, 2005). Direct and indirect citations enable technological knowledge to cascade to descendant patents and hence its technological influence persists over time (Martinelli & Nomaler, 2014).

Standards have assumed a prominent role in the diffusion of technological knowledge. Standardisation has been historically understood as the process of articulating and implementing technological knowledge (Russell, 2005). The genesis and proliferation of standards are closely interrelated in a recursive manner (Botzem & Dobusch, 2012). Thus, the dissemination of technological knowledge via standards has been an indispensable part of standardisation literature (Lyytinen & King, 2006). Particularly in the telecommunications and IT industries, the importance of standardisation has received mounting attention because of its critical role in coordinating the interests of heterogeneous actors and mobilising the resources necessary for compatibility and technology diffusion (Yoo, Lyytinen, & Yang, 2005). The diffusion of a specific technology embodied in standards can be explained by the bandwagon process (Farrell, 1989). In this process, the adoption of standards by someone signals the success of an embodied technology in the market and shapes the expectation that others will follow. Accordingly, the incorporation of patented technology into standards serves as an effective channel to promote a firm's proprietary technology and increase its technological influence.

SEPs are important strategic assets, which influence firms' financial returns (Pohlmann, Neuhäusler, & Blind, 2016). The disclosure of SEPs is positively correlated with the firms' market value (Hussinger & Schwiebacher, 2015). The value of SEPs as strategic assets came under the spotlight in the process of formulating 2G telecommunications standards, when Motorola flexed its muscles and shaped the GSM standardisation process in its favour by utilising its SEP portfolio (Bekkers, Verspagen, & Smits, 2002). Thereafter, several firms began to engage in the strategic patenting of SEPs to gain the upper hand and derive more value from their technological innovation. Regarding the literature of SEPs' value, Rysman and Simcoe's (2008) research is a good starting point. They found that SEPs receive more forward citations over time vis-à-vis non-SEPs and that a greater portion of their cumulative citations arrives in later years. The research also confirms the causal effect of SEPs on subsequent innovation since citations substantially increase following patent disclosure at the SSOs.

Understanding the importance of a patenting strategy that aligns patent applications with standardisation, firms tend to intentionally manipulate the timing of a patent grant via a series of amendments and delays (Berger, Blind, & Thumm, 2012). Some companies deploy a "just-in-time patenting" strategy; just before a standardisation meeting, a firm makes an application for a patent with low technical merit and negotiates this patented technology into the standard (Kang & Bekkers, 2015). This line of literature emphasises the strategic aspect of SEP development.

After examining the determinants of SEPs, Bekkers et al. (2011) concluded that the actual involvement of patent holders in the standardisation process influences the development of SEPs more than the technical value ('merit') of a patent. Kang and Motohashi's (2015) research also showed that patents drafted by those who attended standardisation meetings are more likely to receive forward citations than those drafted by non-attendees. Building on this stream of studies, this paper uses the concept of "SEP strategic manoeuvres" to describe a set of activities to include proprietary technologies in a series of standardisation projects with the aim of achieving strategic motives, such as securing competitive advantage.

The motives of strategic patenting can be summed up by the following three categories: proprietary, defensive and leveraging (Somaya, 2012). Somaya (2012) describes a proprietary strategy as the "resource-based logic of using patents as isolating mechanisms that shield the firm's key competitive advantages from imitation" (p. 1092). Self-citations can be used as an index to measure the strategic activities of building proprietary fences, as hinted in Blind et al. (2009). Defensive patenting involves the "accumulation of patents to use as bargaining [chips] to preserve the freedom to operate and to improve the bargaining position of the firm in resolving patent disputes when they arise" (Noel & Schankerman, 2013, p. 483). By linking patent portfolio size with bargaining power, firms are in a better position to secure favourable outcomes in potential patent litigations. The availability of defensive patent portfolios is positively associated with the filing of countersuits and the probability of follow-on settlement in litigation (Somaya, 2003). Furthermore, firms can leverage patent portfolios as a source of bargaining power to pursue direct and indirect profit opportunities. For instance, "patent rolls" leverage their patent portfolios to extract rents through the threat of patent litigation. While proprietary patenting protects a firm's own technological space as its competitive advantage, defensive and leveraging strategies aim to expand a firm's bargaining power.

The strategic motives of SEPs can be a mix of these approaches. SSOs shape the direction of a particular technological path around which some firms build proprietary fences via SEPs. In addition, those firms can use SEPs as strategic assets to enhance their bargaining position (e.g., Bekkers et al., 2002). The achievement of optimal outcomes through strategic action requires the accumulation of trial-and-error experiences. Following the learning curve, firms obtain efficiency gains as they obtain more experiences of strategic manoeuvring. In the context of SEP strategic patenting, this efficiency gain is predicated on the optimisation of the patterns of SEP declaration activities that include disclosing appropriate technology as a SEP to the standardisation bodies and persuading other firms to support and adopt a firm's specific technology. If new entrant firms make strategic moves to declare patents with less technical value as SEPs, it won't affect other firms' follow-on patenting activities. Yet if these strategic efforts continue, those firms become efficient at finding the right fit between their patented technologies and standardisation activities. In this way, new entrant firms' SEP portfolios take on greater prominence. However, if firms draw too much on the same technology to produce SEPs in a series of different standardisation meetings, these strategic moves may backfire and the technological influence of SEPs will taper off. Following this line of logic, the first hypothesis is developed as follows.

H1: *SEP strategic manoeuvres are curvilinearly associated with a firm's technological capability to influence other firms' innovation.*

2.2. Path-dependence and self-citations

Technology progresses through changes in the socio-technical systems by a particular sequence of problem-solving activities. In Hughes's words (1987), the emergence of "reverse salients" (which hold up the growth of a system) brings innovative energy into focus and, in turn, identifies solvable "critical problems" whose solution will eliminate the bottlenecks of system growth. Thus, technological change is inherently cumulative and irreversible. As Schumpeter stated, "the historic and irreversible change in the way of doing things [is what] we call 'innovation'" (Schumpeter, 1935, p. 7, cited in Rosenberg, 1982, p. 6). Innovation takes place within the historical context of a particular sequence of events and, therefore, the future direction depends heavily on the past trajectory (i.e., path-dependence).

Arthur (1994) accentuates self-reinforcing mechanisms that result in path-dependence. The self-reinforcing sequence shows a pattern of increasing returns with which the adoption of technology continues and becomes entrenched as a way of locking out alternative options, including even more superior ones (e.g., Qwerty vs Dvorak in David, 1985). In this mechanism, the order of prior events shapes self-fulfilling expectations which induce people to take actions that result in the expected outcome.

Path-dependence is salient in the network of technological knowledge embodied in patents due to the patentability constraints. For instance, the novelty (newness) requirement obligates firms to candidly report a stock of preceding technologies on which a patent is built and to differentiate it from the prior knowledge base. This link to knowledge paths delineates the boundary of acceptable technological options, as evidenced by the effect of citations of scientific knowledge on the scope of forward citations in Cassiman et al. (2008). Particularly in fast-evolving fields (e.g., Internet of Things (IoT)), citations to standards facilitate the convergence of heterogeneous knowledge paths into a new cluster of emerging technology (Kim, Lee, & Kwak, 2017).

In this path-dependent world of technological knowledge, it is of great importance that firms shrewdly observe the evolving patterns of knowledge flow, internalise a particular path and develop a self-dependent trajectory. Self-citations represent the history of a firm's innovative in-house efforts to appropriate the values created by its previous inventions (Trajtenberg, Henderson, & Jaffe, 2002). Since those take place within the same agency, self-citations differ from external citations, which capture knowledge spillovers. Those can indicate a firm's efforts to monopolise a specific technological space where the firm has lower search costs and easier access to core technologies. According to Hall et al.'s (2005) research, a stock of additional self forward citations can increase the market value of a firm by 10% whereas that of non-self forward citations raises market value by 4.3%. This highlights the importance of a firm's self-reinforcing capability to develop self-dependent technological paths that connect indigenous prior technologies with its own future innovation. Citations work in a path-dependent manner and thus it is likely that a higher ratio of self backward citations will lead to an increasing number of self forward citations. This implies that self-citations can serve as a proxy to measure a firm's self-reinforcing capability to construct its own technological path.

As discussed earlier, a firm's involvement in standardisation is likely to be driven by strategic motives, considering the substantial amount of time and cost required to be part of it. Among those motives is the development of a particular technological trajectory. According to Blind & Mangelsdorf's (2016) research, the following strategic objectives are placed in a higher position in terms of firms' standardisation motives: 1) enforcing a firm's specific technology; 2) shaping the direction of future standards in line with the firm's interest; 3) acquiring competitive advantage through a head start in knowledge development. It clearly shows that a greater degree of standardisation activities can facilitate the development of a firm's own technological trajectory that links its past internal knowledge assets with future homegrown innovation. Grounded on this flow of logic, the following hypothesis is derived:

> H2: *SEP strategic manoeuvres moderate the relationship between a firm's self-reliance and its capability to reinforce its own innovation.*

2.3. Catch-up/incumbent dynamics and technology cycle time

The role of patents as a disseminator of technological knowledge in emerging economies such as South Korea and China has been emphasised (Sun, 2003). Due to the supportive role played by their governments, South Korean and Chinese firms have been able to access advanced technologies developed by foreign firms in the telecommunications industry (Lee & Lim, 2001; Mu & Lee, 2005). In the high-tech industries where a high level of compatibility between different systems is necessary, the coordination and codification of innovation occur more frequently. The systematisation of explicit knowledge enables latecomers to access external knowledge and build their catch-up capability upon the accumulated knowledge base (Jung & Lee, 2010). Therefore, standardisation can serve as a window of opportunity for catch-up firms to internalise advanced technologies and develop their own technological trajectories in line with evolving standards (Kim et al., 2017).

Technological cycle time has been one of the key drivers of South Korean and Chinese firms' catching-up process. Changes in technological paradigms influence the cost of entry into a new sector by allowing latecomers to bypass heavy investments in old technologies (Perez & Soete, 1988). Some studies have empirically demonstrated that catching-up is more likely to occur in the technological sectors that have a short cycle time (Lee, 2013; Park & Lee, 2006). This is because, in industries where the cycle of technological knowledge moves quickly, there is little need for latecomers to spend time and resources mastering the accumulated stocks of existing knowledge. This structural condition induces entrant firms to develop their own technological capability within fields with frequent knowledge updates. Based on this stream of literature, the following hypothesis is developed:

> H3-1: *The effect of short technology cycle time on self-reinforcing capability is greater for catch-up firms than for incumbents.*

In the fields of telecommunications and IT standards, US and European firms have been regarded as incumbents who vigorously embed their proprietary technologies into standards. For instance, Qualcomm, Ericsson, Nokia and InterDigital extensively influenced the patenting activities of SEPs in the processes of 2G and 3G standardisation, owning more than 85% of them (Bekkers et al., 2011) and, in turn, remained dominant in terms of knowledge positions that constrained subsequent innovations (Bekkers & Martinelli, 2012). In the periods of 3G and 4G standardisation, South Korean and Chinese firms (e.g., Samsung, LG, Huawei and ZTE) joined the competitive SEP race as catch-up firms (Byeongwoo Kang et al., 2014).

One of the main motivations for latecomer countries to take part in standardisation is to strengthen their absorptive capacity through learning (Ernst, Lee, & Kwak, 2014). Technological learning capability (from imitation to innovation) is at the core of East Asian firms' successful catch-up (Kim, 1997). Due to the deficiency of innovative capabilities, catch-up firms acquire and assimilate foreign technological knowledge at an early stage. Yet a high degree of reliance on external knowledge results in the payment of substantial royalties to firms in advanced countries, reducing the profitability of catch-up firms. This is called the "technology or patent trap" (Suttmeier, Yao, & Tan, 2006). To overcome this challenge, catch-up firms have been internalising the source of external knowledge and cultivating innovative capabilities to generate their self-reliant technologies.

The promotion of indigenous technologies at the national and global levels has been a significant strategic motive for standardisation involvement in South Korea and China (Lee & Oh, 2008; Wang, Wang, & Hill, 2010). Standardisation provides East Asian countries with an opportunity to lead the competitive arena of global innovation as long as they successfully integrate local standards into international ones (Kwak, Lee, & Chung, 2012). Some scholars view these standardisation efforts as evidence of neo-techno nationalism, as they intend to control the production and diffusion of self-reliant knowledge by embracing different actors and approaches (Shim & Shin, 2015; Suttmeier et al., 2006). This means that catch-up firms can be more proactive than incumbents in utilising opportunities of standardisation to develop and deploy their homegrown technologies. In this context, the following hypothesis is derived:

H3-2: *The moderating effect of SEP strategic manoeuvres on self-reinforcing capability is greater for catch-up firms than for incumbents.*

2.4. SEP and patent litigation

Friction between standards and patents has been widely researched in the literature on SEPs (e.g., Farrell, 1989; Lemley, 2002), and that tension originates from the different ownership structures of such documents, which can be incorporated in either public or private goods (Kindleberger, 1983). The successful management of this in-built conflict between open standards and proprietary technologies provides firms with a competitive edge (Kim & Hart, 2002; Morris & Ferguson, 1993). Patents and standards have been structurally coupled in a form of standards-essential patents (SEPs), which affect the continuous and discontinuous patterns of technological progress (Baron, Pohlmann, & Blind, 2016).

Some firms use their exclusive rights of patents strategically to block other firms' implementation of technological standards. For instance, in *Apple vs Samsung*, Samsung leveraged its SEPs to litigate against Apple in response to Apple's design patent infringement lawsuit. In 2013, the US International Trade Commission (ITC) ruled that Apple infringed Samsung's 3G SEPs, and granted Samsung's request for an injunction on the sales of certain Apple products (New Delhi Times, 2013).

Concerning the issues of blocking patents (which prevent another technology from being used) and the patent thicket (i.e., an overlapping set of patent rights which require users to obtain licenses from multiple patentees), a number of SSOs mandate participants to license any essential patents on FRAND terms (fair, reasonable, and non-discriminatory) (Shapiro, 2001). However, the question of whether or not SEPs are essential is highly controversial, since most SSOs allow firms to include their disclosed patents in standards without reviewing how essential patents are, as long as they meet FRAND terms (Lemley & Simcoe, 2018). Moreover, FRAND policies face several challenges, such as 1) how to judge costs versus benefits of including patents; 2) how to define what FRAND means in practice; 3) How to promote accurate disclosure of "essential" IPRs; 4) How to deal with a blocking patent held by a third party; 5) How to deal with patent rights that are transferred (Bekkers, Iversen, & Blind, 2011). Due to these loopholes and the blocking potential, SEPs are often involved in patent litigation.

According to Harhoff et al.'s (2003) research, frequently litigated patents tend to be more valuable than non-litigated patents. This finding can be interpreted in a reverse manner. More valuable patents tend to be involved in litigation. The probability of litigation is proportional to the stakes involved in the trial. The stakes increase with the importance of patents. Lanjouw and Schankerman (1997) examined the characteristics of litigated patents and confirmed that more valuable patents are considerably more likely to be involved in litigation. They also found that patents in 'crowded areas' (i.e., where there is a high level of similarity between the patent and its forward citations) are more likely to be litigated.

Within the context of this study, the findings of previous literature can be interpreted as follows. A great number of citing standards reflects a firm's strategic efforts to be involved in frequent updates of similar standards. This implies that these SEP technologies are positioned in a crowded area where a multitude of actors are interacting with one another to compete and innovate. This increases the likelihood of patent litigation. Thus, the following hypothesis is derived:

H4: *SEP strategic manoeuvres are positively associated with the likelihood of patent litigation.*

3. Methodology

3.1. Data: Three phases of data collection

SEP data were collected from the Questel Orbit patent database, which is one of the largest commercial patent databases in Europe. To enhance the validity of the analysis, data were extracted in three different periods: 1) May 11–13, 2018; 2) August 25–27, 2020; 3) August 25–September 12, 2021. Considering the time-varying characteristic of some variables (e.g., forward citations and SEP declarations), the three-phase data collection approach has the advantage of addressing a truncation issue and enhancing the robustness of findings. A truncation issue arises because patents continue to receive subsequent citations after patent issuance and, for recently applied patents, it usually takes two or more years for more citations to be received (Hall, Jaffe, & Trajtenberg, 2002). To minimise a truncation bias, the scope of selected SEP data is limited to patents whose application year is up to 2017. Furthermore, firm-specific data (i.e., the number of employees and the number of total patents from 1983 to 2017) were retrieved from the databases of Thomson Reuters Datastream and Questel Orbit. Some of the missing firm-specific data were collected from firms' annual reports and through internet searches.

The use of patent data has the following advantages (Lee, 2013). First, as a direct output of the innovation process, patents reflect the proprietary structure and competitive landscape of technological change. Second, patent applications are costly and categorised into different technology fields, and hence provide useful information about a firm's strategic direction. Third, patent data are available in large numbers over a lengthy period.

The data of extended patent families are used for this research, instead of individual patent data. A patent family is "the set of patents (or applications) filed in several countries, which are related to each other by one or several common priority filings" (OECD, 2009, p. 71). It is often viewed as a set of all the patents protecting the same invention. The benefit of using patent families is that the data are less susceptible to bias caused by duplicate patents across countries. By relying on extended patent families, it is possible to focus on technology, rather than an invention (EPO, 2014). This SEP family dataset primarily comprises telecommunications and IT technologies, since a substantial number of SEPs were listed at the European Telecommunications Standards Institute (ETSI). This is consistent with Baron and Pohlmann's (2018) finding that over 67% of SEPs are declared at the ETSI. It is therefore unsurprising that several prior studies on SEPs focused on ETSI SEPs (e.g., Bekkers, Bongard, & Nuvolari, 2011; Kang & Motohashi, 2015).

As shown in Figure 1, SEPs are highly concentrated in the top ten firms. This concentration trend has been intensified with the passage of time. In 2001, the top ten firms accounted for 55% of SEPs. By contrast, in 2017, 71% of SEPs were owned by the top ten firms. This shows that a handful of tech giants wield significant influence in the SEP patent race, which justifies the selection of the top ten firms as a research focus.

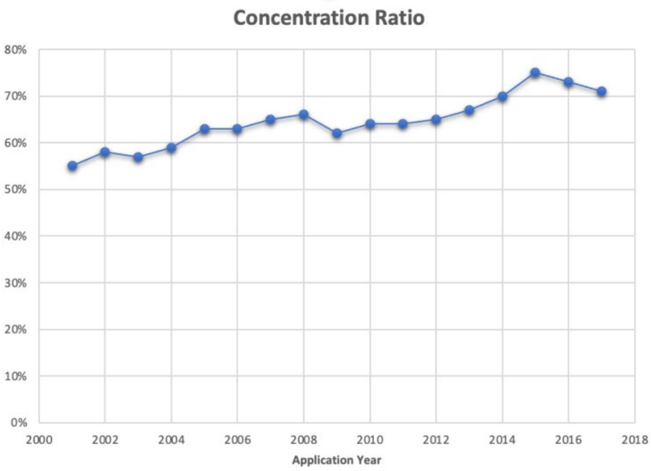

Figure 1. Concentration Ratio of Standard-essential Patents (SEPs) owned by Top 10 Firms

The first phase of data analysis serves as a pilot study which helps test initial hypotheses and adjust the research direction. In the first phase of the data set (collected in 2018), eight focal firms were selected among the top fifteen. The first four firms were the incumbent SEP firm group (i.e., Qualcomm, Nokia, Ericsson, InterDigital). These firms have been key technology firms heavily involved in mobile telecommunications standardisation activities. For instance, according to Bekkers et al.'s (2011) research, Qualcomm, Ericsson, InterDigital and Nokia were the top four owners of 3G telecom standard-essential patents. The other four firms were the catch-up group (i.e., LG Electronics, Samsung Electronics, Huawei, ZTE). In this paper, catch-up firms are defined as latecomers positioned to compete with established firms which have growing capability to catch up with incumbent firms' superior knowledge position. These entrant firms joined the SEP patent race later than the incumbent firms. This indicates that entrant firms were structurally positioned in a peripheral area and under pressure to catch up with incumbent firms' technological capabilities in a fierce patent race. The central knowledge positions of incumbent firms and the peripheral positions of catch-up firms in the high-tech standardisation arena were studied by Bekkers and Martinelli (2012).

The second phase of the data set was collected from the same database in 2020. This data set is less susceptible to a truncation bias since there is a gap of over two years between the year SEPs were applied for and that of subsequent inventions that cite them. This data set was used to structure the models for the statistical analysis and the main hypotheses in the paper. The third phase of the data set was extracted from the same database in 2021 for the purpose of a robustness check. The same models and variables were used for the second and third phase of the data sets to confirm the consistency of the findings. The third phase of the (most recent) data set is primarily used to report findings in the paper, whereas the analysis of the first and second phases of the data sets is reported in Appendices 4 and 5.

As a part of counterfactual analysis, non-essential patent data were also collected from the Questel Orbit database. The counterfactual analysis helps attribute causality between interventions and outcomes and estimate the effect of an intervention by comparing outcomes observed under the intervention with those of a comparison group without intervention. As a comparison group, focal firms' non-essential patents were randomly extracted. The random selection process was constrained by the years in which non-essential patents were applied for in order to generate distributions of similar age (i.e., the difference between the year of application and the present year) between the intervention and comparison groups.

Figure 2 shows the top 10 SEP incumbent and catch-up firms. The top 7 SEP firms have been consistently included in all three phases of the data set—that is, Huawei, LG Electronics, Samsung Electronics, Qualcomm, Nokia, ZTE, Ericsson. Many companies were competing for the other three spots, such as China Academy of Telecommunications Technology (CATT), Intel, Google, NTT Docomo and Sharp. Among these, Datang Mobile, Apple and InterDigital were selected in the third phase of the data set. In the second phase of the data set, CATT and Intel were selected instead of Datang Mobile and InterDigital. Despite the inclusion of different samples, the results of the analysis between the second and third phases of the data sets are highly consistent. This shows the generalisability of the findings to a certain degree.

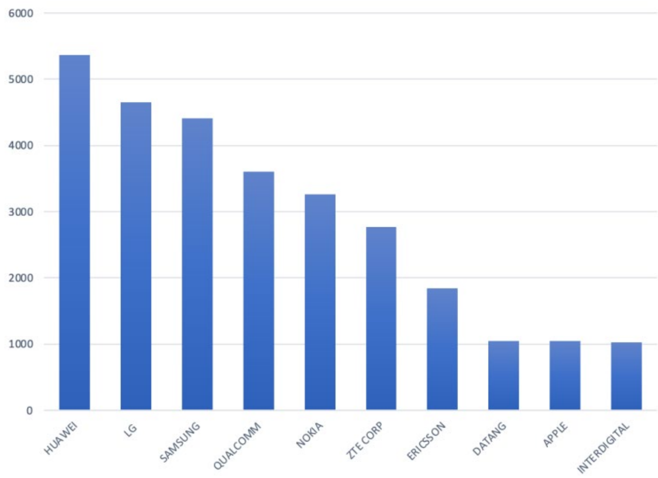

Figure 2. Composition of Top 10 SEP Incumbent and Catch-up Firms

As shown on the left-hand side of Figure 3, in the 1990s the number of catch-up firms' SEPs was smaller than that of incumbent firms', which shows a lack of capability on the part of catch-up firms to include their technologies in high-tech standards. In the mid-2000s, incumbent firms' capability to produce SEPs in large numbers was overtaken by catch-up firms in terms of patent quantity. Nonetheless, regarding patent quality, catch-up firms' technological capability, which can be measured by the number of forward citations, still lagged behind incumbent firms up until recent years. This is exhibited on the right-hand side in Figure 3. In the last few years, these latecomer firms' technological capabilities have nearly caught up with those of incumbent firms.

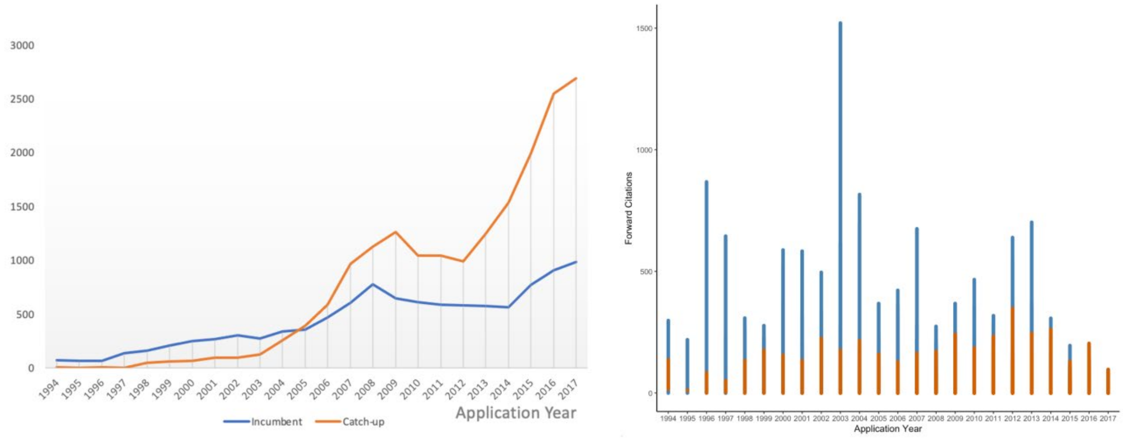

Figure 3. Top 10 SEP Firms' SEP Count and SEP Forward Citations. Note: Incumbent_Blue (Qualcomm, Nokia, Ericsson, Apple, InterDigital), Catch-up_Red (Huawei, LG, Samsung, ZTE, Datang).

3.2. Variables

For the testing of SEP effects on the catching-up process, the count of non-self forward citations (*NFC*) is used as one of the main dependent variables (DV). Several studies show that the number of forward citations is a valid index that measures the value of a patent (e.g., Carpenter, Narin, & Woolf, 1981; Harhoff, Scherer, & Vopel, 2003; Trajtenberg, 1990). The technological influence of cited patents on the knowledge base of citing inventors is at the core of this value, as it is confirmed that citations of patents are associated with the spillovers of technological knowledge (Jaffe et al., 2002). In addition to knowledge diffusion, patent citations may reflect strategic alignments between firms, which increase the likelihood of patent validity (Allison & Lemley, 1998; Delcamp & Leiponen, 2014). In line with prior studies, this research draws on non-self forward citations to test the effect of SEP strategic manoeuvring under the name of technological influence.

For another DV, weighted self forward citations (*WSFC*) are used to measure self-reinforcing capability. Self-citations can be understood as a reflection of the degree to which a firm's innovative efforts build upon its own knowledge base (Lee, 2013). It also relates to in-house capabilities to appropriate the values created by a firm's own innovations through their follow-up patents (Trajtenberg et al., 2002). Accordingly, a firm's strategic efforts to generate their own technological trajectories (i.e., self-citations) build a self-reinforcing mechanism to internalise and expand their core knowledge base and, thereby, influence a search scope of innovation.

As a measure of in-house capabilities to appropriate the value of a firm's own invention, Trajtenberg et al. (2002) use the ratio of self forward citations to the total number of forward citations. However, some patents receive very few forward citations. In turn, those patents tend to have an extremely high or low ratio value—for instance, 100% (1 out of 1) or 0% (0 out of 1). To address this issue, the number of self forward citations (*SFC*) is multiplied by the ratio of self forward citations (*RSFC*). The number of self forward citations captures the full picture of their own technological trajectories. The ratio of self forward citations works as a weight factor that captures how much a patent influences internal follow-up innovation, as compared to external follow-up innovation. In simple terms, *WSFC* is higher when a patent contains a higher number of self forward citations and, at the same time, a lower number of non-self forward citations.

Weighted Self forward Citations (WSFC) =

$Number\ of\ Self\ forward\ Citations\ (SFC)$ x $Ratio\ of\ Self\ forward\ Citations\ (RSFC) = SFC$ x $\frac{SFC}{NFC+SFC}$

A binary dependent variable is used for patent litigation (*Litigation_Binary*). The SEPs involved in patent litigation are coded as one, whereas non-litigated SEPs are zero. Relying on this categorical variable, logistic regression estimates the likelihood of SEP litigation. Other studies on patent litigation (e.g., Lanjouw & Schankerman, 1997) use the same form of binary dependent variable.

Regarding independent variables (IV), first, the number of citing standards (*CS*) is used as one of the main IVs. So as to keep abreast of technological progress, standards-setting organisations (SSOs) revise standards on a regular basis (Baron et al., 2016). This generates a variety of standards with updated versions over time. In this data set, many citing standards stem primarily from a firm's strategic efforts to continuously incorporate its patented technology into the variation of standard updates. This series of strategic activities intends to access and control the process of knowledge exchange in SSOs and, thereby, produce SEPs by including a firm's own technological knowledge into standards-setting outcomes. In this context, the number of citing standards (*CS*) is used to measure the degree of SEP strategic manoeuvres.

Second, self-reliance (*SR*) is calculated by the ratio of self backward citation to the total number of backward citations a patent cites. It reflects the degree of knowledge leverage through which a firm harnesses and internalises its prior knowledge in the innovation process (Novelli, 2015). For the analysis of moderating effects, interaction terms of *CS* and *SR* are generated, using the multiplication of normalised *CS* and *SR.* The normalisation of terms helps reduce collinearity.

Third, technological cycle time (*TCT*) is measured by the time gap between the year the citing patent was applied for and that of the cited patents (i.e., mean backward citation lag) (Hall et al., 2002; Narin, 1994). A longer cycle time represents the importance of old knowledge accumulated over time, which latecomer firms need to acquire (Park & Lee, 2006).

Fourth, the number of countries (*CN*) is taken into consideration. This is also known as a patent family size, which is computed by the number of countries in which patent protection was sought (Harhoff et al., 2003). Patents are inherently territorial, and, in turn, international patent filings involve substantial costs. Accordingly, the number of countries in which a SEP patent is protected reflects a firm's strategic motives (Dang, Kang, & Ding, 2019).

For control variables, the number of backward citations is factored in. Prior studies have treated backward citations as an indicator of technological cumulativeness (Cassiman et al., 2008; Reitzig, 2004). As an indicator of preceding technologies, backward citations constrain the scope of a future invention (Harhoff et al., 2003). A great number of backward citations tend to be associated with a large number of forward citations as "importance breeds importance" (Trajtenberg et al., 2002, p. 81). For firm-specific variables, a firm's size is gauged by the number of employees. Also, a firm's general technological capability and accumulated experience are measured by the total number of patents it has (e.g., Leiponen, 2008). By using the natural logarithm, these numbers were scaled down. Year dummies are used to control any specific year effect.

Other control variables were also factored into the first phase of the data analysis. These include technological diversity (measured by the Herfindahl index of a patent's technological classes (4-digit IPC codes)), patent scope (measured by the number of independent claims in a patent) and family age (measured by months between the application date of the oldest patent and that of the most recent). However, the inclusion of these variables did not significantly affect the analysis of the relationship between independent and dependent variables. Therefore, those variables were excluded in the second phase of data analysis. The analysis of the first phase of the data set with those variables is nevertheless reported in Appendix 4.

The descriptive statistics and correlation matrix of variables are presented in Appendices 1, 2 and 3. Multicollinearity was checked by examining variance influence factors (VIF). The test showed that all VIF values were less than 10, the commonly accepted threshold level (O'Brien, 2007). This indicates that multicollinearity is very unlikely to distort the results.

3.3. Regression models

This research relies on regression models with limited dependent variables (e.g., non-negative integer). Firstly, the negative binomial (NB) regression model is used for count data of patent citations. NB and Poisson are the commonly used regression models for count data, where the dependent variable is a non-negative integer (Cameron & Trivedi, 1998). Whereas Poisson is based on the equipdispersion assumption (i.e., variance is equal to the mean), NB allows for overdispersion (i.e., higher observed variance than assumed) (Hausman, Hall, & Griliches, 1984). As with other studies using patent citation data (e.g., Cassiman et al., 2008), the NB model was selected for the count of non-self forward citations after conducting the overdispersion test. Second, the Tobit model is employed for weighted self forward citations whose value is a rational number. This allows for a continuous range of values bounded below by zero. Third, logistic regression is used to model the probability of a dichotomous outcome variable (i.e., whether a patent is involved in litigation or not). For statistic software packages, this research uses R.

4. Findings

4.1. Curvilinear effect of SEP strategic manoeuvres on technological influence

A suite of statistical tests was conducted to demonstrate the effects of SEP strategic manoeuvring on a firm's ability to influence the technology development of other firms, as shown in Table 1. First, Models 2, 3 and 4 (in Table 1) show that the square of citing standards (CS^2) is associated with the number of non-self forward citations (*NFC*) with statistical significance. The scatter plot of citing standards and non-self forward citations shows in visual form the curvilinear effect of SEP strategic manoeuvres on technological influence for incumbent and catch-up firms (Figure 4). The results of these tests support the following hypothesis. H1: *SEP strategic manoeuvres are curvilinearly associated with a firm's technological capability to influence other firms' innovation*.

In addition to the confirmation of the first hypothesis, the results show that the curvilinear effect of SEP strategic manoeuvres for catch-up firms is positive. As shown in Figure 4 (left-hand side), catch-up firms' initial attempts to develop SEPs do not exert a strong influence on other firms' patenting activities. Rather, they discourage others from using their patented technologies. However, after passing a certain threshold, catch-up firms' SEPs become more influential as they continue to make strategic efforts to include their patented technologies in a series of standardisation meetings. By contrast, as shown in Figure 4 (right-hand side), some cases of incumbent firms' high-level SEP strategic moves do not lead to a greater level of non-self forward citations. This implies that SEP strategic manoeuvres do not automatically increase the importance of the patented technologies.

Regarding other independent variables, Models 1 and 2 (Table 1) show that technology cycle time (*TCT*) is negatively associated with technological influence (*NFC*) at the 0.01 significance level. This means that the more a firm relies on up-to-date technologies, the more influential its SEPs become. Moreover, Models 1 and 2 show that the number of countries (*CN*) is positively associated with non-self forward citations (*NFC*) at the 0.01 significance level. This is in line with Harhoff et al.'s (2003) finding that the number of forward citations and family size (number of countries) are both important contributing factors to the value of patents. This confirms that the strategic aspect of patenting affects a firm's capability to exert technological influence.

Regarding the effects of control variables, most of the results are consistent with the findings of previous studies. Models 1 and 2 (Table 1) show that a high number of backward citations increases the probability of a specific technology being cited by other firms' patents. This confirms that "importance breeds importance" (Trajtenberg et al., 2002, p. 81). For firm-specific variables, the number of patents is positively related to non-self forward citations, whereas the number of employees is not (*Ln_Patents, Ln_Employees*). This implies that regarding technological influence, the history of patenting activities matters, rather than the overall firm size.

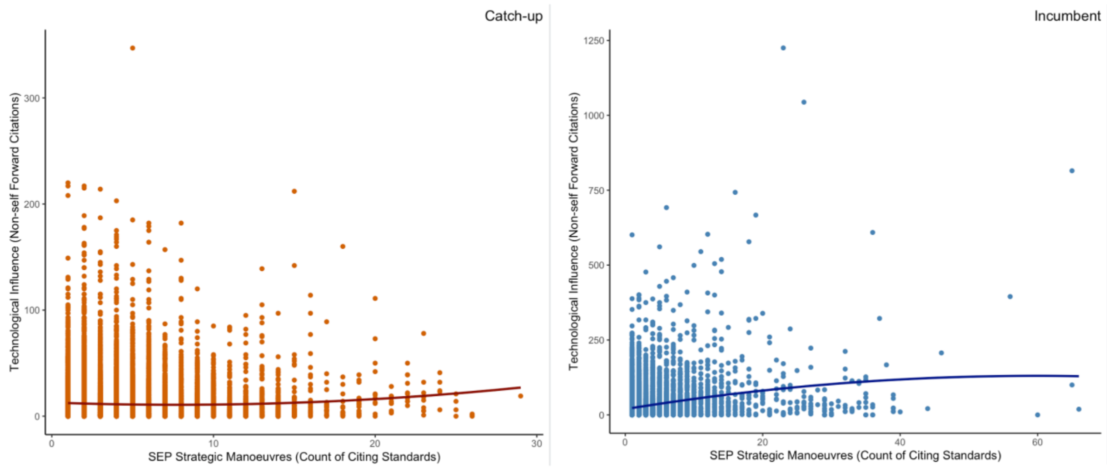

Figure 4. Scatter Plots of Citing Standards and Non-self Forward Citations for Catch-up and Incumbent firms

Table 1. Effects of SEP Strategic Manoeuvres on Technological Influence and Self-reinforcing Capability

	Model 1	Model 2	Model 3 (Incumbent)	Model 4 (Catch-up)	Model 5	Model 6	Model 7 (Incumbent)	Model 8 (Catch-up)
	NB (CSE)	NB (CSE)	NB (CSE)	NB (CSE)	Tobit (CSE)	Tobit (CSE)	Tobit (CSE)	Tobit (CSE)
Dependent Variable (DV)	NFC	NFC	NFC	NFC	WSFC	WSFC	WSFC	WSFC
Citing Standards (CS)	0.003 (0.018)	0.046*** (0.017)	0.042** (0.019)	-0.044** (0.018)	0.065 (0.071)	0.142 (0.092)	0.132* (0.079)	0.007 (0.011)
CS^2	-0.0002 (0.0004)	-0.001** (0.0005)	-0.001* (0.0005)	0.002** (0.001)				
Catch x CS		-0.070** (0.033)				-0.131 (0.091)		
Catch x CS^2		0.002 (0.001)						
Self-reliance (SR)	-0.204 (0.146)	-0.137 (0.201)	0.015 (0.160)	-0.193 (0.146)	2.702** (1.116)	6.865*** (0.937)	8.668*** (1.452)	0.916*** (0.050)
Catch x SR		-0.050 (0.266)				-5.279*** (0.705)		
CS x SR					0.050 (0.081)	0.578*** (0.180)	0.572*** (0.200)	-0.005 (0.051)
Catch x CS x SR						-0.601*** (0.184)		
Technology Cycle Time (TCT)	-0.071*** (0.013)	-0.085*** (0.021)	-0.078*** (0.020)	-0.071*** (0.016)	-0.047 (0.040)	0.075 (0.047)	0.060 (0.039)	-0.079** (0.037)
Catch x TCT		0.017 (0.023)				-0.213** (0.085)		
Countries (CN)	0.076*** (0.011)	0.032*** (0.006)	0.036*** (0.003)	0.105*** (0.011)	0.186*** (0.047)	0.160*** (0.050)	0.209*** (0.040)	0.132*** (0.051)
Catch x CN		0.083*** (0.010)				0.066 (0.081)		
Catch-up_Binary (Catch)		-0.979*** (0.209)				1.726* (0.977)		
Backward Citations	0.006*** (0.001)	0.005*** (0.001)	0.004*** (0.001)	0.013*** (0.002)	0.024*** (0.001)	0.023*** (0.001)	0.024*** (0.001)	0.018*** (0.0004)
Ln_Employees	-0.126* (0.074)	-0.243*** (0.060)	-0.167*** (0.051)	-0.420*** (0.069)	-0.221 (0.307)	-0.165 (0.293)	-0.032 (0.484)	-0.212 (0.354)
Ln_Patents	0.007 (0.128)	0.347*** (0.111)	0.133 (0.151)	0.581*** (0.119)	0.308 (0.378)	0.213 (0.493)	-0.621 (0.643)	0.570 (0.509)
Year Dummies	Yes	Yes	Yes	Yes	No	No	No	No
Intercept	5.859*** (0.703)	6.136*** (0.478)	6.246*** (0.367)	4.167*** (0.817)	-2.473 (2.929)	-3.403 (3.018)	0.140 (5.426)	-3.142 (1.949)
Log-likelihood	-100987.32	-100331.90	-43325.42	-56577.63	-56183.79	-56065.9	-24936.63	-26184.34
Observations	27546	27546	10402	17144	25657	25657	9908	15749

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Dependent Variables: Non-self Forward Citations (NFC) and Weighted Self forward Citations (WSFC).
Regression Models: Negative Binomial Regression (NB), Tobit Regression (Tobit). Clustered Standard Errors (CSE), standard errors in parentheses.

Several tests were conducted for robustness checks. First, clustered standard errors were estimated in order to address a large sample data issue. In the case of a large sample size where the error terms of the model are assumed to be correlated within clusters, error estimation without clustering may lead to small p-values. To enhance the robustness of the findings, standard errors are clustered by firm and year and then computed and reported in Table 1. The main findings are consistent with clustered standard errors. Second, the findings of the third phase of the data set (collected in 2021) were compared with those of the second phase of the data set (collected in 2020). This comparison makes the findings robust against the time-varying characteristics of variables (e.g., forward citations and SEP declarations). The results of the second phase of data analysis are reported in Appendix 5. As confirmed in Models 1 and 2 (Appendix 5), SEPs have curvilinear effects on non-self forward citations (CS^2).

4.2. Effects of SEP strategic manoeuvres and technology cycle time on self-reinforcing capacity

A set of statistical analyses of SEPs was conducted to examine the effects of SEP strategic manoeuvres on firms' self-reinforcing capabilities, including interaction effects, and results are reported in Table 1 (Models 5-8). It is assumed that a firm's strategic endeavours to incorporate a specific patent into a series of standards enhance its capability to select and reinforce prior technologies for future technological trajectories. According to the test results, the ratio of self backward citations (*SR*) is positively correlated with weighted self forward citations (*WSFC*). This means that the more a firm depends on its internal past technologies, the more likely it is to reuse those technologies for its own future innovation.

SEP strategic endeavours moderate this relationship between a firm's past dependence and its future trajectories, as evidenced by *CS* x *SR* (in Model 6) with statistical significance at the 0.01 level. The positive coefficient sign of *CS* x *SR* indicates that a firm's strategic efforts to develop SEPs intensify the curvilinear relationship between self-reliance and self-reinforcing capability for future innovation. This lends support to the following hypothesis. H2: *SEP strategic manoeuvring moderates the relationship between a firm's self-reliance and its capability to reinforce its own innovation.*

Moreover, three-way interaction terms of catch-up, citing standards and self-reliance were added in order to test whether there is a difference in the moderating effect of SEP strategic manoeuvring between incumbent and catch-up firms (Aiken & West, 1991). Model 6 shows that the three-way interaction term *Catch* x *CS* x *SR* is negatively correlated with weighted self forward citations (*WSFC*) at the 0.01 significant level. The negative coefficient sign of *Catch* x *CS* x *SR* reveals that the effects of SEP strategic manoeuvres on self-dependent path creation are not strong for catch-up firms, as compared to incumbent firms. Surprisingly, this result is exactly opposed to hypothesis H3-2. In fact, it supports the counter-hypothesis: *The moderating effect of SEP strategic manoeuvres is greater for incumbent firms than for catch-up firms*.

Figure 5 represents in graph form the moderating effect of SEP strategic manoeuvring on the relationship between self-reliance and self-reinforcing capability. It shows unambiguously that a high degree of SEP strategic manoeuvring leads to an increase in the effect of self-reliance on firms' patterns of creating their prospective trajectories. What is remarkable here is that the intensifying effect of SEP strategic actions becomes stronger for incumbent firms as the degree of self-reliance increases. This implies that there is a difference in the strategic intentions and effects of SEP development between incumbent and catch-up firms.

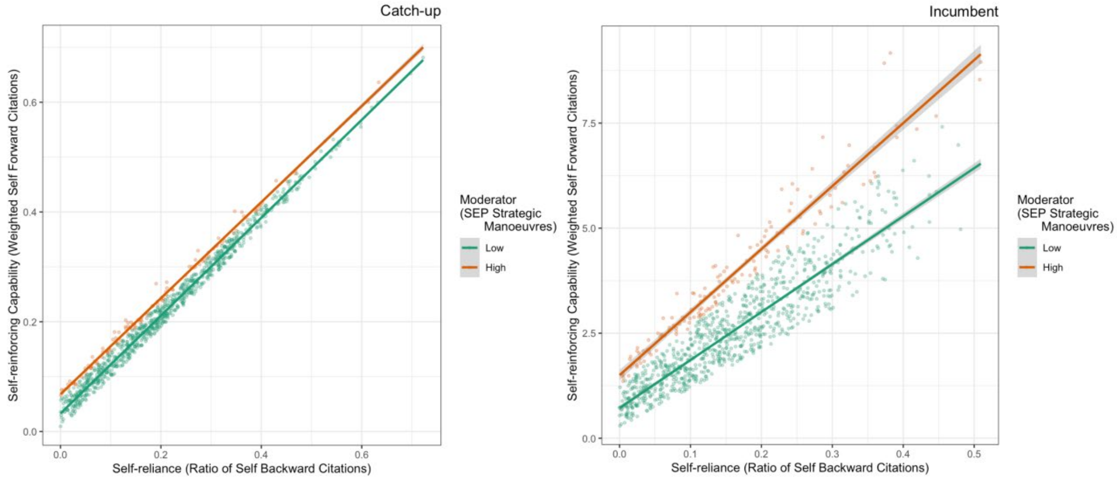

Figure 5. Graphical Representation of Moderating Effects of SEP Strategic Manoeuvres

In addition, Model 6 (Table 1) shows that catch-up firms rely on shorter cycle technology for their follow-up patents, as compared to incumbent firms (*Catch* x *TCT*). This difference in the effect of short cycle time on self-reinforcing capability (*WSFC*) is interesting, considering there is no statistically significant difference in the effect of technological cycle time between incumbent and catch-up firms on non-self forward citations (*NFC*) (*Catch* x *TCT* in Model 2). This implies an important role for short cycle time especially in catch-up firms' innovation strategy of developing indigenous technology. This supports the following hypothesis. H3-1: *The effect of short technology cycle time on self-reinforcing capability is greater for catch-up firms than for incumbents.*

Table 2 shows the differences between SEPs and non-SEPs in self-reinforcing capability. As shown in Models 1 and 2 (Table 2), SEPs exert more technological influence and self-reinforcing power than non-SEPs (*CS_B*). While Model 5 (Table 2) confirms that the effect of short technology cycle time on self-reinforcing capability is greater for catch-up firms when it comes to SEPs, Model 6 (Table 2) shows that there is no statistically significant difference between incumbent and catch-up firms for non-SEPs (*Catch* x *TCT*). This indicates that differences in approach to short technology cycle time between incumbent and catch-up firms are greater for SEPs vis-a-vis non-SEPs. For robustness checks, the method of clustered standard errors and the comparison of the second and third phases of the data sets were conducted. Most of the main findings are highly consistent. Regarding control variables, the regression results on self-reinforcing capability are consistent with the results on technological influence.

Table 2. Differences between SEPs and Non-SEPs

	Model 1 (SEP+Non-SEP)	Model 2 (SEP)	Model 3 (Non-SEP)	Model 4 (SEP+Non-SEP)	Model 5 (SEP)	Model 6 (Non-SEP)
	NB (CSE)	NB (CSE)	NB (CSE)	Tobit (CSE)	Tobit (CSE)	Tobit (CSE)
Dependent Variable (DV)	NFC	NFC	NFC	WSFC	WSFC	WSFC
Citing Standards_Binary (CS_B)	0.504*** (0.083)			0.654** (0.297)		
Self-reliance (SR)	-0.346*** (0.111)	-0.201 (0.143)	-0.473*** (0.147)	4.529*** (1.268))	2.588* (1.045)	7.422*** (1.955)
Technology Cycle Time (TCT)	-0.054*** (0.008)	-0.071*** (0.013)	-0.050*** (0.008)	-0.082*** (0.018)	-0.060 (0.044)	-0.123** (0.059)

Catch x TCT					-0.190** (0.084)	0.033 (0.070)
Countries (CN)	0.076*** (0.008)	0.076*** (0.011)	0.086*** (0.013)	0.227*** (0.059)	0.194*** (0.048)	0.363*** (0.116)
Catch-up_Binary					1.003 (0.655)	-0.141 (0.881)
Backward Citations	0.008*** (0.001)	0.006*** (0.001)	0.010*** (0.001)	0.032*** (0.003)	0.025*** (0.002)	0.037*** (0.008)
Ln_Employees	-0.099 (0.066)	-0.125* (0.072)	-0.058 (0.069)	-0.315 (0.353)	-0.178 (0.300)	-0.519 (0.463)
Ln_Patents	0.025 (0.102)	0.006 (0.118)	0.054 (0.097)	0.545 (0.369)	0.198 (0.549)	0.981* (0.580)
Year Dummies	Yes	Yes	Yes	No	No	No
Intercept	4.747 (0.574)	5.862 (0.705)	2.929 (0.607)	-4.642 (3.129)	-2.448 (3.672)	-7.664 (4.926)
Log-likelihood	-174002.67	-100993.72	-72294.62	-94803.15	-56194.13	-36991.66
Observations	52436	27546	24890	45743	25657	20086

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Dependent Variables: Non-self Forward Citations (NFC) and Weighted Self forward Citations (WSFC). Regression Models: Negative Binomial Regression (NB), Tobit Regression (Tobit). Clustered Standard Errors (CSE), standard errors in parentheses.

4.3. Positive effect of SEP strategic manoeuvres on patent litigation

Logistic regression tests were performed to ascertain the effects of independent variables on the likelihood of patent litigation and are reported in Table 3. Models 4, 5 and 6 (Table 3) show that the number of citing standards (*CS*) is positively associated with an increased likelihood of a SEP being involved in litigation. This indicates that the probability of patent litigation increases if a patented technology is incorporated into more standards. Hence, this finding corroborates the following hypothesis. H4: *SEP strategic manoeuvres are positively associated with the likelihood of patent litigation.*

Thereafter, a comparative analysis between SEPs and non-SEPs was conducted to investigate the strategic importance of SEPs vis-à-vis non-SEPs. As shown in Model 1 (Table 3), SEPs are more likely to be involved in patent litigation than non-SEPs (*CS_B*). In addition, Models 1, 2 and 3 demonstrate that it is more probable that SEPs with a greater number of international protections will be involved in patent litigation as compared to non-SEPs (*CN*, *CS_B* x *CN*). Considering the substantial costs involved, filing patents in foreign countries and developing SEPs both require firms' to be strongly strategically motivated. This confirms that patents where the strategic stakes are higher are likely to be involved in patent litigation.

Another interesting finding is that the weighted self forward citations are not associated with the likelihood of patent litigation (*WSFC* in Models 4, 5 and 6). This means that SEPs used for the purpose of developing self-reliant trajectories are less likely to be involved in patent suits. This finding is consistent with the effect of the self backward citation ratio (*SR*). Self-reliance (*SR*) is negatively associated at the 0.01 significance level (Models 1-6). This implies that a high degree of reliance on an external technological knowledge base increases the probability of a patent suit.

This research also examined whether there is a difference between catch-up firms and incumbents in the effects of variables on patent litigation. In Model 4 (Table 3), the effects of SEP strategic manoeuvres and the number of countries on the probability of patent litigation are stronger for catch-up firms than for incumbent firms at the 0.05 significance level (*Catch* x *CS, Catch* x *CN*). Considering the strategic natures of both SEP activities and patent filing activities for international protection, this finding implies that an increase in catch-up firms' strategic activities to enhance their bargaining power is likely to result in a higher probability of patent litigation.

Figure 6 represents the predicted probability of patent litigation involving SEPs. This dramatically increases after catch-up firms' SEP strategic manoeuvres and patent filing activities for international protection surpass certain thresholds. In both cases (*Catch* x *CS, Catch* x *CN* in Model 4), the acceleration effect is stronger for catch-up firms than for incumbent firms.

Regarding the effects of other variables, technology cycle time has little effect on the probability of patent litigation in general (*TCT* in Models 1 and 4). The number of backward citations in SEPs affects the likelihood of patent litigation (*BC* in Models 1 and 2). In contrast, backward citations in non-SEPs are not associated with patent litigation (*BC* in Model 3). The latter finding is consistent with Lanjouw and Schankerman's (1997) study which found no strong evidence that the number of backward citations affects the likelihood of patent litigation. This indicates that information about backward citations can play an important role in patent litigation where SEPs are involved. Firm size (*Ln_Employees*) and patenting experience (*Ln_Patents*) are not statistically significant. For a robustness check, clustered standard errors are estimated and reported in Table 3.

Table 3. Effect of SEP Strategic Manoeuvres on Patent Litigation

	Model 1 (SEP+Non-SEP)	Model 2 (SEP)	Model 3 (Non-SEP)	Model 4 (SEP)	Model 5 (SEP_Incumbent)	Model 6 (SEP_Catch-up)
	BL (CSE)	BL (CSE)	BL (CSE)	BL (CSE)	BL (CSE)	BL (CSE)
Dependent Variable (DV)	Litigation (Binary)	Litigation (Binary)	Litigation (Binary)	Litigation (Binary)	Litigation (Binary)	Litigation (Binary)
Citing Standards_Binary (CS_B)	0.813*** (0.313)					
Citing Standards (CS)				0.052*** (0.011)	0.058*** (0.009)	0.081*** (0.018)
Catch x CS				0.056** (0.025)		
Non-self Forward Citations (NFC)	0.004*** (0.001)	0.003*** (0.001)	0.008*** (0.001)	0.003** (0.001)	0.003** (0.001)	0.011 (0.009)
Weighted Self forward Citations (WSFC)	0.009* (0.005)	-0.006 (0.009)	0.014*** (0.004)	-0.017 (0.011)	-0.019 (0.014)	0.018 (0.029)
Self-reliance (SR)	-3.070*** (0.668)	-3.124*** (0.718)	-3.177*** (1.017)	-2.862*** (0.830)	-2.979*** (1.058)	-2.192*** (0.246)
Technology Cycle Time (TCT)	0.033 (0.034)	0.027 (0.055)	0.035 (0.035)	0.039 (0.041)	0.073*** (0.012)	-0.145 (0.157)
Countries (CN)	0.085*** (0.016)	0.117*** (0.013)	0.057*** (0.021)	0.108*** (0.009)	0.108*** (0.008)	0.212*** (0.074)
CS_B x CN	0.111*** (0.043)					
Catch x CN				0.084** (0.033)		
Catch-up_Binary				-0.204 (0.472)		
Backward Citations	0.001* (0.001)	0.003*** (0.001)	-0.0004 (0.0004)	0.003*** (0.001)	0.003*** (0.001)	0.003 (0.005)
Ln_Employees	0.201 (0.130)	0.206 (0.167)	0.284* (0.154)	0.357* (0.216)	0.243 (0.291)	1.013 (1.000)
Ln_Patents	-0.162 (0.145)	-0.177 (0.185)	-0.280 (0.222)	-0.498 (0.320)	-0.211 (0.528)	-0.957* (0.490)
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Intercept	16.530 (72.381)	18.361 (353.035)	-4.655*** (1.473)	18.035 (390.364)	17.777 (316.695)	-27.085 (129.890)
McFadden's Pseudo R^2	0.271	0.218	0.297	0.315	0.306	0.334
Observations	45743	25657	20086	25657	9908	15749

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Dependent Variable: Litigation (Binary).
Regression Model: Binary Logistic Regression (BL). Clustered Standard Errors (CSE), standard errors in parentheses.

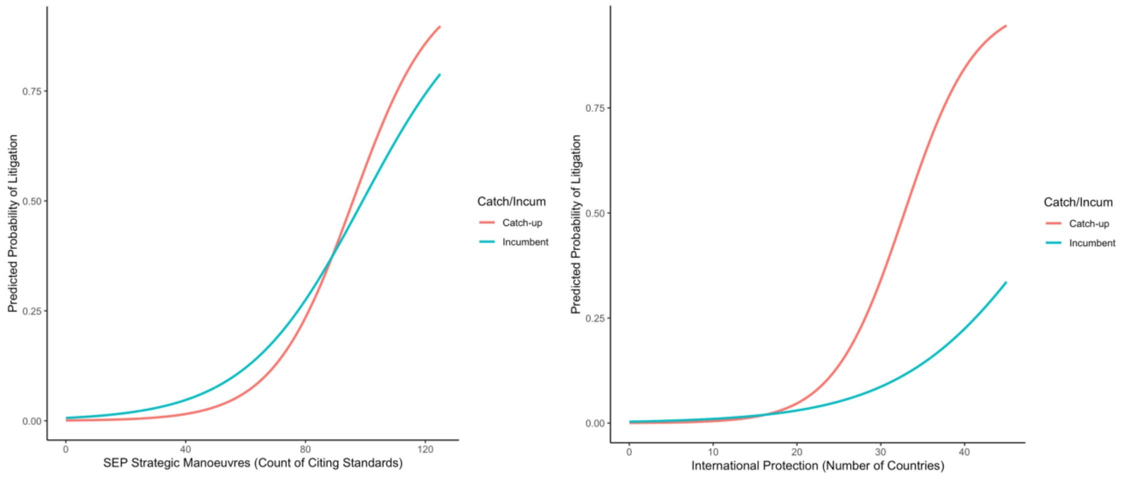

Figure 6. Predicted Probability of Litigation involving SEPs

Table 4. Summary of Hypothesis Test Results

	Hypothesis	**Results**
H1	SEP strategic manoeuvres are curvilinearly associated with technological influence.	Supported
H2	SEP strategic manoeuvres moderates the relationship between self-reliance and self-reinforcing capability	Supported
H3-1	The effect of short technology cycle time on self-reinforcing capability is greater for catch-up firms than incumbents.	Supported
H3-2	The moderating effect of SEP strategic manoeuvres on self-reinforcing capability is greater for catch-up firms than incumbents.	Counter-hypothesis is supported
H4	SEP strategic manoeuvres are positively associated with the likelihood of patent litigation.	Supported

5. Discussion

5.1. SEP strategic manoeuvres as an effective way of expanding catch-up firms' sphere of influence

5.1.1. Exponential increase in catch-up firms' influence after adapting to the rules of the SEP game

Overall, the test results in this paper have academic and practical implications for firms' SEP strategy within the context of catch-up/incumbent competitive dynamics. The first and most important finding is that a high degree of catch-up firms' strategic endeavours to incorporate their patents into a variety of standards leads to an increase in technological influence after surpassing a certain threshold, as shown in Figure 4. It is important to note that this relationship is curvilinear. Catch-up firms' initial attempts to incorporate their patented technologies into standards as SEPs do not increase their technological influence, and rather discourage other firms from adopting catch-up firms' technologies. Yet, if these strategic efforts continue and reach a certain threshold, catch-up firms' influence starts expanding in an exponential manner.

This threshold can be further contextualised as follows. SEPs are important strategic assets since the ownership of these patents increases a firm's knowledge position, which can be beneficial in negotiating licensing conditions with other firms and deriving economic rents (Bekkers & Martinelli, 2012; Bekkers et al., 2002). This is due to the embedded structure of patented technologies within a standard, resulting in the unavoidability of the SEP infringement for standard users. It means any firm using standardised technologies (e.g., 2G, 3G, 4G, and 5G standards) is obliged to negotiate the licensing conditions with relevant SEP owners. The strategic activity of including patented technologies into a standard enables firms to territorialise the foundational knowledge space and reap the benefits of royalties as other firms develop subsequent innovations building on their technology. This asymmetric power structure incentivises catch-up firms, which often are located on the periphery of the knowledge space, to enter the field of international standardisation to overcome the technology dependence trap (i.e., a paradoxical situation that the more products or services catch-up firms sell, the more royalties they pay to incumbents owning relevant patents) (Wang, Kwak, & Lee, 2014).

International standardisation is often viewed as an arena of fierce competition where powerful actors seek to control and legitimise the process of knowledge generation to secure favourable distributional outcomes (Mattli & Büthe, 2003).[1] If a firm enters this competitive field as a latecomer, there are a number of invisible barriers for them to overcome—e.g., institutional rules, language, culture and expertise (Schmidt & Werle, 1998)—before they can effectively raise their voices to influence others. Institutional barriers and a lack of experience put catch-up firms at a disadvantage when it comes to finding the right fit between their patented technologies and the future direction of standardisation. This misalignment can explain the negative relationship between catch-up firms' initial SEP strategic attempts and technological influence. However, as catch-up firms gain more experience through an increased number of SEP strategic manoeuvres, they become more efficient at aligning appropriate technologies with a series of standardisation activities. In turn, catch-up firms' ability to influence others' innovation activities grows exponentially. In other words, the continuation of SEP strategic manoeuvring transforms the area of standardisation from a learning place to a knowledge dissemination place for catch-up firms.

5.1.2. Catch-up firms' internalisation of short cycle technologies to disrupt the existing knowledge base of standards

Another significant finding to discuss is that the effect of short technology cycle time on self-reinforcing capability is greater for catch-up firms than for incumbents. Technology cycle time reflects the dynamics of creative destruction, where the persistence and obsolescence of technological knowledge oscillates. Short cycle time is of particular importance for catch-up firms because it eviscerates the reliance on older technologies which give in-built advantages to incumbents. According to Park and Lee's (2006) study, catch-up takes place more frequently in short cycle sectors only when latecomer firms have a certain level of absorptive capacity. This is because faster technological changes can interfere with the accumulation of entrant firms' learning experiences. Their research suggests that specialisation in short cycle sectors has been latecomer firms' crucial catch-up strategy.

Lee (2013) confirms that short cycle time is a key explanatory variable for the profitability of catch-up firms in South Korea. Despite providing highly valuable insights, Lee (2013) does not directly demonstrate how catch-up firms' investments in short cycle areas contribute to the closing of the gap in technological capabilities between incumbent and catch-up firms, particularly within the context of high-tech industries where fast technological changes occur. This paper contributes to providing answers to such research lacuna by investigating the

[1] This quotation from the Federal Trade Commission (FTC) supports this view. "[And] although the considerations of the standard tend to be expressed in rather technical language, behind this façade of engineering jargon, what is actually happening is an economic fight, often of the most savage type imaginable because the stakes are so high" (Mattli & Büthe, 2003, p. 1).

instrumental role of SEPs in the catching-up process of technological capabilities. As shown in Table 2, SEPs are different from non-SEPs in terms of their potential to influence others' innovation activities (*CB_B* in Model 1). Due to their significant potential, catch-up firms internalise short cycle technologies as their in-house knowledge base for standards-setting (*Catch x TCT* in Model 5). This difference between incumbent and catch-up firms when it comes to the effect of short cycle time occurs only in the SEP patenting area, not in non-SEP patenting (*Catch* x *TCT* in Model 6). This finding indicates that catch-up firms' strategic motivation for SEP patenting differs from that of incumbent firms. Whereas incumbent firms cultivate self-reliant technologies to ensure the continuity of the existing knowledge foundation of standards, catch-up firms internalise short cycle technologies to strategically render older technologies embedded within standards insignificant.

5.2. SEP strategic manoeuvres as a catalyst to generate incumbent firms' self-reliant trajectories

One of the most novel and significant findings is that the moderating effect of SEP strategic manoeuvres on self-reinforcing capability is greater for incumbents than for catch-up firms, as shown in Figure 5. Counter-intuitively, it overturns the initial hypothesis that standards-related activities are expected to influence the development of catch-up firms' ability to produce indigenous innovations more than that of incumbents. Quite a number of previous studies emphasise the importance of participation in standardisation bodies for catch-up firms' innovation (e.g., Zhang, Wang, & Zhao, 2020). Yet there is relatively little literature that discusses how incumbent firms' SEP patenting differs from that of catch-up firms. In this context, the finding of this paper is valuable as it points out the facilitating role of SEP strategic moves in incumbent firms' self-reliant technological path generation in line with the future direction of standardisation.

The functions of self-citations differ from those of non-self citations. Firms' self-citing activities reflect the cumulative nature of innovation and the appropriability of the return from its own knowledge base (Hall et al., 2005). This internalisation leads to competitive advantages in producing follow-up innovation more quickly thanks to lower search costs. A high degree of alignment between self backward citations and self forward citations results in the creation of a protected technology space where other firms are put under pressure to circumvent an inventing firm's monopolised territory. In fact, Novelli (2015) confirms that self-citations are positively associated with the number of patent claims, which works to deter competitors from entering an inventing firm's technological area. The construction of patent fences is particularly salient if the expected monopoly profits are large in the competitive patent race (Schneider, 2008).

In this paper, self-citations are used to measure a firm's self-reinforcing capability to consolidate the internal mechanism of self-reliant technological path generation. As with Lee and Lim (2001), this capability is a function of technological effort and the existing knowledge base. The effects of self-reinforcing capability (e.g., low search costs and the construction of patent fences) may lead to firms' higher performance. For instance, Lee's (2013) study shows that for advanced firms (e.g., US firms), self-citations are positively associated with sales. While Lee (2013) focuses on the relationship between the self-citation ratio and firms' performance, this paper discusses the role of SEPs in creating sequences of follow-on patents linked by self-citations in line with a particular trajectory of technological standardisation. The finding on the intensifying effects of incumbent firms' strategic SEP efforts towards self-reinforcing capability implies that incumbent firms have been strategically employing the rules of the SEP game to align their self-dependent trajectories closely with the direction of anticipatory standardisation. This alignment is strategically significant, because incumbent firms' mistakes in sponsoring non-dominant standards open up a window of opportunity for latecomers to leapfrog (Cusumano, Mylonadis, & Rosenbloom, 1992; Lee et al., 2005). Understanding this risk, the alignment of external standardisation with the internal self-reinforcing mechanism is a crucial part of the strategic objective of incumbent firms' SEP patenting. This strategic motive is reflected in the finding on the moderating effect of SEP strategic manoeuvres.

5.3.SEP strategic manoeuvres as determinants of patent litigation

5.3.1. Catch-up firms' SEP strategic manoeuvring as defensive patenting

As shown in Figure 6 (left-hand side), a high degree of SEP strategic manoeuvring is positively associated with patent litigation. It is likely that the strategic aspect of SEPs contributes to this relationship. As evidenced in the GSM case, firms' strategic attempts to own a large portfolio of SEPs increases their knowledge position in a specific technological domain (Bekkers et al., 2002). Firms may leverage SEPs as valuable bargaining chips to dictate in their favour the conditions of cross-licensing and market access. In addition, firms may employ SEPs defensively to counteract other firms' patent suits (Somaya, 2003). This type of patenting activity is referred to as defensive patenting, which "involves the accumulation of patents to use as bargaining chips to preserve the freedom to operate and to improve the bargaining position of the firm in resolving patent dispute when they arise" (Noel & Schankerman, 2013, p 483). The finding that the effect of SEP strategic manoeuvres on patent litigation is greater for catch-up firms than for incumbent firm can be interpreted within the context of catch-up firms' defensive patenting motive of SEPs to enhance their bargaining position in addressing potential patent disputes. In fact, the well-known patent dispute case of Apple vs Samsung shows how Samsung capitalised on their SEPs to counter-sue Apple, resulting in the negotiation for the settlement.

The number of countries (international protection) is also positively associated with the probability of patent litigation, and its effect is stronger for catch-up firms. Some catch-up firms (e.g., South Korean firms) are highly active in protecting SEPs in many different countries (Dang et al., 2019). These patents with large family size (a high number of international protections) are considered more valuable (Harhoff et al., 2003). The filing of a patent for international protection reflects firms' strategic intention to increase the size of patent protection for the same technology. Accordingly, catch-up firms' patenting activities for a higher number of international protections can also be interpreted in line with the logic of defensive patenting.

5.3.2. Incumbent firms' SEP strategic manoeuvring as proprietary patenting

This paper shows that incumbent firms have been using SEPs to create a self-reliant knowledge base in line with anticipatory standardisation. This suite of strategic actions can be interpreted as proprietary patenting that aims to stake out a proprietary market advantage and create isolating mechanisms that protect the firm's key competitive advantages from imitation (Somaya, 2012). This is different from catch-up firms' defensive patenting approach, that uses patent litigation as an instrument for securing greater bargaining power. In fact, the effects on patent litigation of SEP strategic manoeuvres and the number of countries are less strong for incumbent firms. Moreover, weighted self forward citations on patent litigation are not associated with patent litigation and the self-reliance ratio is negatively correlated with litigation. Based on this set of facts, the main function of incumbent firms' strategic manoeuvres can be described as the creation of a self-reliant technological trajectory that forms a protected space where incumbent firms retain a competitive edge.

6. Conclusion

Following the successful catch-up experience, leading firms in East Asian countries (e.g., South Korea and China) are now discussing post catch-up strategy. Standardisation is at the centre of post catch-up strategy, as it shapes a new technological path for others to follow. By comparing the SEP data sets of incumbent and catch-up groups, this paper has demonstrated statistically significant differences in the effects of SEP strategic manoeuvres between incumbent and catch-up firms. First, SEP strategic manoeuvres function as a potent way of expanding the sphere of catch-up firms' influence. Especially after passing a certain threshold, catch-up firms' technological influence increases in an exponential manner. With respect to the cultivation of self-reinforcing capability, catch-up firms tend to strategically specialise in short cycle technologies, which can be used to disrupt the existing knowledge base of standardisation. Second, for incumbent firms, SEP strategic manoeuvres serve as a catalyst to deepen the development of self-reliant trajectories in line with the direction of anticipatory standardisation. Third, the effects of SEP strategic manoeuvres and international protection size are greater for catch-up firms than for incumbent firms.

The implications of the findings are twofold. First, within the context of catch-up strategy, this research shows that participation in standardisation is an effective channel for catch-up firms not only to learn advanced technologies in progress, but also to increase technological influence via SEPs. It is strategically important for catch-up firms to understand SSOs' dual role of knowledge-learning and knowledge-diffusion spaces. In contrast, for incumbent firms, emphasis is placed more on the alignment of their self-reliant trajectories with the direction of anticipatory standardisation, which is "intended to guide the emergence of new technologies and consequently set far in advance of the markets' ability to signal the features of products and processes that users will value" (David, 1995, p. 29). It is regarded as incumbents' strategic efforts to preclude making the mistake of sponsoring the wrong standards, which opens up a window of opportunity to catch-up firms.

This difference can be interpreted as a lesson for post catch-up strategy. Once catch-up firms close the gap in technological capability with incumbent firms by fully harnessing SSOs' effects on knowledge sharing, they need to consider the pivoting of their catch-up strategy, from disrupting the existing knowledge base with short cycle technologies to enhancing the continuation of their self-reliant trajectories in line with the direction of anticipatory standardisation. That is to say, *post catch-up strategy* implies that catch-up firms need to not only disseminate their indigenous innovations, but also generate the long-standing trajectories of self-reliant knowledge embodied in the history and future of standards.

Second, the findings contribute to the strategic patenting literature (e.g., Blind et al., 2009; Somaya, 2012). This stream of literature has discussed the different types of strategic patenting (e.g., proprietary, defensive and leveraging). Building on that literature, this paper shows that catch-up firms use the development of SEPs as a defensive patenting approach that aims to increase their bargaining power within the competitive field of standardisation. On the other hand, incumbent firms' approach to SEP development is closer to proprietary patenting. This aims to create self-reinforcing mechanisms to reproduce self-reliant technological paths and stake out proprietary competitive advantages.

There are some limitations to the findings of this paper. First, the data set of SEPs is mostly related to telecommunications and IT technologies. It is also based on a selected sample group of the top 10 SEP firms, as those firms account for a large majority of the SEP data distribution. Accordingly, the generalisability of the findings beyond these high-tech industries and the top ten SEP firms is somewhat limited. Thus, the extended application of these findings to other industries should be done with care. Second, there may be mutual causality between SEP strategic manoeuvres and technological influence (or self-reinforcing capability). More robustness tests could have been carried out to address the endogeneity issue if the patent database provided the declaration years of SEPs and separated forward citations' application years into those of non-self and self forward citations.

Regarding possible directions for future research, the following issues could be further explored: first, investigation of the SEP strategies of incumbent and new entrant firms in technological sectors with industry convergence (e.g., connected vehicles); second, study of the effects of SEPs on start-ups' investment portfolios and patent litigation strategy.

References

Aiken, L. S., & West, S. G. (1991). *Multiple Regression: Testing and Interpreting Interactions*. SAGE Publications.

Allison, J. R., & Lemley, M. A. (1998). Empirical evidence on the validity of litigated patents. *AIPLA Quarterly Journal*, *26*(3), 185–275.

Amsden, A. H. (1989). *Asia's Next Giant: South Korea and Late Industrialization*. https://doi.org/10.1093/0195076036.001.0001

Arthur, W. B. (1994). *Increasing Returns and Path Dependence in the Economy*. University of Michigan Press.

Baron, J., & Pohlmann, T. (2018). Mapping standards to patents using databases of declared standard-essential patents. *Journal of Economics and Management Strategy*, *27*(3), 504–534.

Baron, J., Pohlmann, T., & Blind, K. (2016). Essential patents and standard dynamics. *Research Policy*, *45*(9), 1762–1773. https://doi.org/10.1016/j.respol.2016.05.004

Bekkers, R., Bongard, R., & Nuvolari, A. (2011). An empirical study on the determinants of essential patent claims in compatibility standards. *Research Policy*, *40*(7), 1001–1015. https://doi.org/10.1016/j.respol.2011.05.004

Bekkers, R., Iversen, E., & Blind, K. (2011). Emerging ways to address the reemerging conflict between patenting and technological standardization. *Industrial and Corporate Change*, *21*(4), 901–931. https://doi.org/10.1093/icc/dtr067

Bekkers, R., & Martinelli, A. (2012). Knowledge positions in high-tech markets: Trajectories, standards, strategies and true innovators. *Technological Forecasting and Social Change*, *79*(7), 1192–1216. https://doi.org/10.1016/j.techfore.2012.01.009

Bekkers, R., Verspagen, B., & Smits, J. (2002). Intellectual property rights and standardization: the case of GSM. *Telecommunications Policy*, *26*(3), 171–188.

Berger, F., Blind, K., & Thumm, N. (2012). Filing behaviour regarding essential patents in industry standards. *Research Policy*, *41*(1), 216–225. https://doi.org/10.1016/j.respol.2011.07.004

Blind, K., Cremers, K., & Mueller, E. (2009). The influence of strategic patenting on companies' patent portfolios. *Research Policy*, *38*(2), 428–436. https://doi.org/10.1016/j.respol.2008.12.003

Blind, K., & Mangelsdorf, A. (2016). Motives to standardize: Empirical evidence from Germany. *Technovation*, *48–49*, 13–24. https://doi.org/10.1016/j.technovation.2016.01.001

Botzem, S., & Dobusch, L. (2012). Standardization cycles: A process perspective on the formation and diffusion of transnational standards. *Organization Studies*, *33*(5–6), 737–762. https://doi.org/10.1177/0170840612443626

Carpenter, M. P., Narin, F., & Woolf, P. (1981). Citation rates to technologically important patents. *World Patent Information*, *3*(4), 160–163. https://doi.org/10.1016/0172-2190(81)90098-3

Cassiman, B., Veugelers, R., & Zuniga, P. (2008). In search of performance effects of (in)direct industry science links. *Industrial and Corporate Change*, *17*(4), 611–646. https://doi.org/10.1093/icc/dtn023

Criscuolo, P., & Verspagen, B. (2008). Does it matter where patent citations come from? Inventor vs. examiner citations in European patents. *Research Policy*, *37*(10), 1892–1908. https://doi.org/10.1016/j.respol.2008.07.011

Cusumano, M. A., Mylonadis, Y., & Rosenbloom, R. S. (1992). Strategic maneuvering and mass-market dynamics - the triumph of VHS over Beta. *Business History Review*, *66*(1), 51–94.

Dang, J., Kang, B., & Ding, K. (2019). International protection of standard essential patents. *Technological Forecasting and Social Change*, *139*(July 2018), 75–86. https://doi.org/10.1016/j.techfore.2018.06.039

David, P. (1985). Clio and the economics of QWERTY. *The American Economics Review*, *75*(2), 332–337.

David, P. (1995). Standardization policies for network technologies: The flux between freedom and order revisited. In R. Hawkins, R. Mansell, & J. Skea (Eds.), *Standards, Innovation and Competitiveness: The Politics and Economics of Standards in Natural and Technical Environments* (pp. 15–35). Edward Elgar Publishing Ltd.

David, P., & Steinmueller, W. E. (1994). Economics of compatibility standards and competition in telecommunication networks. *Information Economics and Policy*, *6*(94), 217–241. https://doi.org/10.1016/0167-6245(94)90003-5

Delcamp, H., & Leiponen, A. (2014). Innovating standards through informal consortia: The case of wireless telecommunications. *International Journal of Industrial Organization*, *36*, 36–47. https://doi.org/10.1016/j.ijindorg.2013.07.004

EPO. (2014, March). Beyond patent families - an updated perspective. *Patent Information News*, (1), 4–5. Retrieved from http://documents.epo.org/projects/babylon/eponet.nsf/0/CE0CCA52C8BAEFCDC1257C99004C1BA2/$File/patent_information_news_0114_en.pdf

Ernst, D., Lee, H., & Kwak, J. (2014). Standards, innovation, and latecomer economic development: Conceptual issues and policy challenges. *Telecommunications Policy*, *38*(10), 853–862. https://doi.org/10.1016/j.telpol.2014.09.009

Farrell, J. (1989). Standardization and intellectual property. *Jurimetrics*, *30*(1), 35–50.

Griliches, Z. (1990). Patent statistics indicators as economic indicators: A survey. *Journal of Economic Literature*, *28*(4), 1661–1707. Retrieved from http://www.jstor.org/fcgi-bin/jstor/listjournal.fcg/00220515/.21-.30

Hall, B. H., Jaffe, A., & Trajtenberg, M. (2005). Market value and patent citations. *RAND Journal of Economics*, *36*(1), 16–38.

Hall, B., Jaffe, A., & Trajtenberg, M. (2002). The NBER patent citation data file: Lessons, insights and methodological tools. In A. B. Jaffe & M. Trajtenberg (Eds.), *Patents, Citations, and Innovations: A Window on the Knowledge Economy* (pp. 403–459). MIT Press.

Harhoff, D., Scherer, F. M., & Vopel, K. (2003). Citations, family size, opposition and the value of patent rights. *Research Policy*, *32*(8), 1343–1363. https://doi.org/10.1016/S0048-7333(02)00124-5

Hughes, T. P. (1987). The evolution of large technological systems. In W. E. Bijker, T. P. Hughes, & T. J. Pinch (Eds.), *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology* (pp. 51–82). MIT Press.

Hussinger, K., & Schwiebacher, F. (2015). The market value of technology disclosures to standard setting organizations. *Industry and Innovation*, *22*(4), 321–344. https://doi.org/10.1080/13662716.2015.1049866

Jaffe, A. B., Trajtenberg, M., & Fogarty, M. S. (2002). The meaning of patent citations: Report on the NBER/Case-Western Reserve survey of patentees. In A. B. Jaffe & M. Trajtenberg (Eds.), *Patents, Citations, and Innovations: A Window on the Knowledge Economy* (pp. 379–401). MIT Press.

Jensen, R., & Thursby, M. (1996). Patent races, product standards, and international competition. *International Economic Review*, *37*(1), 21–49.

Joo, S. H., & Lee, K. (2010). Samsung's catch-up with Sony: An analysis using U.S. patent data. *Journal of Asia-Pacific Economy*, *15*(3), 271–287.

Joo, S. H., Oh, C., & Lee, K. (2016). Catch-up strategy of an emerging firm in an emerging country: Analysing the case of Huawei vs. Ericsson with patent data. *International Journal of Technology Management*, *72*(1–3), 19–42. https://doi.org/10.1504/IJTM.2016.10001555

Jung, M., & Lee, K. (2010). Sectoral systems of innovation and productivity catch-up: Determinants of the productivity gap between Korean and Japanese firms. *Industrial and Corporate Change*, *19*(4), 1037–1069. https://doi.org/10.1093/icc/dtp054

Kang, B., & Bekkers, R. (2015). Just-in-time patents and the development of standards. *Research Policy*, *44*(10), 1948–1961. https://doi.org/10.1016/j.respol.2015.07.001

Kang, Byeongwoo, Huo, D., & Motohashi, K. (2014). Comparison of Chinese and Korean companies in ICT global standardization: Essential patent analysis. *Telecommunications Policy*, *38*(10), 902–913. https://doi.org/10.1016/j.telpol.2014.09.004

Kang, Byeongwoo, & Motohashi, K. (2015). Essential intellectual property rights and inventors' involvement in standardization. *Research Policy*, *44*(2), 483–492. https://doi.org/10.1016/j.respol.2014.10.012

Kim, D., Lee, H., & Kwak, J. (2017). Standards as a driving force that influences emerging technological trajectories in the converging world of the Internet and things: An investigation of the M2M/IoT patent network. *Research Policy*, *46*(7), 1234–1254. https://doi.org/10.1016/j.respol.2017.05.008

Kim, L. (1997). *Immitation to Innovation: The Dynamics of Korea's Technoloigcal Learning*. Harvard Business School Press.

Kim, S., & Hart, J. A. (2002). The global political economy of Wintelism: A new mode of power and governance in the global computer industry. In J. M. Rosenau & J. P. Singh (Eds.), *Information Technologies and Global Politics: The Changing Scope of Power and Governance* (pp. 143–168). State University of New York (SUNY) Press.

Kindleberger, C. P. (1983). Standards as public, collective and private goods. *Kyklos*, *36*(3), 377–396.

Kwak, J., Lee, H., & Chung, D. B. (2012). The evolution of alliance structure in China's mobile telecommunication industry and implications for international standardization. *Telecommunications Policy*, *36*(10–11), 966–976. https://doi.org/10.1016/j.telpol.2012.07.017

Lanjouw, J. O., & Schankerman, M. (1997). *Stylized Facts of Patent Litigation: Value, Scope and Ownership* (No. 6297).

Lee, H., & Oh, S. (2006). A standards war waged by a developing country: Understanding international standard setting from the actor-network perspective. *The Journal of Strategic Information Systems*, *15*(3), 177–195. https://doi.org/10.1016/j.jsis.2005.10.002

Lee, H., & Oh, S. (2008). The political economy of standards setting by newcomers: China's WAPI and South Korea's WIPI. *Telecommunications Policy*, *32*(9–10), 662–671.

Lee, K. (2013). *Schumpeterian Analysis of Economic Catch-up*. Cambridge University Press.

Lee, K., & Lim, C. (2001). Technological regimes, catching-up and leapfrogging: findings from the Korean industries. *Research Policy*, *30*(3), 459–483. https://doi.org/10.1016/S0048-7333(00)00088-3
Lee, K., Lim, C., & Song, W. (2005). Emerging digital technology as a window of opportunity and technological leapfrogging: catch-up in digital TV by the Korean firms. *International Journal of Technology Management*, *29*(1/2), 40. https://doi.org/10.1504/IJTM.2005.006004
Leiponen, A. (2008). Competing through cooperation: The organization of standard setting in wireless telecommunications. *Management Science*, *54*(11), 1904–1919. https://doi.org/10.1287/mnsc.1080.0912
Lemley, M. (2002). Intellectual property rights and standard-setting organizations. *California Law Review*, *90*, 1889–1980. Retrieved from http://www.jstor.org/stable/3481437
Lemley, M. A., & Simcoe, T. (2018). How essential are standard-essential patents? *Cornell Law Review*, *104*, 607–642.
Lin, J. Y., Cai, F., & Li, Z. (1996). *China Miracle*. Hong Kong: Chinese University Press.
Lyytinen, K., & King, J. L. (2006). Standard making: A critical research frontier for information systems research. *MIS Quarterly*, *30*(August), 405–411.
Martinelli, A., & Nomaler, Ö. (2014). Measuring knowledge persistence: A genetic approach to patent citation networks. *Journal of Evolutionary Economics*, *24*(3), 623–652. https://doi.org/10.1007/s00191-014-0349-5
Mattli, W., & Büthe, T. (2003). Setting international standards: Technological rationality or primacy of power? *World Politics*, *56*(01), 1–42. https://doi.org/10.1353/wp.2004.0006
Morris, C. R., & Ferguson, C. H. (1993). How architecture wins technology wars. *Harvard Business Review*, *71*(2), 86–96.
Mu, Q., & Lee, K. (2005). Knowledge diffusion, market segmentation and technological catch-up: The case of the telecommunication industry in China. *Research Policy*, *34*(6), 759–783. https://doi.org/10.1016/j.respol.2005.02.007
Narin, F. (1994). Patent bibliometrics. *Scientometrics*, *30*(1), 147–155. https://doi.org/10.1007/BF02017219
New Delhi Times. (2013, June 5). *US ITC Says Apple Infringes Samsung Patent, Bans Some Products*. Retrieved from https://www.newdelhitimes.com/itc-apple-infringes-samsung-patent-bans-products/
Noel, M., & Schankerman, M. (2013). Strategic patenting and software innovation. *Journal of Industrial Economics*, *61*(3), 481–520. https://doi.org/10.1111/joie.12024
Novelli, E. (2015). An examination of the antecedents and implications of patent scope. *Research Policy*, *44*(2), 493–507. https://doi.org/10.1016/j.respol.2014.09.005
OECD. (2009). *OECD Patent Statistics Manual*. Retrieved from https://www.oecd-ilibrary.org/science-and-technology/oecd-patent-statistics-manual_9789264056442-en
Park, H., & Magee, C. L. (2017). Tracing technological development trajectories: A genetic knowledge persistence-based main path approach. *PloS One*, *12*(1), 1–18. https://doi.org/10.1371/journal.pone.0170895
Park, K. H., & Lee, K. (2006). Linking the technological regime to the technological catch-up: Analyzing Korea and Taiwan using the US patent data. *Industrial and Corporate Change*, *15*(4), 715–753. https://doi.org/10.1093/icc/dtl016
Perez, C., & Soete, L. (1988). Catching up in technology: entry barriers and windows of opportunity. In C. Freeman, R. Nelson, G. Silverberg, & L. Soete (Eds.), *Technical Change and Economic Theory* (pp. 458–479). London: Pinter.
Pfeffer, J. (1981). *Power in Organizations*. HarperBusiness.
Pohlmann, T., Neuhäusler, P., & Blind, K. (2016). Standard essential patents to boost financial

returns. *R and D Management*, *46*(2011), 612–630. https://doi.org/10.1111/radm.12137
Reitzig, M. (2004). Improving patent valuations for management purposes - Validating new indicators by analyzing application rationales. *Research Policy*, *33*(6–7), 939–957. https://doi.org/10.1016/j.respol.2004.02.004
Rosenberg, N. (1982). *Inside the black box: Technology and economics*. Cambridge University Press.
Russell, A. L. (2005). Standardization in history: A review essay with an eye to the future. *The Standards Edge: Future Generations*, 247–260.
Russon, M.-A. (2020, August 24). Carmakers urge FTC to fight Qualcomm ruling. *BBC News*. Retrieved from https://www.bbc.co.uk/news/business-53897401
Rysman, M., & Simcoe, T. (2008). Patents and the performance of voluntary standard-setting organizations. *Management Science*, *54*(11), 1920–1934. https://doi.org/10.1287/mnsc.1080.0919
Schmidt, S. K., & Werle, R. (1998). *Coordinating technology: Studies in the international standardization of telecommunications*. MIT Press.
Schneider, C. (2008). Fences and competition in patent races. *International Journal of Industrial Organization*, *26*, 1348–1364. https://doi.org/10.1016/j.ijindorg.2008.01.003
Schumpeter, J. (1935). The analysis of economic change. *The Review of Economic Statistics,* (May).
Shapiro, C. (2001). Navigating the patent thicket: Cross licenses, patent pools, and standard setting. In A. B. Jaffe, J. Lerner, & S. Stern (Eds.), *Innovation Policy and the Economy* (Vol. 1, pp. 119–150). MIT Press.
Shim, Y., & Shin, D.-H. (2015). Analyzing the development of 4th generation mobile network in China: Actor network theory perspective. *Info*, *17*(1).
Somaya, D. (2003). Strategic determinants of decisions not to settle patent litigation. *Strategic Management Journal*, *24*(1), 17–38. https://doi.org/10.1002/smj.281
Somaya, D. (2012). Patent strategy and management: An integrative review and research agenda. *Journal of Management*, *38*(4), 1084–1114. https://doi.org/10.1177/0149206312444447
Sun, Y. (2003). Determinants of foreign patents in China. *World Patent Information*, *25*(1), 27–37. https://doi.org/10.1016/S0172-2190(02)00086-8
Suttmeier, R. P., Yao, X., & Tan, A. Z. (2006). *Standards of Power? Technology, Institutions, and Politics in the Development of China' s National Standards Strategy* (Vol. 7). The National Bureau of Asian Research.
Trajtenberg, M. (1990). A penny for your quotes: Patent citations and the value of innovations. *The RAND Journal of Economics*, *21*(1), 172–187.
Trajtenberg, M., Henderson, R., & Jaffe, A. B. (2002). University versus corporate patents: A window on the basicness of invention. In A. B. Jaffe & M. Trajtenberg (Eds.), *Patents, Citations, and Innovations: A Window on the Knowledge Economy* (pp. 51–87). The MIT Press.
Von Wartburg, I., Teichert, T., & Rost, K. (2005). Inventive progress measured by multi-stage patent citation analysis. *Research Policy*, *34*(10), 1591–1607. https://doi.org/10.1016/j.respol.2005.08.001
Wang, P., Kwak, J., & Lee, H. (2014). The latecomer strategy for global ICT standardization: Indigenous innovation and its dilemma. *Telecommunications Policy*, *38*(10), 933–943. https://doi.org/10.1016/j.telpol.2014.09.001
Wang, P., Wang, Y., & Hill, J. (2010). *Standardization Strategy of China -- Achievements and Challenges*. East-West Center.
Yoo, Y., Lyytinen, K., & Yang, H. (2005). The role of standards in innovation and diffusion of broadband mobile services: The case of South Korea. *Journal of Strategic Information Systems*, *14*(3), 323–353. https://doi.org/10.1016/j.jsis.2005.07.007
Zhang, M., Wang, Y., & Zhao, Q. (2020). Does participating in the standards-setting process

promote innovation? Evidence from China. *China Economic Review*, *63*, 1–18. https://doi.org/10.1016/j.chieco.2020.101532

Appendix 1. Descriptive Statistics of Variables (First and Second Phases of Data Set)

First Phase of Data set (SEP + Non-SEP)							Second Phase of Data set (SEP)					
Variables	Description	Obs.	Mean	SD	Min.	Max.	Variables	Obs.	Mean	SD	Min.	Max.
Non-self forward citations (NFC)	Number of citations that a patent receives from other firms' subsequent patents	25406	15.18	35.65	0.00	1030.00	NFC	20539	18.25	35.37	0.00	1162.00
Weighted self forward citations (WSFC)	Number of self forward citations weighted with the ratio of self forward citations						WSFC	18041	0.99	3.86	0.00	190.88
Litigation (LI)	Whether a patent is involved in litigation						LI (Binanry)	20539	0.006	0.077	0.00	1.00
Citing standards (CS)	Number of standards citing a specific patent	12703	3.26	3.43	1.00	54.00	CS	20539	4.00	3.77	1.00	56.00
Self-reliance (SR)	Ratio of self backward citations to backward citations	22209	0.19	0.23	0.00	1.00	SD	19375	0.14	0.16	0.00	1.00
Technological cycle time (TCT)	Mean backward citation lag between the application year of the citing patent and that of cited patents	23845	3.76	1.93	-1.00	23.45	TC	19375	3.71	1.99	-4.00	28.00
Backward citations (BC)	Number of citations made by a patent to prior patents	25406	20.05	37.31	0.00	1456.00	BC	20539	19.24	47.51	0.00	953.00
Countries (CN)	Number of countries in which legal protection was sought for a patent family	25406	5.18	4.36	1.00	31.00	CN	20539	5.38	4.50	1.00	31.00
Firm Size (EMP)	Number of total employees	25406	58722.81	39726.15	80.00	180000.00	EMP	20492	69757.09	45453.77	350.00	180000.00
Patents (PAT)	Number of total patents	25406	4545.96	4001.31	2.00	21010.00	PAT	20532	4498.92	3528.16	11.00	21010.00
Diversity (DIV)	Herfindahl index of a patent's classification (4-digit IPC code)	25392	0.40	0.26	0.00	0.87						
Claims (CLA)	Number of independent claims	23938	3.94	2.52	0.00	60.00						
Family Age (AGE)	Months between the oldest patent and the latest patent within the same family	25406	24.08	32.21	0.00	234.00						

Appendix 2. Descriptive Statistics of Variables (Third Phase of Data Set)

SEP							Non-SEP					
Variables	Description	Obs.	Mean	SD	Min.	Max.	Variables	Obs.	Mean	SD	Min.	Max.
Non-self forward citations (NFC)	Number of citations that a patent receives from other firms' subsequent patents	29024	18.75	35.34	0.00	1225.00	NFC	29024	8.77	23.32	0.00	945.00
Weighted self forward citations (WSFC)	Number of self forward citations weighted with the ratio of self forward citations	26489	0.85	3.72	0.00	289.93	WSFC	21854	0.80	5.00	0.00	257.47
Litigation (LI)	Whether a patent is involved in litigation	29024	0.006	0.077	0.00	1.00	LI (Binanry)	29024	0.0013	0.036	0.00	1.00
Citing standards (CS)	Number of standards citing a specific patent	29024	3.98	3.63	1.00	66.00						
Self-reliance (SR)	Ratio of self backward citations to backward citations	27599	0.14	0.16	0.00	1.00	SR	24891	0.12	0.18	0.00	1.00
Technological cycle time (TCT)	Mean backward citation lag between the application year of the citing patent and that of cited patents	27599	3.75	2.42	-2.00	27.75	TCT	24891	5.22	3.38	-3.00	8.00
Countries (CN)	Number of countries in which legal protection was sought for a patent family	29024	5.23	4.39	1.00	33.00	CN	29024	2.70	2.75	1.00	34.00
Backward citations (BC)	Number of citations made by a patent to prior patents	29024	18.96	42.40	0.00	956.00	BC	29024	15.26	58.85	0.00	3337.00
Firm Size (EMP)	Number of total employees	28941	72736.16	49589.03	80.00	180000.00	EMP	29020	72880.95	49549.02	191.00	180000.00
Patents (PAT)	Number of total patents	28969	4422.94	3361.88	2.00	21010.00	PAT	29020	4454.98	3430.90	42.00	21010.00

Appendix 3. Correlation matrix (Third Phase of Data Set)

	SEP								
	NFC	WSFC	LI	CS	SR	TCT	BC	CN	EMP
WSFC	0.24								
LI	0.15	0.07							
CS	0.11	0.09	0.07						
SR	-0.04	0.04	-0.02	-0.01					
TCT	-0.06	0.02	0.01	-0.02	-0.08				
BC	0.32	0.27	0.09	0.18	-0.02	0.05			
CN	0.36	0.15	0.12	0.04	-0.03	0.03	0.28		
EMP	-0.22	-0.08	-0.03	0.09	0.01	0.04	-0.12	-0.10	
PAT	-0.15	-0.02	-0.05	0.07	0.12	-0.06	-0.09	-0.21	0.35

NSF: non-self forward citations, WSFC: weighted self forward citations, LI: litigation (binary), CS: citing standards, SR: self-reliance, TCT: technological cycle time, BC: backward citations, EMP, CN: countries, EMP: Employees, PAT: The number of patents, DIV: diversity, CLA: claims, AGE: family age.

Appendix 4. Comparison of SEPs with non-SEPs (First Phase of Data Set)

	Model 1 (SEP + non-SEP)	Model 2 (SEP + non-SEP)	Model 3 (only SEP)	Model 4 (SEP + non-SEP)	Model 5 (only SEP)	Model 6	Model 7
	NB	NB	NB	NB	NB	Probit	Probit
Dependent Variable (DV)	NFC	NFC	NFC	SFC	SFC	SEP_Binary	SEP_Binary
Citing Standards (CS_Binary)	0.347***	0.105***		0.062**			
Count of Citing Standards (CS)			0.052***		0.044***		
Self-reliance (SR)		0.324***	0.668***	1.293***	1.617***	-0.114***	-0.456***
Technology Cycle Time (TCT)		0.105***	0.091***	0.055***	0.061***	-0.041***	-0.027***
Diversity (Div)		0.422***	0.478***	0.532***	0.581***	-0.346***	-0.542***
Catch-up (Catch_Binary)							0.402***
Catch x SR							0.137***
Catch x TCT							-0.046***
Catch x Div							0.094***
Backward Citations		0.007***	0.006***	0.005***	0.006***	0.001***	0.001***
Claims		0.026***	0.021***	0.052***	0.038***	0.028***	0.029***
Countries		0.022***	0.028***	0.023***	0.026***	0.061***	0.063***
Family Age		0.007***	0.006***	0.007***	0.006***	0.007***	0.007***
Ln_Employees		-0.098***	-0.121***	-0.145***	-0.160***		
Ln_Patents		0.039***	0.098***	0.210***	0.223***		
Year Dummies	No	Yes	Yes	No	Yes	No	No
Intercept	2.532***	1.338	1.381***	-0.628***	-1.025***	-0.548***	-0.496***
Log-likelihood	-94699.41	-76227.59	-39456.77	-43293.39	-22586.98	-13401.15	-13370.23
Observations	25406	20898	10459	20898	10459	20898	20898

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Dependent Variable: Non-self Forward Citations (NFC), Self Forward Citations (SFC), Standard-essential Patents (SEP_Binary).
Regression Model: Negative Binomial Regression (NB), Probit Regression (Probit).

Appendix 5. Effects of SEP Strategic Manoeuvres on Technological Influence, Self-reinforcing Capability and Patent Litigation (Second Phase of Data Set)

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
	NB	NB (CSE)	Tobit	Tobit (CSE)	BL	BL (CSE)
Dependent Variable (DV)	NFC	NFC	WSFC	WSFC	Litigation (Binary)	Litigation (Binary)
Citing Standards (CS)	-0.009**	0.044** (0.019)	0.092***	0.117 (0.109)	0.064***	0.056*** (0.016)
CS^2	0.0004**	-0.001* (0.001)				
Non-self Forward Citations (NFC)					0.005***	0.005*** (0.002)
Weighted Self Forward Citations (WSFC)					-0.007	-0.015 (0.013)
Self-reliance (SR)	1.128***	0.531 (0.389)	5.499***	10.169*** (2.297)	-2.865***	-4.504*** (0.866)
SR^2	-2.439***	-1.319* (0.771)	-5.293***	-11.168*** (2.014)		
Technology Cycle Time (TCT)	-0.090***	-0.091*** (0.011)	-0.052***	0.085 (0.055)	-0.028	0.048 (0.084)
Catch-up (Catch_Binary)		-0.297 (0.252)		1.736 (1.217)		1.391 (0.960)
Catch x CS		-0.113** (0.054)		-0.052 (0.107)		0.025 (0.017)
Catch x CS^2		0.004** (0.002)				
Catch x NFC						0.013*** (0.003)
Catch x WSFC						0.054* (0.029)
Catch x SR		0.833* (0.505)		-6.779*** (1.543)		3.236*** (0.878)
Catch x SR^2		-1.462 (0.937)		7.889*** (1.369)		
Catch x TC		-0.014 (0.011)		-0.250** (0.104)		-0.209 (0.209)
CS x SR				1.172*** (0.275)		
CS x SR^2				-1.258*** (0.310)		
Catch x CS x SR				-1.216*** (0.349)		
Catch x CS x SR^2				1.240*** (0.347)		
Backward Citations	0.006***	0.005*** (0.001)	0.022***	0.022*** (0.002)	0.001	0.001 (0.002)
Countries (CN)	0.077***	0.062*** (0.012)	0.172***	0.166*** (0.044)	0.142***	0.157*** (0.023)
Ln_Employees	0.005	-0.151 (0.096)	-0.970***	-0.879*** (0.317)	0.628***	0.964*** (0.215)
Ln_Patents	-0.011	0.260** (0.104)	0.412***	0.382 (0.559)	0.127	-0.618*** (0.212)
Year Dummies	Yes	Yes	No	No	Yes	Yes
Intercept	5.496***	5.857*** (0.839)	4.829***	3.105 (5.006)	-29.404	-31.821
Log-likelihood	-69068.19	-68704.700	-39018.70	-38946.00		
McFadden's Pseudo R^2					0.334	0.355
Observations	19330	19330	17357	17357	17357	17357

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Dependent Variables: Non-self Forward Citations (NFC), Weighted Self Forward Citations (WSFC), Litigation (Binary).
Regression Models: Negative Binomial Regression (NB), Tobit Regression (Tobit), Binary Logistic Regression (BL). Clustered Standard Errors (CSE), standard errors in parentheses.