Join an open collaborative licensing? A configurational analysis of patent pool participation

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Résumé

Cet article examine la causalité de la participation des détenteurs de brevets dans les patent pools, en se concentrant sur les effets conjoints des facteurs dans une perspective configurationnelle. Nous intégrons la théorie des plateformes et la théorie des actifs complémentaires avec la littérature sur les patent pools. En utilisant la méthode fsQCA (fuzzy-set Qualitative Comparative Analysis) sur un échantillon de 11 pools de brevets comprenant 217 cas, nous explorons les configurations de conditions menant au résultat souhaité. Nos résultats soutiennent le cadre configurationnel et offrent de nouvelles perspectives sur les rôles complexes des facteurs et leurs implications stratégiques. Cette étude contribue à la théorie existante de la participation aux patent pools en fournissant une compréhension plus holistique des facteurs influençant les décisions de participation, en élargissant le champ de recherche dans ce domaine et en introduisant des outils de recherche innovants prometteurs pour les futures investigations sur la dynamique de la participation aux patent pools.

Mots-clés : Patent pools, fsQCA, plateforme, actifs complémentaire, innovation ouverte

Abstract

This paper investigates the causality of patent holders' participation in patent pools, focusing on the joint effects of factors from a configurational perspective. We integrate platform theory and complementary assets theory with patent pool literature to develop a configurational framework of participation causality. Utilizing a fuzzy-set Qualitative Comparative Analysis (fsQCA) approach on a sample of 11 patent pools with 217 cases, we explore the configurations of conditions that yield the desired outcome. Our findings of seven sufficient solutions support the configurational framework and offer new insights into the complex roles of factors and their strategic implications. This study contributes to the existing theory of patent pool participation by providing a more holistic understanding of the factors influencing participation decisions, expanding the scope of research in this area, and introducing innovative research tools that hold promise for future investigations into the dynamics of patent pool participation.

Keywords: Patent pools, fsQCA, platform, complementary assets, open innovation

1. INTRODUCTION

Patents serve as a multifaceted strategic instrument, transcending their traditional role as legal protection for technological innovations (Corbel, 2004). They play a pivotal part in open innovation (OI) by facilitating knowledge flows, mitigating collaboration risks, and serving diverse functions in the innovation process (Pénin and Neicu, 2018) and have become indispensable due to their close association with these standards. Fragmented patent ownership has been a critical issue, with misaligned licensing patterns posing potential hindrances to innovation and entrepreneurship in emerging technologies (Henkel, 2021). The widespread presence of "patent thickets" (Shapiro, 2000) in knowledge-intensive industries exacerbates this situation, leading to reduced market efficiency and stifled innovation. Patent pools and other collective licensing organizations form an integral part of the multi-layered, open innovation ecosystem of privately-ordered market governance (Bogers et al., 2012; Ayerbe and Azzam, 2014; Grzegorczyk, 2020; Peter et al., 2022).

The objective of this paper is to investigate the causality of patent holders' participation in patent pools. Although patent pools offer numerous benefits, participation remains challenging due to coordination problems (Aoki and Nagaoka, 2004). Multiple factors can influence participation, with existing literature primarily examining their net effect but leaving the joint effects of factors relatively unexplored. This paper delves into these joint effects from a configurational perspective and addresses to the causal relationship between the factors and participation outcome.

To address the complex causality, we first integrate platform theory and complementary assets theory with patent pool literature to develop a comprehensive configurational framework of participation causality. We then apply a fuzzy-set Qualitative Comparative Analysis (fsQCA) approach (Ragin, 2000, 2009) to a sample of 11 patent pools, encompassing 217 cases, to explore the configurations of conditions that yield the desired outcome. Our findings of seven sufficient solutions support the configurational framework and offer new insights into the complex roles of factors and their strategic implications.

This paper makes several contributions to the literature. First, it augments the existing theory of patent pool participation by providing a more holistic understanding of the factors influencing participation decisions. Second, it expands the scope of research in this area by exploring the joint effects of multiple factors from a configurational perspective. Lastly, the implementation of a configurational approach introduces innovative research tools that hold promise for future investigations into the dynamics of patent pool participation. By shedding light on the complex interplay of factors that determine patent holders' participation in patent pools, this study has the potential to guide strategic decision-making for firms operating within the broader open innovation ecosystem.

2. LITARATURE REVIEW

2.1. PATENT POOLS

The patent pool is an agreement among patent holders to license a set of their patents to one another or to third parties. Patent pools can unblock the “patent thicket”, an overlapping set of patents requiring that those seeking to commercialize new technology obtain licenses from multiple patent holders (Shapiro, 2000). A pool integrates fragmented patents relating to a standard into a patent portfolio and offers a “one-stop licensing” to replace multiple individual licensing agreements. As a result, patent right transaction of such “complex technology”

(Rycroft and Kash, 1999) becomes simplified and market efficiency is enhanced (Lerner and Tirole, 2004).

Patent pools are naturally strategic alliance since they always consist of multiple patent holders who are often rivals in downstream markets. Rival patent holders cooperate in pools to establish industrial standards. Therefore, patent pools are a "coopetition" strategy from the OI perspective (Philipson, 2020) which allows the use of external patented knowledge (outside-in OI strategy) to secure companies' freedom to operate (Pénin et al, 2011). On the other hand, it is also an inside-out OI allowing the valuation of internal patented knowledge on a large scale (Rayna and Striukova, 2010) through collective licensing programs (Bogers et al., 2012). As strategic alliance for exploitative goals, knowledge transfers within pools is intensive (Ayerbe and Azzam, 2014), which may eventually promote further innovation (e.g., the four generations of disc optical technologies promoted by MEPG LA). Companies increase their R&D effort for essential technologies as the number of patents grows to the anticipated pool size (Dequiedt and Versaevel, 2013). In addition, pools are often used to promote industrial standards and ecosystem which can create transparency and foster market adoption (Grzegorczyk, 2020). Patent pools have special advantage of balancing the different interests of innovators and implementers in an innovation ecosystem to promote the level playing field that at the core of fair market competition (Dini and Piola, 2022).

2.2. PARTICIPATION OF PATENT HOLDERS

Despite many benefits, patent pools are not observed on large scale. Aoki and Nagaoka (2004) argue that the main cause of the difficulty of forming patent pools is coordination problems related to heterogeneous membership of patent holders. In this paper, we divide them by their business model of strategic use of patents: practicing entities (PEs) or non-practicing entities (NPEs). PEs produce patented knowledge and use it for downstream activities such as production (e.g., manufacturing companies, service providers); NPEs only produce patented knowledge and focus on other ways to gain revenues such as licensing (e.g., fabless firms, universities, patent brokers and patent trolls (Shrestha, 2010). Patent holder heterogeneity results in varying strategic interests, particularly concerning participation. NPEs, relying solely on royalties for income, exhibit greater sensitivity to royalty rates and tend to avoid patent pools, potentially assuming a hold-up position for higher returns (Aoki and Nagaoka, 2004). Conversely, PEs are more inclined to join patent pools to secure freedom to operate and integrate SEPs into their portfolios (Layne-Farrar and Lerner, 2011). However, Mattioli (2018) argues that pools maintain a strong bargaining position, diminishing NPE outsider influence. Moreover, Nikolic and Galli (2022) discuss an NPE-only patent pool (Avanci), suggesting that excluding PEs can align member interests and foster stability.

In addition to heterogeneous membership, patent pool participation is influenced by royalty sharing rules, which can be either numeric proportional or value-based. Generally, numeric sharing rules distribute royalties among licensors based on the number of pooled patents, whereas value-based rules allocate royalties according to the pooled patents' value. Vertically integrated firms (PEs) favor numeric rules, while R&D-focused organizations (NPEs) prefer value-based ones. Despite lower participation rates for numeric rules (Layne-Farrar & Lerner, 2011), value-based rules incur higher complexity and costs (Nikolic & Galli, 2022). Nevertheless, within Avanci's 5G NPE-exclusive patent pool, the value-based rule is crucial for attracting and maintaining participant engagement.

Third, number of licensors, or pool size, can either facilitate or impede coordination. The pool size results from a coalition formation protocol that exclusively involves successful innovators (Dequiedt and Versaevel, 2013). A large pool size may augment membership heterogeneity, while a smaller size can diminish it (Aoki and Nagaoka, 2005). However, it is essential to recognize that the number of licensors is contingent on both the quantity of patents and the ownership landscape. The patent count is heavily influenced by the technology itself, such as its complexity or SEP portfolio. For example, the High Efficiency Video Coding (HEVC) has a more extensive patent portfolio than the EV Charging (EVC), resulting in a greater number of licensors for HEVC than EVC.

3. THEORITIECAL FRAMEWORK

The aforementioned factors are analyzed as interdependent elements, with discussions emphasizing their net effect, although the literature acknowledges their interdependencies. Consequently, this approach fails to address recent trends in patent pool participation, such as the rising presence of NPEs in recent patent pools, despite arguments suggesting that NPEs possess reduced incentives for participation. To bridge this gap, both a comprehensive theoretical framework and empirical approach is required. In our previous work (Authors, 2022), we employ the two-sided platform framework to analyze patent pool strategy, as this theory offers a holistic perspective on organizations and strategies grounded in network externalities (Parker et al., 2016). Additionally, we integrate the platform framework with complementary asset theory to enhance our understanding of PEs' participation dynamics.

3.1. INTEGRATION OF PLATFORM THEORY

3.1.1. Patent pools as two-sided platforms

Prior to incorporating platform theory into patent pool strategy modeling, it is essential to elucidate how patent pools function as two-sided platforms. Platforms exhibit three common characteristics: linking at least two market sides, facilitating interactions between linked sides, and displaying network externalities. As demonstrated in our previous work (Authors, 2022), patent pools embody these three properties.

Patent pools primarily connect two sides: patent holders (licensors) and licensees, with potential additional involvement from regulators and standard-setting organizations (SSOs). The main interaction between licensors and licensees is patent licensing, which alleviates patent thickets and reduces transaction costs (Lerner and Tirole, 2004). Furthermore, patent pools facilitate technology development, adoption, risk distribution among members, support for smaller firms, and mitigation of spillover effects (Clarkson, 1999).

Patent pools generate indirect network externalities for both licensors and licensees, although their effects differ. For licensors, an increase in the number of licensees leads to conflict between the revenue effect and the rent dissipation effect (Arora and Fosfuri, 2003). These effects differ between PEs and NPEs due to their varying involvement in downstream competition. PEs must contend with the gains from royalties (revenue effect) and the market loss due to new entrants (rent dissipation effect). Conversely, NPEs do not experience the rent dissipation effect. Despite this, PEs can still benefit from joining patent pools as a result of reduced transaction costs, standardized terms, and enhanced market predictability.

3.1.2. New insights: network externalities and participation

Platforms often exhibit asymmetric pricing due to differences in value generated for each side and the associated indirect network externalities. Asymmetric pricing is linked to price sensitivity (demand elasticity) of each side (Rochet & Tirole, 2003). One side might generate more substantial network externalities, known as "marquee" participants (Eisenmann et al., 2006). Consequently, platforms implement cross-subsidization to encourage participation from price-sensitive or marquee participants (Armstrong, 2006).

As argued in our previous work (Authors, 2022), patent pools may also implement asymmetric pricing through royalty rates and royalty sharing rules. This paper focuses on royalty sharing rules, which can be asymmetric to meet the specific needs and motivations of each group. Subsidization can encourage participation from NPEs who are likely to be price sensitive since their revenues depend only on royalties. Patent pools may also subsidize early licensors, who bring various benefits (Lévêque and Ménière, 2008, 2011; Llanes and Poblete, 2014). Early commitments stimulate participation, reduce hold-up problems, and minimize negotiation complexities. Early licensors foster trust and cooperation, contributing to more efficient patent pools that encourage innovation and technology diffusion. Ex ante agreements also promote more inclusive patent pools, ultimately leading to comprehensive pools encompassing a broad spectrum of technologies.

3.2. INTEGRATION OF COMPLEMENTARY ASSET THEORY

In this section, we integrate complementary asset theory to complement our framework. This integration brings two new insights. First, from the complementary asset perspective, the SEPs included in a portfolio are complementary to each other. This provides a new explanation of patent pooling as a way of combining these co-specialized complementary assets. Second and more importantly, it helps to understand the participation of PEs who are confronted with the rent dissipation effect. Consequently, we identify two complementary assets which may have impact on the rent dissipation: manufacturing capabilities and R&D capabilities.

3.2.1. Complementary asset theory to understand complementarity of pooled patents

Complementary assets, as defined by Teece (1986), encompass various capabilities, competencies, and resources that need to be employed alongside a firm's core knowledge when commercializing an invention. Manufacturing capabilities, including efficient production facilities, equipment, and processes, are necessary for large-scale, cost-effective production of novel inventions. Established distribution networks or partnerships with distributors facilitate effective and far-reaching product or service delivery to consumers. A robust sales and marketing strategy is critical for promoting awareness, stimulating demand, and persuading potential consumers to adopt new inventions. Additionally, complementary assets may encompass technical support and services, intellectual property protection, regulatory expertise, financing and investment, skilled workforce, strategic partnerships, and management and organizational capabilities.

Based on accessibility and interdependency, complementary assets can be classified into generic complementary assets, specialized complementary assets, and co-specialized complementary assets. In the contemporary technological landscape, particularly in the digital context, complementary assets serve not only as potential mechanisms for capturing innovation value but also as indispensable elements for the technology's functionality (Teece, 2018). This is especially true when complementary assets are patented. Complex technologies often necessitate the combination of SEPs to function properly. In this regard, patents within a pool can be considered "co-specialized" complementary assets to one another. These pooled patents exhibit both specialization and interdependence. Consequently, participation in a patent pool represents an outside-in strategy for acquiring co-specialized complementary assets, motivating both PEs and NPEs to partake.

3.2.2. Complementary asset theory to understand the rent dissipation effect

When co-specialized complementary patents jointly form a complete technology, this technology emerges as the core asset. To commercialize this technology and maintain competitiveness against new entrants, PEs must possess supplementary complementary assets. If PEs' complementary assets are less effective than those of new entrants, they may face a significant loss of market share, reflecting a substantial rent dissipation effect. Conversely, when PEs possess more effective complementary assets, the rent dissipation effect can be reduced. Thus, holding effective complementary assets is a crucial leverage for PEs when contemplating participation in patent pools, as an increased rent dissipation effect can diminish their incentives to join pools.

Among the variety of complementary assets, our analysis emphasizes the critical roles of manufacturing and R&D capabilities. First, as many pool-based standards are product-oriented, PEs need to possess manufacturing capabilities. Although licensors in early patent pools were predominantly manufacturing companies, the growing number of NPEs in recent pools indicates a shift towards standards for services or digital products. For instance, recent video coding and compression technologies (AVC and HEVC) have become increasingly prevalent in online streaming videos. Moreover, the division of labor in the innovation process has intensified, leading to a rising number of start-ups, fabless firms, private labs, universities, and even manufacturing companies adopting the NPE model to circumvent high technological risk and uncertainty.

The second vital complementary asset, R&D capabilities, is required for both PEs and NPEs. Ayerbe and Azzam (2014) argue that absorptive and desorptive capabilities related to patent pool fields are essential. Absorptive capabilities enable the identification and acquisition of relevant external patents, while desorptive capabilities facilitate the recognition of profitable licensing-out opportunities and the transfer of patents to independent organizations (Azzam, 2019). R&D capabilities serve as a key source of these organizational capabilities and can influence patent pool participation. Strong R&D capabilities enhance a firm's ability to discern the value of external knowledge, assimilate and apply pertinent information, and establish processes for experimentation, learning, and knowledge sharing. Additionally, robust R&D capabilities enable firms to generate valuable knowledge and technologies that can be shared with external partners, contributing to collaborative initiatives such as patent pools. These capabilities also help build a firm's reputation as an innovative player in its industry, fostering trust among external partners and facilitating knowledge and technology sharing, ultimately improving desorptive capacities.

3.3. CAUSALITY OF PATENT POOL PARTICIPATION

In this study, we bridge the gap between existing patent pool literature, platform theory, and complementary asset theory. This integration offers novel insights into the causality of patent pool participation, such as interactions in the presence of network externalities and the potential impacts of complementary assets on participation. Additionally, this approach helps to identify three new factors that may influence patent holder participation: subsidy, manufacturing capabilities, and R&D capabilities.

The causality of patent pool participation is complex, as multiple factors can affect the decision to participate. The impact of these conditions is not always clear-cut; they can be positive or negative depending on the circumstances or combinations with other factors. For example, numeric rules may yield a high participation rate when many patent holders are PEs, while resulting in a low participation rate when many patent holders are NPEs. Evidently, there is interdependency among the factors, indicating that a single factor cannot fully explain participation causality. As a result, we do not investigate the net effect of each factor individually. Instead, we focus on the joint effects of factors, aiming to understand how they combine to produce the participation outcome. This leads us to adopt a configurational approach for our research.

4. DATA AND METHOD

4.1. FSQCA: A CONFIGURATIONAL APPROACH

We employ fuzzy-set qualitative comparative analysis (fsQCA), a case-oriented configurational approach designed to capture complex causality. fsQCA is an extension of the QCA approach introduced by Charles Ragin in 1986. Rooted in set theory, Boolean algebra, and counterfactual analysis, fsQCA enables researchers to explore intricate causal relationships and configurations, allowing for the analysis of multiple conditions (factors) leading to an outcome (Ragin, 2000). This method is particularly useful for examining complex social phenomena and organizational studies, where multiple factors often interact in sophisticated ways. Indeed, fsQCA has been applied to managerial research (e.g., Fiss, 2011; Greckhamer et al., 2013; Park et al., 2017).

fsQCA allows for the examination of causal asymmetry and equifinality (Ragin, 2009), assuming that multiple causal paths can lead to the same outcome. Thus, fsQCA focuses on exploring causal paths rather than determining the net effects of independent variables on an outcome. The method is designed to investigate conjunctional causation, where specific outcomes result from the presence or absence of certain conditions in combination. Consequently, fsQCA is well-suited to address the complex causality between the seven conditions (see Table 1) and patent pool participation.

Table 1. Conditions and measurement

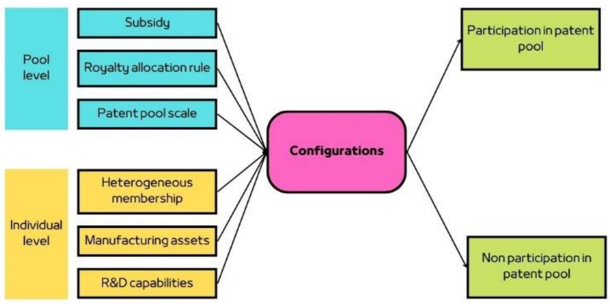
	Condition/Outcome	Measurement
Conditions (Independent variables)	Heterogeneous membership (PE/NPE)	Binary score; PE is on both list of licensors and licensees; NPE is only on list of licensees
	Patent pool size	Number of licensors
	Royalty sharing rule	Binary score
	Subsidy	Binary score
	Manufacturing capabilities	Net PPE
	R&D capabilities	Number of patents in the same field before participation date
Outcome (Dependent variable)	Participation of patent holders in patent pool	Difference between participation date of licensor and formation date of pool

Our framework, depicted in Figure 1, demonstrates the configurational causality between seven conditions and the participation outcome. These conditions combine to form distinct "configurations" or "combinations" of conditions that lead to the outcome. This approach assumes the equifinality of participation causality, which can be addressed by fsQCA. In essence, our results will reveal multiple configurations of conditions highly consistent with the outcome, rather than the net effect of individual factors or the optimal configuration to achieve the outcome (Ragin, 2009).

Moreover, our framework assumes that the configurations in our solution are asymmetric. The opposite configurations of those with a high degree of participation (presence of outcome) do not necessarily result in a low degree of participation (absence of outcome). For instance, if a configuration consisting of the presence of conditions A and B yields the presence of outcome O, it is not valid to conclude that the absence of A and B results in the absence of O.

Lastly, we categorize the seven conditions into two levels. Patent pool size, royalty sharing rule, and subsidy are considered at the pool level, as they are determined by the pool itself or jointly by pool members. Heterogeneous membership and two complementary assets are at the firm level, where patent holders can decide their patent strategy as either PEs or NPEs and implement different strategies to acquire complementary assets.

Figure 1. Configurational framework of patent pool participation



4.2. DATA

To investigate the causality of patent pool participation, we examined eleven patent pools administered by MPEG LA, a specialized licensing company. MPEG LA began operations with the formation of the MPEG-2 patent pool, recognized as the first modern patent pool (Merges, 1999). Several patent pools in our sample address audio and video coding and compression standards, such as MPEG-2, MPEG-2 Systems, VC-1, AVC, and HEVC. Three patent pools focus on different personal electronic standards: DisplayPort for connecting audio/video sources among products, EVS (Enhanced Voice Service), and QI for providing power to personal electronics in a safe wireless charging environment. The ATSC patent pool offers a digital terrestrial television standard implemented mainly in the U.S., South Korea, and Japan. The EVC patent pool grants access to the EV Charging Patent Portfolio underlying worldwide standards for conductive AC and DC charging, connection, communication, and safety used in equipment providing electric charging in and to electric vehicles.

As of 05/05/2022, 217 licensors participated in the eleven patent pools. We did not include licensors added to the pools after this date. It is common for a patent holder to participate in multiple patent pools. In this study, we treat the multiple participations of the same patent holder as separate cases, resulting in 217 cases in our sample.

For our analysis, we primarily relied on publicly available secondary data, such as public documents from the official MPEG LA website (https://www.mpegla.com/) and internal documents provided by MPEG LA. To comprehend the data, we conducted interviews with MPEG LA managers via video conferences, who explained the data in internal documents. Additionally, we used financial data of net property, plant, and equipment (PPE) from Wall Street Journal Financials' balance sheets. For firms whose data were not available in this database, we gathered financial data from alternative sources. We obtained the financial data of Robert Bosch GmbH from its 2020 annual report and collected financial data for Maxell (https://ng.investing.com/equities/hitachi-maxell-ltd-balance-sheet) and NTT DoCoMo (https://www.investing.com/equities/ntt-docomo-balance-sheet). We compiled patent data from PATENTSCOPE, a *World Intellectual Property Organization* patent database.

4.3. MEASUREMENT AND CALIBRATION

The data for royalty sharing rules, subsidy, and patent holder type are binary qualitative, while data for other variables, including the outcome, are quantitative. The patent holders in our sample exhibit considerable heterogeneity, encompassing manufacturing companies, fabless firms, universities, and patent brokers. This high level of heterogeneity makes it challenging to apply accurate and precise measurements for specific conditions, as these methods are tailored to particular types of agents. Consequently, we adopted simple yet universal measurement techniques to ensure compatibility with all types of patent holders in our analysis.

In particular, we assigned the scores to the royalty sharing ways due to the lack of quantitative sharing percentages of each rule. The pool implements a sharing rule closer to numeric proportional is assigned a score "**-1**" and the pool implements a sharing rule closer to value-based is assigned a score "**-2**" as the "distance" from the pure numeric rule. Similarly, for measuring subsidy, we assign a score "*1*" to **the pools implementing a subsidy rule**, representing the presence of subsidy and a score "*0*" to **the pools without subsidy**, representing the absence of subsidy. For measuring manufacturing assets, we use net PPE (property, plant and equipment) as an approximate measurement. For measuring R&D capabilities, we use an approximate measurement: the number of applied patents in the same technology field (based on IPC codes) as of the time of joining the patent pool.

As to dependent variable, we used participation times as an approximate measurement due to the lack of data of "nonparticipation", the companies which should have participate but do not participate. This measurement is based on the argument that early participation can generate more welfare than late participation (Lévêque and Ménière, 2008; Llanes and Poblete, 2011).

We calibrate raw data into set-membership scores. Calibration defines the extent to which a given case has membership in the set of, for example, an early or late patent pool participation. Calibration allows to tie attributes of cases to substantive theoretical concepts and more exactly define a group of cases that have similar membership (Ragin, 2009; Fiss, 2011). In our research, we implement the direct method of calibration based on three anchors: full membership (0.95), full nonmembership (0.05) and crossover point (0.5) of maximum ambiguity regarding membership of a case in the set of interest (Ragin, 2009). Calibration was calculated by fsQCA 3.0 software package (Ragin and Sean, 2016).

4.4. TRUTH TABLE ANALYSIS

Then we apply truth table algorithm that identifies combinations of elements that produce the outcome of interest. A truth table includes all logically possible combinations of the elements, and each row corresponds to one combination (Ragin, 2009). *We set the minimum acceptable frequency of cases at 3, the threshold of raw consistency at 0.85 and the threshold of PRI consistency at 0.65.* In the truth table, the participation column shows a value "1" for the configurations with raw consistency higher than 0.85 and PRI consistency higher than 0.65 or otherwise "0". With the truth table assembled, we then applied the truth table algorithm to reduce the numerous combinations into a smaller set of configurations based on the QM algorithm and counterfactual analysis. The truth table algorithm results in 3 kinds of sufficient solutions: a complex solution that uses no counterfactuals, an intermediate solution that uses only "easy" counterfactuals, and a parsimonious solution that uses both "easy" and "difficult" counterfactuals. In this study, we focus on the intermediate solution as recommended in literature (Ragin, 1987).

5. CONFIGURATIONAL RESULTS

5.1. DESCRIPTIVE STATISTICS

Table 2 presents the descriptive statistics of this study, revealing several intriguing phenomena and trends. Firstly, most patent pools in our sample tend to be classified as "large pools," as the mean value (0.7496636) is close to 1, which is defined as "large size" in calibration. This observation could be attributed to our sample's focus on patent pools related to video coding and compression standards, which typically have large patent portfolios and fragmented patent ownership. However, this also demonstrates that appropriately designed large patent pools can be successfully formed.

Secondly, the patent pools in our sample tend to employ value-based rules, as the mean value (0.4432166) is close to 0, defined as the value-based rule in calibration. This finding is consistent with Nikolic and Galli (2022). However, a statistical mean alone does not provide robust evidence to support the claim that value-based rules are more effective than numeric rules.

Thirdly, subsidies are not frequently implemented by patent pools in our sample. While MPEG LA started implementing subsidies with the formation of the HEVC pool in 2016, all pools established after 2016 have adopted subsidies, indicating a clear trend.

Fourthly, our sample predominantly comprises non-practicing entities (NPEs), which contradicts conventional wisdom. In fact, there has been an increasing trend of NPE participation in recent patent pools.

Additionally, the two complementary assets, manufacturing and R&D capabilities, tend to be low in our sample. The low mean of manufacturing assets suggests that most patent holders in our sample are not traditional manufacturing companies, even though many still function as practicing entities (PEs). For example, companies such as Apple and Microsoft outsource their manufacturing processes. Furthermore, the low manufacturing assets may also reflect digitalization, as many PEs use patents for digital products or services that do not require manufacturing assets. The low R&D capabilities could be a consequence of heterogeneous membership and our rough measurement approach. Larger companies often possess much larger patent portfolios (e.g., Canon, Samsung, Sony) than smaller patent holders, such as universities.

Lastly, the relatively high average degree of participation (0.611417) indicates that most licensors joined the pools during their early stages.

Table 2. Descriptive statistics

Variable	Mean	Std. Dev.	Minimum	Maximum
Number of licensors	0.7496636	0.2895485	0.051	0.961
Royalty sharing rule	0.4432166	0.4237727	0.051	0.622
Subsidy	0.3496175	0.4237727	0.051	0.951
Type of patent holder	0.4781889	0.4494215	0.051	0.951
Manufacturing assets	0.2433502	0.3006161	0.031	0.981
R&D capabilities	0.4222903	0.3199211	0.041	0.991
Participation (time)	0.6114147	0.3584404	0.021	0.951

5.2. NECESSARY CONDITION

fsQCA allows one to identify both necessary conditions and sufficient conditions for outcome (Rihoux and Ragin, 2009). Specifically, if the value of set membership of a condition is essentially always equal to or higher than value of set membership in the outcome, then that condition is a candidate for a necessary condition. Table 3 presents the results of necessary analysis of all conditions including their opposite conditions. The threshold of the consistency of a necessary condition is 0.9 (Ragin, 2009). In our study, there is not a condition whose consistency is equal or larger than 0.9. *Thus, there is not necessary condition in our study.*

Table 3. Necessary analysis

	Patent Pool Participation	
	Consistency	Coverage
Pool size (large)	0.776375	0.633199
Pool size (small)	0.341816	0.834839
Royalty sharing (numeric)	0.569375	0.785451
Royalty sharing (value-based)	0.67002	0.735759
Subsidy	0.387611	0.677858
No subsidy	0.692836	0.651325
PE	0.544534	0.696243
NPE	0.53564	0.627617
High manufacturing assets	0.349549	0.878236
Low manufacturing assets	0.766833	0.619642
High R&D capabilities	0.551694	0.798771
Low R&D capabilities	0.610031	0.645621

5.3. SUFFICIENT SOLUTION

Table 4 graphically depicts the results using the notation system from Ragin and Fiss (2009). Graphic description is a tool for more effectively interpreting and comparing the complex structure of configurations in a way that explains how the elements combine simultaneously and systematically to result in the outcome and the role of each element in the dynamics involved in achieving participation. Each rectangle in this table represents a configuration and corresponds to one recipe of the intermediate solution. Large circles refer to core elements and small circles are peripheral elements. Full circles ("●" or "•") indicate presence of condition and crossed-out circles ("⊕" or "⊕") indicates absence of condition. In particular, the absence of "large size" refers to "small size"; the absence of "numeric rule" refers to "value-based rule";

the absence of "subsidy rule" means that the pool does not implement subsidy rule; the absence of "PE" refers to the presence of "NPE"; the absences of "high manufacturing assets" or "high R&D capabilities" respectively refer to low possession of the complementary assets. In addition, blank spaces refer to "don't care" where the elements are not important at all in that receipt.

Table 4. Sufficient solution

Condition		Configurations of conditions						
		S1	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**
Pool's level	Large size	•	•	•	•	⨁	⊕	•
	Numeric rule		●	⊕	⊕	⨁	•	
	Subsidy rule	⨁	⊕	⨁	●	⊕	●	⨁
Firm's level	PE patent holder		●	•		•	⊕	●
	High manufacturing assets	●	⊕	●	⨁	⊕	⊕	
	High R&D capabilities	•			●	⊕	●	●
Raw coverage		0.23	0.24	0.20	0.16	0.13	0.09	0.29
Unique Coverage		0.03	0.02	0.01	0.08	0.0048	0.02	0.04
Consistency		0.91	0.85	0.94	0.87	0.93	0.95	0.82
Overall solution coverage		**0.47**						
Overall solution consistency		**0.80**						

6. DISCUSSION

6.1. INTERPRETATION OF SUFFICIENT SOLUTION

Our study reveals seven configurations of conditions yielding the outcome: high degree of participation of patent holders in patent pools. Here is the verbal description of the configurations:

S1. A large patent pool without a subsidy rule is likely to attract patent holders with high manufacturing assets and high R&D capabilities. In *S1*, the core conditions are the absence of subsidy rule and manufacturing assets while the peripheral conditions are large patent pool and high R&D capabilities. Meanwhile, royalty sharing rule and heterogeneous membership do not play significant role in S1 (in the following verbal descriptions we will not mention the conditions “don’t care”).

S2. A large pool employing a numeric rule but not offering subsidies is likely to attract PEs with low manufacturing assets. In *S2*, numeric rule and PE are core conditions while large size, absence of subsidy rule and low manufacturing assets are peripheral conditions.

S3. A large pool employing a value-based rule without a subsidy is likely to attract PEs with high manufacturing assets. In *S3*, absence of subsidy rule, high manufacturing assets are core conditions while large size, value-based rule and PE are peripheral conditions.

S4. A large pool employing a value-based rule and offering subsidies is likely to attract patent holders with low manufacturing assets and high R&D capabilities. In *S4*, subsidy rule, low manufacturing assets and high R&D capabilities are core conditions while large size, value-based are peripheral conditions.

S5. A small pool employing a value-based rule without offering subsidies is likely to attract PEs with low manufacturing assets and low R&D capabilities. Small size and value-based rule are core conditions in *S5* while absence of subsidy, PE and low complementary assets are peripheral conditions.

S6. A small pool employing a numeric rule and offering subsidies is likely to attract NPEs with low manufacturing assets and high R&D capabilities. In *S6*, subsidy rule and high manufacturing assets are core conditions while small size, numeric rule, NPE and low manufacturing assets are peripheral conditions.

S7. A large pool without offering subsidies is more likely to attract PEs with high R&D capabilities. In *S7*, absence of subsidy, PE and high R&D capabilities are core conditions while large size is a peripheral condition.

Several examples fitting perfectly within *S1* include Samsung, Hitachi, Canon, and Mitsubishi in the MPEG-2 patent pool. These companies are renowned as large manufacturers and technology giants, although they adopt different IP strategies. Hitachi, Canon, and Mitsubishi are PEs, while Samsung is an NPE in this pool. Indeed, large manufacturers are increasingly adopting the NPE model, such as Siemens in the VC-1 patent pool. Patent pools, as platforms facilitating patent transactions, expand the strategic space for utilizing patents, as argued by Arora et al. (2000). *S3* cases are found in MPEG-4, VC-1, and AVC patent pools. Although sharing the same core conditions as S1, S3 applies to PEs and value-based rules, illustrating the equifinality of patent pool participation.

S2 cases are primarily concentrated in MPEG-2 and MPEG-2 Systems pools. PEs with low manufacturing assets often include software companies (e.g., Cisco), technology-specialized subsidiaries (e.g., GE Technology Development), and telecommunication operators (e.g., British Telecom and NTT in MPEG-2). The combination of the core conditions PE and numeric rule aligns with Layne-Farrar and Lerner (2011); however, our results suggest that this combination applies when two peripheral conditions appear.

S4 cases are found in the HEVC patent pool, a successor to the MPEG-2, MPEG-4, and AVC standards of video coding and compression technologies. An intriguing characteristic is "patent holders with low manufacturing assets but high R&D capabilities," which includes tech giants (e.g., Apple, JVCKENWOOD), telecommunication operators (e.g., Orange, KT, SKT, NTT), research institutes, and universities (e.g., ETRI, KETI, KAIST, MIT, SungKyunKwan University, Kyung Hee University), with an emphasis on Korean research institutes and universities. *S7* cases are present in MPEG-2, MPEG-4, and AVC pools. *S7* shares two core conditions with *S4*: subsidy rule and R&D capabilities, despite their differences.

S5 and *S6* illustrate participation patterns in small patent pools. Only three cases in the ATSC pool fit perfectly within S5: Cisco, JVCKENWOOD, and Zenith, although it is highly consistent with the outcome (consistency=0.93). Two cases in the EVC pool, Robert Bosch and GE Hybrid Technologies, and one case in the DisplayPort pool, Sun Patent Trust, belong to *S6*. Since fsQCA can be applied to small samples, we can identify these two configurations. Both related to small patent pools, *S5* and *S6* differ in royalty-sharing rules, subsidy rules, heterogeneous memberships, and R&D capabilities. Small size is a core condition in *S5* but a peripheral condition in *S6*. This distinction further demonstrates equifinality.

6.2. ROLE OF POOL SIZE

Pool size consistently appears in the configurations, but it is only a core condition in S5, which covers few cases despite its high consistency. Contrary to conventional wisdom, pool size does affect participation, but it may not be as important as previously assumed. Moreover, 5 of the 7 configurations include large size as a condition, which challenges the notion that smaller pool sizes are always more desirable. In reality, pool size is often determined by the technological nature and patent landscape of the technology involved. For complex technologies with highly dispersed patent rights, it may be impractical to reduce pool size while still including all essential patents. For example, the HEVC pool has a larger patent portfolio than the ATSC pool due to their distinct technologies and patent landscapes. Thus, patent pools should focus on other conditions to moderate the impact of pool size rather than concentrating solely on size.

Regarding associations with other conditions, large size is often associated with PEs, as 3 of the 7 configurations including large size contain the condition of PE. No configurations including large size contain the condition of NPE. However, this argument is not definitive since large size frequently appears as a peripheral condition and the cases fitting this association are concentrated in video coding technologies, making generalization difficult. The absence of subsidy is often associated with large size, as 4 of the 5 configurations containing the absence of subsidy include large size. Nonetheless, in S4, the application of subsidy is a core condition, with large size appearing as a peripheral condition, resulting in an ambiguous association between these factors.

Proposition 1. Pool size is less important condition of participation. Large scale is significantly associated with PEs. Meanwhile, small scale is associated with value-based rule.

6.3. Role of Royalty Sharing Rule and Subsidy

The role of royalty sharing rules appears to be less crucial, as they are present in 5 configurations but only act as core conditions in 2 of them. The association of this condition with heterogeneous membership is ambiguous. For example, in S2, PEs participate in pools implementing numeric rules; in S3 and S5, PEs join pools with value-based rules; and in S7, royalty sharing rules are absent while PE is a core condition. Although NPEs may prefer numeric rules, this preference only appears in S6, which has a low coverage. Consequently, royalty sharing rules are diverse and flexible, aligning with Aoki and Nagaoka (2005).

Subsidy rules seem more crucial, as they are core conditions in 5 configurations. In S4 and S6, the application of subsidies leads to participation outcomes, while in S1, S3, and S7, the absence of subsidies yields outcomes. Regarding joint effects, PE is associated with the absence of subsidies (S2, S3, S5, S7), and NPE is associated with the presence of subsidies (S5). Heterogeneous membership is thus strongly associated with subsidies. A possible explanation is that NPEs are more price-sensitive than PEs, making them more likely to be attracted by subsidies. Conversely, PEs rely less on royalties and have diverse motivations for joining patent pools, such as cross-licensing, standardization, or defensive strategy. As a result, they may prefer "even" sharing without special offers.

This suggests that patent pools should focus on using subsidies flexibly to attract specific patent holders, rather than concentrating on royalty sharing rules. When the majority of patent holders are NPEs, patent pools should consider providing appropriate subsidies. Conversely, when the majority are PEs, pools should exercise caution. Patent pools should avoid adhering rigidly to a particular sharing rule and instead explore diverse strategies to attract various patent holders.

Proposition 2a. Royalty sharing rule is less important and its impact is ambiguous.

Proposition 2b. Subsidy rule is a crucial condition which is often associated with heterogeneous membership. NPEs would prefer subsidy rule while PEs would prefer no subsidy.

6.4. ROLE OF COMPLEMENTARY ASSETS

The roles of both complementary assets, manufacturing assets and R&D capabilities, are indeed crucial in determining patent pool participation. However, their impacts are ambiguous and require further specification to fully understand their influence on participation decisions.

Manufacturing assets appear as core conditions in three configurations. Interestingly, there is a strong association between manufacturing assets and the presence or absence of subsidies.

When high manufacturing assets are a core condition, the absence of subsidies is also a core condition (S1, S3). This may be because patent holders with high manufacturing assets have greater financial resources and are less reliant on subsidies to participate in patent pools. Conversely, when low manufacturing assets are a core condition, the presence of subsidies is a core condition (S4). In this scenario, patent holders with low manufacturing assets might be more sensitive to financial incentives, making subsidies an attractive factor for joining patent pools. Although low manufacturing assets appear with the presence of subsidies in S6, they are a peripheral condition in this case.

High R&D capabilities emerge as core conditions only when low manufacturing assets are present or not considered (S4, S6, S7). Patent holders in this category, such as software companies, communication operators, universities, patent brokers, and technological subsidiaries, might prioritize R&D investments and may not possess significant manufacturing capabilities. These organizations may focus on generating valuable knowledge and technologies and could be more interested in participating in patent pools that facilitate technology sharing and collaboration.

Moreover, the combination of high R&D capabilities and low manufacturing assets is strongly associated with the presence of subsidies as a core condition (S4, S6). This suggests that patent holders in this category prefer special sharing arrangements, perhaps due to their greater sensitivity to financial incentives. As a result, patent pools can strategically apply subsidies when there is a significant presence of patent holders in this category to increase the likelihood of their participation.

In conclusion, while manufacturing assets and R&D capabilities play critical roles in determining patent pool participation, their impacts are complex and subject to various factors. Patent pools should consider the specific needs and preferences of different types of patent holders when designing their participation strategies. By offering targeted incentives such as subsidies or special sharing arrangements, patent pools can more effectively attract and retain a diverse group of participants, ultimately fostering greater collaboration and innovation.

Proposition 3. Complementary assets play crucial role on participation. High manufacturing assets are negatively associated with the presence of subsidy rule to jointly yield the outcome. In particular, patent holders with low manufacturing assets and high R&D capabilities prefer subsidy rule.

6.5. IMPLICATIONS

In terms of managerial implications, first, for patent pools, we suggest that pool managers should not focus much on limiting pool size or on fixing a "golden" royalty sharing rule. Due to heterogeneous membership as well as diverse technologies, pool managers should be flexible. Coordination problems due to large size can be mitigated by jointly implementing other instruments. Selection of a royalty sharing rule must give sufficient consideration of heterogeneous membership, technological nature and patent landscape, and it should be flexible. Second, subsidy is a strong instrument for mitigating coordination problems and attracting specific patent holders. Pool managers must consider whether the majority of patent holders are PEs or NPEs, or whether they are with low manufacturing assets but high R&D capabilities (e.g., software companies, communication operators). However, since participation in patent pools is a sequential process, patent pools should perhaps add a time frame to the subsidy rule, for instance, a subsidy rule for five years. The subsidy rule without time frame may hurt the incentive of following participants.

For patent holders, they should first determine their patent strategy: being PEs or NPEs. In digital context, patent holders can be flexible. Large manufacturers can act as NPEs while small firms can be PEs who develop software or provide digital services. Once a patent holder determines its patent strategy, it can use its bargaining power to fight for royalty sharing and subsidy rules that benefit it. It should notice that subsidy is not always beneficial.

In terms of theoretic contributions, our configurational framework expands the boundary of patent pool theory. New insights and implications can be draw from the other theories. Indeed, apart from platform and complementary assets theories, ecosystem and coopetition theories can also be taken into account. Second, we use a new approach: configurational analysis and a method: fsQCA. It reveals the complexity of participation causality. Our results empirically complement existing literature as some are in line with existing literature while some are contrary. Therefore, it is important to rethink patent pools and patent pool strategy in a more open and networked context.

7. CONCLUSION

Our research investigates the causality of patent pool participation from a configurational standpoint. Utilizing the fuzzy-set Qualitative Comparative Analysis (fsQCA) approach, we identify seven configurations composed of seven conditions derived from the existing literature. The sufficient solution obtained through our analysis highlights the complex, equifinal, and asymmetric causality between these conditions and the decision to participate in patent pools. Additionally, our findings reveal new insights into the roles of various conditions.

Contrary to the emphasis in the literature, we discover that pool size and royalty sharing rules play less critical roles in determining patent holders' participation. On the other hand, we find that subsidy and complementary assets, which have been newly identified across the literature, significantly impact participation. Consequently, both pool managers and patent holders should reevaluate the conditions influencing their decisions to join patent pools. By doing so, they can better understand the nuances of patent pool participation, allowing them to make more informed decisions and maximize the benefits derived from their involvement in patent pools.

Our study has some limitations. First, some factors are not considered in our framework. Second, we do not consider a sequential game. First movers may have impact on followers' participation. Third, our sample is the patent pools of MPEG LA and concentrated on video coding technologies. As a case-orientation research, generalization of our results is limited.

Future studies can begin from our limitations by improving condition selection, integrating sequential game and sampling more diverse cases. Discussions of creating patent pools for emerging technologies are unexplored, such as Internet of Things, blockchain and AI, etc.

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