

**INNOVATION, IMITATION, AND IPR STRATEGY
IN THE GLOBAL TIRE INDUSTRY**

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Jung Kwan Kim
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Examining Committee Members:

Dr. Ram Mudambi, Advisory Chair, Department of Strategic Management
Dr. Vivek Tandon, Department of Strategic Management
Dr. Jennifer Tae, Department of Strategic Management
Dr. Anthony Di Benedetto, Department of Marketing
Dr. Snehal Awate, External Member, Indian School of Business

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ABSTRACT

This dissertation research aims to illuminate the interdependence of inimitability, competitive landscape, and the factors that bind them. Specifically, this study examines the antecedents and effectiveness of investments in inimitability within a historical context of innovation and competition in a mature sector, the global tire industry. The findings here contribute to our understanding of the complexity of inimitability that works for competitive advantage in light of the dynamics of competition in an industry as the adoption of innovation and intellectual property rights (IPR) protection continues to change.

The contribution of this dissertation is two-fold. First, this dissertation highlights the dynamic nature of resource inimitability and protection. Although it is conventionally assumed that firms have strong incentives to protect valuable innovations with weak inimitability, this study shows that weak inimitability of a key resource does not necessarily trigger protection from imitation. Moreover, the link between resource inimitability and imitation protection is not static. When imitating a key resource would destroy the imitator's other valuable resources, the key resource stays inimitable, and the owner firm of the resource does not engage in active protection.

The findings of this study deepen our understanding of why firms choose not to invest in imitation protection and the timing when firms finally decide to deter imitation. This research aims to shift the resource-based view (RBV) toward a more dynamic and

practical setting in which firms can delay their investment in inimitability and alter their protection strategy according to a newly emerged competitive landscape.

Second, this dissertation reveals the strategic choice of emerging economy firms between innovation and imitation beyond global agreements of IPR protection. Formal IPRs under global agreements are a policy linchpin of the new global knowledge economy. However, while some emerging economy firms have successfully transitioned from imitation to innovation, others persist in imitation, sometimes resulting in IPR violations. To understand the divergent behaviors, this study follows design innovation in the global tire industry, uncovering patterns of IPR violations after the establishment of a global IPR protection standard. The findings show that the presence of “keystone organizations” in a national industry ecosystem matters because these organizations enforce innovation in the ecosystem. This study thus emphasizes the importance of linkages to keystone organizations as crucial elements supporting operations that comply with global IPR regulations. Policymakers are recommended to devise policy instruments to facilitate the growth of keystone organizations and their close alliances with embedded actors to build a critical mass of innovation capability and IP stocks.

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CHAPTER 1

INTRODUCTION TO INNOVATION, IMITATION, AND IPR STRATEGY IN THE GLOBAL TIRE INDUSTRY

Dissertation Overview

The resource-based view (RBV) posits that the basis of a firm's competitive advantage originates from applying a bundle of valuable resources at the firm's disposal (Barney, 1991; Penrose, 1959; Wernerfelt, 1984). Given that some innovations are critical knowledge-based resources that enhance competitive advantage (Bates & Flynn, 1995; Grant, 1996; Rumelt, 1984), conventional wisdom holds that firms have strong incentives to protect valuable innovations. Nevertheless, if a valuable innovation has significant inimitability due to high complexity (Rivkin, 2000), tacitness (Polanyi, 1966), and/or specificity (Williamson, 1985), firms may not engage in active protection. For example, firms may simply take advantage of secrecy by establishing special procedures to handle trade secrets if the locus of innovation mainly comes from a type of process (Levin, Klevorick, Nelson, & Winter, 1987), or they may rely on non-tradeable assets such as tacit knowledge and social complexity (Dierickx & Cool, 1989).

However, easily imitable innovations do not enjoy these luxuries. If the core of a key innovation is easily identifiable and instantly imitable, formal intellectual property right (IPR) protections may serve better for innovative firms' economic rents. IPRs define exclusive rights to use and profit from assets (Barzel, 1997; Foss, 2005) and to engage in litigation against infringing imitators (Rudy & Black, 2018). IPR protection strengthens the weak inimitability of an innovation to ward off (potential) imitators

(Somaya, 2003). Although the extant literature has repeatedly emphasized the importance of IPR protection (Foss & Foss, 2004; 2005), this taken-for-granted link between easily imitable innovations and IPR protection only explains the static incentive of firms' choice for IPR-based protection. Prior studies have rarely questioned if the relationship between an imitable innovation and IPR protection is dynamic. In other words, understanding how certain changing conditions may lead a firm to adjust its innovation and IPR strategy requires in-depth investigation (Polidoro & Toh, 2011; Priem & Butler, 2001; Sirmon, Hitt, & Ireland, 2007). To offer a comprehensive view, I examine the antecedents and effectiveness of investments in inimitability as the focus of this dissertation.

To fill the research gap in innovation and inimitability, this dissertation investigates an unknown history and dynamics in a known industry: tread design in the global tire industry. This context is replete with dynamics that offer clues to understand the link between key innovations and IPR protection. Tread design features the geometric voids and molded elements on the surface of the tire, such as circumferential grooves, transverse sipes, and shoulder blocks. Various configurations and combinations of the elements generate differential traction by expelling water and dirt from beneath the tire. Although tread design is one of the most critical features in determining tire performance and quality (Clark, 1981) and has impacted firm performance from the early days of the industry (Lief, 1951; O'Reilly, 1983), it is very vulnerable to imitation due to its visible nature to competitors. However, tread design was not formally protected for several decades after its inception in 1908.

Chapter 2 explores the historical and contextual background of weak protection on tread design innovation from the 1900s through the 1970s. Global tire makers have consistently innovated their tread designs, which are a critical source of tire performance, but even though the tread designs could be easily copied, protection of the designs by patents was rare during this period (Warner, 1966; Scalera, Mukherjee, Perri, & Mudambi, 2014). This chapter illustrates that tread designs' unique characteristics as innovations and the market structure of the tire industry worked as a barrier to imitation and an alternative protection mechanism to IPR. The weak legal protection of the design was not inaction but active adaptation in the competitive reality in the tire industry.

After explaining the rich context and subtle implications of tread designs, Chapter 3 focuses on the firm-level antecedents of investments in inimitability. This chapter studies advanced firms and their competitive dynamics under IPR protection, addressing why the advanced players shifted to patenting tread designs in the 1990s after a decades-long period of weak protection. This study solves the puzzle by observing that the timing of this protection coincided with the large-scale entry of tire manufacturers from emerging economies. This study thus generates new insights regarding when investment in inimitability is necessary for competitive advantage. For decades, innovative tire makers operating in advanced economies were deterred from imitating each other's tread designs due to the potentially high cost of imitation to their reputations. However, emerging entrants had no such costs in global markets and were not deterred from imitating designs. As a result, leading innovators started to keenly patent tread designs.

The findings in Chapter 3 suggest that the competitive landscape and market structure facing incumbents considerably affect the incentives to actively protect innovations. Competitors engage in strategic initiatives that challenge the status quo of the market structure, and in turn focal firms respond accordingly (Ferrier, Smith, & Grimm, 1999). Responding to “specific and detectable competitive moves initiated by a firm to defend or improve its relative competitive position” (Smith, Grimm, Gannon, & Chen, 1991, p. 61), firms’ actions on IPR protection may change accordingly. Therefore, the change in IPR protection can be associated with the threat of imitation by competitors. When there is no practical threat of imitation by competitors, efforts to deter imitation can be minimized. In particular, the threat of imitation relies on the condition that imitation destroys other valuable resources of an imitator. If this condition holds throughout the industry, imitation may not readily occur, and IPR protection may in turn not be essential. Once the condition is compromised by the emergence of competitors that are free from the condition, however, active formal protection of valuable innovations from imitation should be enforced.

The study in Chapter 3 helps deepen our understanding of why firms choose not to invest in imitation protection (Polidoro & Toh, 2011) and the timing of when firms finally do decide to deter imitation. This study adds dynamism to the link between innovation and IPR protection by arguing that firms invest in protecting valuable resources if there is a threat to inimitability. This argument aims to shift the RBV from a static and basic setting in which the link between valuable-but-imitable resources and their protection is established both instantly and stably toward a more dynamic and

practical setting where firms can delay their investment in inimitability and alter their protection strategy according to a newly emerged competitive landscape. Therefore, the “I” of the VRIO framework (Barney, 1991) is a function of the nature of competitive interaction (Porter, 1985).

Chapter 4 examines how different institutional factors in economic systems influence the effectiveness of investing in inimitability. More specifically, I ask why the governments of emerging economy sometimes fail to curb continuous intellectual property right (IPR) infringements by local firms. Formal IPR protections under global agreements are a policy linchpin to discourage IPR infringements and promote innovation in the global knowledge economy. However, global agreements have not necessarily protected innovations from infringement. The evidence in the global tire industry shows that there many firms in emerging economies exhibit divergent behaviors when pursuing innovation versus imitation. Some emerging firms have successfully transitioned from imitation to innovation. Others persist in imitation, sometimes resulting in IPR violations. In this context, Chapter 4 takes an in-depth look at Korean and Chinese tire makers. Under the same stringent global protection standard, Korean tire firms successfully transitioned to developing their own tread design innovations by the 2000s, while Chinese firms persisted in imitation, as evidenced by continuing IP lawsuits.

Chapter 4 offers the ecosystem lens as a plausible explanation for the divergent behaviors of Korean and Chinese tire makers in innovation and IPR infringements. An ecosystem refers to a business network in which firms collaborate and coevolve (Moore, 2006). The actors and their interdependent relationships in the network determine focal

firms' innovation capability (Casadesus-Masanell & Yoffie, 2007; Adner & Kapoor, 2010) and economic success (Moore, 1993; 2006). Building on the ecosystem literature, this study traces the difference between Korean and Chinese makers to the existence of national automobile manufacturers as “keystone organizations” in an ecosystem that are critical to facilitating the transition to innovation. A keystone organization is the leading firm in a business ecosystem that forms a common strategic vision for all other embedded firms (Iansiti & Levien, 2004; Nambisan & Baron, 2013). The organization offers key knowledge and market information to other actors that may impact the actors' strategic choice between innovation and imitation (Adner & Kapoor, 2010; Iansiti & Levien, 2004). Hence, the role of a keystone organization within an ecosystem is vital because it provides stronger incentives to innovate and in turn to avoid IPR infringements. In this sense, the ecosystem perspective explains how the relationship with leading innovators in an ecosystem influences a focal firm's strategic position in innovation and IPR strategy.

The findings in Chapter 4 add the ecosystem perspective to the recent debate about IPR protection in China (Verbeke, Ahlstrom, Carraher, Peng, & Vertinsky, 2017). Prior studies attribute Chinese firms' continuous IPR infringements to various institutional factors such as culture (Alford, 1995; Suttmeier & Yao, 2011), state ownership (Zimmerman, 2013), and institutional voids (Khanna & Palepu, 1997) and fail to explain the ongoing IPR infringements (Peng, 2013; Yu, 2014). This study suggests another dimension, the ecosystemic lens, to better understand the divergent behaviors in the case of Chinese and Korean tire makers. This chapter concludes that there may be a

reduction in IPR violations not because of a change in enforcement, but because of increased benefits of innovation in the ecosystem.

Overall, this dissertation research aims to illuminate the interdependence of inimitability, competitive landscape, and the factors that bind them. By doing so, this study attempts to examine the antecedents and effectiveness of investments in inimitability within a historical context of innovation and competition of a mature sector. The findings thus contribute to the understanding of the complexity of inimitability that works for competitive advantage in light of the dynamics of competition in an industry as the adoption of innovation and IPR protection continues to change.

CHAPTER 2

**THE HIDDEN HISTORY OF VISIBLE DESIGN: TREAD DESIGN AND
PROTECTION IN THE TIRE INDUSTRY**

Introduction

Imitation readily prevails where innovation works as a significant source of competitive advantages. Particularly if innovation requires consistent and heavy investments, imitation offers obvious benefits for competitors (Rudy & Black, 2018). Imitation has been a critical concern for firms in innovation-driven industries, where the market success of products relies on intangible resources such as innovative knowledge and enhanced technology. In response, successful innovation owners have protected their intellectual property rights globally (Clarkson & Toh, 2010).

In this study, I examine the prevention of imitation and infringement in regard to a specific area of innovation: design. Design as the physical form of a product tends to be associated simply with appearances or ornamental aestheticism, but it can also be the main source of differentiated qualities in product performance, precision, appeal, and even price (Porter, 1980). Management and economic histories find many cases in which design directly improves product functionality as well as dynamic associations between design innovation and firm performance (Rubera & Droge, 2013).

Surprisingly, the historical cases in design innovation rarely highlight mechanisms other than intellectual property rights (IPR) that prevent imitation of design. One type of IPR is the design patent. A design patent is a form of legal protection of visually unique qualities of a functional item. Specifically, it protects a distinct

configuration, surface ornamentation, or both against competitors. Design patents are especially valuable in industries where the design directly confers or is associated with the differentiated functionality of a manufactured product.

In this paper, I focus on the global tire industry, whose product quality and demands are tightly associated with tread design, or the geometric voids molded on the surface of a tire. While quite a few prior studies observed that tire makers rose and fell for the lack of timely adoption of technologies such as new tire materials and structure (e.g., see Klepper & Simons, 2000), the anti-imitation mechanism of the most visible part, that is, the tread design, has not been investigated despite its critical implication of innovation.

Tread design decisively affects a tire's quality and performance. According to a series of extensive experiments to identify the factors in tire performance, the tread design mainly determines the effectiveness of braking friction (Allbert & Walker, 1965), traction on wet or snowy roads (Novopolskii & Tretyakov, 1963), and tire longevity (Tretyakov & Novopolskii, 1969), to name a few. The value of an effective tread design has been well recognized from the early period of the industry, ever since the first tread designs were invented by Goodyear and Firestone in 1908. Emphasizing the importance of innovative tread design in tire performance, firms have consistently advertised tread designs as one of the main features of a tire to appeal to firm and individual buyers.

This study covers a succession of tread design innovations from the 1900s to the 1970s, starting from the beginning of modern tread designs. Before 1908, automobile tires used to have slick (or pattern-less) treads that consistently suffered from weak

traction and resulted in skidding problems on slippery roads. As car speed improved, the skidding problem became significant. To secure an anti-skidding feature, some European tire makers started to equip tires with steel studs implanted in the tread rubber. However, steel studs easily fell out when the tires were rolling (O'Reilly, 1983). Alternatively, tire manufacturers embedded “metal rivets, leather protuberances, or rubber buttons” molded on the circumference of the tire (Lief, 1951). For example, Dunlop and Continental manufactured a tire with protruding rubber buttons and dimpled slots as an early version of tread patterns in 1904. The era of tread design innovation finally began with the first invention of grooves and patterns molded into rubber tires by Goodyear and Firestone in 1908. Currently, tread design continues to be a major way to increase traction, extend mileage, and reduce noise.

We explore how design innovations were protected without resorting to intellectual property rights and litigations. In examining the mechanism protecting tread designs, which were highly valuable but easily imitable, we examine what factors contributed to the development of protection mechanisms in the tire industry. More specifically, we identify how market conditions and innovation characteristics formulated an anti-imitation mechanism alternative to IPRs in the early period of the tire industry.

This study is based on various historical documents, including academic manuscripts published by management and rubber science scholars in the context of the tire industry, books about tire makers in the early years, trade magazines, news articles, and archival advertisements. I investigated major historical events of tread design innovations with the following criteria: design innovations of long-standing, large tire

makers, and accessibility of historical evidence. The reason for the criteria is two-fold. First, since major firms were the group of technologically advanced leaders throughout the tire history, their innovations were attractive targets for imitation. Second, major firms had enough financial resources that they did not have to rule out patent protection due to legal costs. These criteria help us show firms' clear reliance on non-legal anti-imitation mechanisms.

Tread Design as a Key Innovation

The tread of a tire is the rubber part around its circumference that contacts the road or the ground. The word "tread" is sometimes mistakenly used to indicate the grooved patterns on the rubber surface. However, the correct term for the geometric voids on the surface of the tire molded into the tread is the "tread pattern" or "tread design." Various configurations and combinations of pattern elements such as circumferential grooves, transverse sipes, and shoulder blocks generate differential traction by expelling water and dirt from beneath the tire (Tire Technology International, 2017). If roads were always dry and clear of dirt and snow, it would not be necessary to have sophisticated tread patterns. For example, some racing cars that compete only on dry tracks can be equipped with smooth (or pattern-less) tires. However, tires on cars and trucks intended for regular driving (as opposed to racing) normally have such geometric patterns to maximize driving maneuverability.

The importance of tread patterns has been well documented by numerous scientific studies. More specifically, the width, number, size, and shape of tread elements

control how the tire contacts the road surface in various environmental conditions. As a result, tread design along with other tire factors such as rubber thickness and bending stiffness creates differential traction (Clark, 1981). While the tire compound material is an important factor to maximize the traction between the tire and the road, the tread pattern and the nature of the road surface are the variables that affect driving outcomes the most. Allbert and Walker (1965) compared various factors that influence effective braking friction on a wet road and found that the largest change in tread materials only shows a variability of 1.5:1, whereas a patterned tire versus smooth tire creates a variability of 8:1 and different tread designs do so up to 4:1. It is no wonder why many researchers and tire makers throughout the tire history have studied different shapes and dimensions of tread design elements to minimize hydroplaning and maximize snow traction from the early period of the tire industry (Smith & Clough, 1972). Clark (1981, p. 318) revealed:

In view of the several constraints on the practical range of tire rubber properties, the available range of friction is not large. By far the most important variables are the nature of the road surface and the tread pattern.

Different tread designs also affect tire pressure distribution, which is directly associated with tire longevity (Tretyakov & Novopolskii, 1969) and reduction of rolling noise (Clark, 1981).

While a tread design may look plain and straightforward, creating it is a challenging task as tread design involves complicated tradeoffs. It is not possible to meet and satisfy all desirable properties of a tire even if costs are not a factor. For instance, while the deeper and complex patterns of tread may secure better safety on wet or snowy roads, a thinner and simpler design may attenuate roadway noise and save manufacturing

costs. Ultimately, every tread element is a delicate compromise between hundreds of performance attributes (Bodziak, 2008). In this sense, an effective tread pattern with carefully designed shapes and measures is a valuable innovation to secure strong traction, proper maneuverability, and high comfort in different road and automobile conditions while reducing manufacturing complexity and costs according to each tire maker's capability (Clark, 1981).

The History of Tire Treads: The Symbol of Innovation

Tire makers have long understood the criticality of having tread patterns on tires. As horseless carriages (i.e., cars in the terminology of that time) gained popularity and began to be used on muddy or wet roads in the late nineteenth century, tire makers were required to invent tires with better traction. Some US tire makers started to engrave simple lines on the rubber tread, while others leveraged the license for the Bailey tread, which had a band of rubber with round buttons vulcanized to the tire carcass (Bodziak, 2008; Prowler, 1898). In 1908, Paul W. Litchfield, who was a superintendent at Goodyear's Akron plant and thereafter quickly promoted to be a president and chairman of the board (The Editors of Encyclopaedia Britannica, 2019), created the first anti-skid tire for cars, Goodyear's "All-Weather Tread." The tire featured diamond-shaped tread design with four-way edges that were designed to reduce skidding problems in any direction. This tread pattern became a symbol of Goodyear's identity and reputation as an innovator. O'Reilly (1983, p. 23) wrote:

[The diamond-shaped tread with four-way edges] immediately became identified with Goodyear and for many years was mechanically better than

any other nonskid tread on the market. For more than a half century, in fact, the distinctive diamond tread symbolized Goodyear around the world.

Also in 1908, Firestone, another US tire maker, commercialized the first angular anti-skid tires featuring a unique tread pattern with reverse molding. Harvey S. Firestone, the founder of Firestone Tire and Rubber Company, conceived a tire with “FIRESTONE NON-SKID” in block-lettering, diagonally placed across the tread: “FIRESTONE on one line, NON-SKID below it, repeated again and again along the circumference” (Lief, 1951, p. 50). An October 8, 1908 advertisement in *Motor Age* stated,

The name prevents the slip ... the letters of the words form more angles and points of contact than any other non-skid tread. The spaces in and between the letters cause just the right amount of suction to grip the slippery road and prevent the side slipping.

The tread pattern indeed served as intended for effective traction and, in turn, received high customer demand. Tires with the unique tread pattern generated strong traction and reduced car accidents while enhancing the life of tires and cars overall. Customers responded to this tire quickly and strongly: 40% of the 105,000 Firestone tires sold in 1909 and 60% of 168,000 units in 1910 were the anti-skid tire, leading to a profit of more than one million dollars for the first time in Firestone’s business history. Years later, Firestone further innovated by simplifying the tread pattern to include only two words, “NON” and “SKID,” and fine-tuned the thickness of the tread to further enhance the tire’s durability.

The first pneumatic tractor tire was another example of the ongoing innovation in tread pattern in the tire industry. Traction resistance is a critical issue, especially considering the types of soils where a tractor would operate. A tractor tire should grab

soft and wet earth in the field to move forward while sustaining its heavy load. To accomplish this, the “Ground Grip” tires by Firestone in 1932 introduced “a connected bar design – the continuation of one side of a chevron to the bar above it – and variations on that theme” (Lief, 1951, p. 217). By experimenting with different tread patterns and changing the tread pattern of the Ground Grip tire afterward, Firestone proved that a tractor with enhanced traction took less time to cover the same area of field and consumed less fuel. Subsequent efforts to improve the tread design of tractor tires resulted in a new tread design called Group Grip Type R in 1937. Its chevron was taller in height and narrower in width and its spacing was wider for better gripping and self-cleaning. A special version of this tire later featured the tread pattern of “converging ribs and more open spaces” designed to discharge mud even in rice fields (Lief, 1951, p. 218).

The series of tread patterns under the design of Ground Grip gave Firestone significant success in tractor tires. The market responded instantly to the tall length and open spacing of the bars that ensured wide contact areas and strong traction with the soft ground. Ground Grip tires started to replace the prevailing steel wheels on tractors. Leif (1951, p. 218) reported about the quick growth of innovative tractor tires:

Pneumatics as original equipment increased from 17,800 out of 118,600 tractors sold in 1935 to 92,400 out of 216,000 in 1937, the percentage growing to 85 two years later. Changeovers on old steel wheels took place at a more rapid rate.

At the same time, the passenger tire continued to be the primary arena of innovation in newer and better tread patterns. Since Goodrich introduced the first cord tires in the industry by acquiring the exclusive rights to use a cord tire manufacturing machine (developed by Chris Gray), the “Silvertown” tire employed various tread

patterns to enhance traction, especially for snowy conditions (Bryant, 1997). Following the naming tradition of tire products in the industry at the time, Goodrich named each variation of the Silvertown tire brand after the target functionality of different treads. For example, the anti-skid feature of a tread pattern was reflected in the product name of “Safety Silvertown” in 1938; in 1962, a new tread design was called “BFG Big Edge,” highlighting the extended rubber portion on the sides of the tread that was intended to prevent excessive wearing. In later years, Goodrich marketed the “T/A,” a new brand at the time optimized for high-performance muscle cars.

One of Goodyear’s most successful entries in the snow tire market, the 1952 “Suburbanite,” represents the outcome of consistent efforts to develop effective tread patterns. Its initial tread design featured a herringbone pattern, which Goodyear stated was the first logical winter tread design. Its four-edged cleats were designed to dig into snow or mud, while the flat tread reduced noise and shaking on a dry roadway. The succeeding tread design called “Hub-Cap Deep Dynamic Traction” further improved the Suburbanite. The 3,728 edges on the 260 tread cleats of this tread design garnered 51% more traction in snow and 17% more traction in mud. In later years, this tread design in Suburbanite’s tread material and tire structure was advertised as successfully passing the test for high-speed driving, resulting in better gas mileage and safety than other comparable tires.

Firestone also continued to commercialize innovative tread designs. In an effort to enhance the snow tire, Firestone introduced the “Polar Grip” tread in 1947. This tread had numerous “isocel” particles, or small pores, molded into the tread, working as a “tiny

suction cup with biting edges” and resulting in high traction on the road (Lief, 1951, p. 361). This tread design had multiple variations to secure extra traction, with studs implanted in the tread for the Firestone Studded Polar Grip and Firestone Ground Grip Super-Balloons. Firestone further introduced new tread designs, such as the improved eight-rib tread design for the De Luxe Champion passenger car tire and the extra-deep tread patterns of the Rock Grip tire tailored to industrial applications for mining and excavation (Lief, 1951).

In later years, asymmetric tread patterns appeared as a market trend. Michelin commercialized the first asymmetric pattern in 1965, a tread design with “large, closely spaced, interlocking elements on the outboard shoulder for handling and a more wide-open design on the inboard shoulder for traction” (Tire Technology International, 2017: para. 6). The superiority of this tread design was widely recognized throughout the 1970s, especially for racing and rallies, where an extreme level of tire performance is required. Currently, asymmetry in tread patterns is common in the original equipment and replacement tires that most drivers can easily find.

Unpatented Tire Tread Designs

Although the critical role and value of the tread pattern for tire performance have been known from the early years, most tread patterns were not patented in the tire industry. For instance, the diamond-shaped tread pattern of Goodyear’s All-Weather tire and Firestone’s famous NON-SKID lettering were not patented even though those tread patterns were key features of the anti-skid tires and created significant revenues for the

tire pioneers for a long time. Many other innovative tire designs were not patented years after their commercialization, including Ground Grip (the first tractor tire) and De Luxe Champion by Firestone, the Sure-Grip tractor tire by Goodyear, and some Silvertown and All-Terrain Radials by BFGoodrich.

Meanwhile, tire makers steadily engaged in innovations in tread designs. Thanks to their efforts to invent novel tread designs along with tire materials and structures, tire longevity increased from 500 miles in the 1900s to 20,000 miles in the 1930s (Charles, 1982). During a similar period (1910s – 1930s), the price index of tires dropped by over 73% (United States Department of Commerce, 1934).

The remarkable enhancement of tire performance and price in the early industry was mainly attributed to a series of cumulative innovations in design (Gaffey, 1940; Reynolds, 1938). While the R&D departments of major tire makers consistently changed and differentiated their products in terms of the configuration and combination of their tread shapes and sizes from the 1940s through the 1960s, design patents remained rare, with only about one per year in all design areas including tread patterns, diameter, and cosmetic ornamentation, between 1940 and 1965 (Warner, 1966). This trend persisted throughout the 1970s, despite increasingly more tread designs in the market. For example, Firestone alone had about 4,000 individual tire types in 1968 and increased the number to about 6,700 by 1972 (Sull, 1999). During this period, about 50% of Firestone's advertisements highlighted its tread designs as the main source of tire traction in the 1960s and roughly 52% in the 1970s. Furthermore, innovations in tread patterns enabled emerging tire makers such as Goodyear and Firestone to compete with the large

incumbents coming from the traditional bicycle tire market at the time (French, 1991). After all, innovative tread designs offered pivotal technological advantages over traditional bicycle tire makers. Protecting against imitation of the tread design should have been a necessity rather than a luxury.

The loose legal protection of tread design is even more surprising when we consider that the tire industry started off with a major lesson about the strong first mover advantage and effectiveness of protection against imitation. John Boyd Dunlop of Belfast, Ireland, patented a wide range of pneumatic tire-relevant inventions such as “fastening the tire to the wheel by means of a wired-on method, which applied a pneumatic tire to a flat-based rim with detachable flanges” (O’Reilly, 1983, p. 13). These patents gave significant technological advantages to Dunlop, suppressing free competition in automobile pneumatic tires in the late 1800s. However, long-forgotten but preceding key patents of pneumatic tires by Robert W. Thompson of England were found twenty years after his death in 1873. At that point, Goodyear, Firestone, and other emerging tire makers were finally able to bypass Dunlop’s clout. Nevertheless, although early tire makers well learned the value of protecting new innovations from the nascent stage of the industry, they were not active when it came to protecting tread designs that provided key competitive advantages.

The Reason for Loose Protection of Tread Design

The clue to the puzzle of the loose protection of tread design requires an understanding of the close supply relationship between tire and car makers. In the sense

that tires are the only contact points between a car and the road, the performance of original equipment (OE) tires is an obvious concern for car makers. As car performance dramatically improved over time, car makers had to secure OE tires that could match and even maximize the advancement of car performance (Rajan, Volpin, & Zingales, 2000). Moreover, due to diverse road and weather conditions in geographically different markets, large car makers frequently require OE tires to be customized for their new cars in each individual market. Thus, car makers aggressively demand that tire makers develop innovative products that evolve together with car performance and driving conditions.

Notably, car makers' pressure for tire innovation left no choice for tire makers but to innovate OE tires constantly. In an interview with *Rubber World* (January 1966), a tire expert revealed that car makers pushed their OE tire makers to be technological innovators and that OE tire makers could not survive without meeting car makers' expectation of tire innovation (Rajan, Volpin, & Zingales, 2000). Car makers explicitly required OE tires that could sustain greater torques, payloads, and speed for their new cars. Tire makers had no choice but to make a large R&D expenditure on better OE tires to maintain their OE supplier status (Rajan, Volpin, & Zingales, 2000). Tire makers thus chose to be technologically leading innovators rather than imitators by continuously developing better tires and supplying fitter original tires.

Tire makers also have another strong incentive to initiate and keep the supply relationship with car makers. Although the profit margin of OE tires tends to be about 60% of that in the replacement tire market historically (Rosenbloom & Benioff, 1990),

OE tire brands that were advertised nation-wide enjoyed higher price tags, offering critical competitive advantages over other tires. Tire makers therefore strived to achieve OE supplier status and heavily advertised the status. For example, Firestone widely advertised its tires featured on the Ford Zephyr 4-door estate car in the 1950s, BFGoodrich promoted a series of advertisements for its T/A 60 Radial tires that were equipped on Chevrolet's Corvette in the 1970s, and Goodyear's NCT tire was advertised as an OE tire for Ford's Capri 2.8i. Furthermore, it is well known in the industry that a significant portion of OE tires transfers to the choice of replacement tires. OE tire makers historically secured about a 30 – 40 percent rebound effect in which car owners reselect the same brand of OE tires when purchasing new replacement tires (Quelch & Isaacson, 1994). Therefore, tire makers heatedly engage in expanding and shielding their market share in OE tires.

This market dynamic pushed tire makers to go the extra mile and adopt car makers' requests for tire innovation. For example, Firestone's field marketing and sales personnel actively approached manufacturing managers at car makers to identify the tailored needs of specific OE tires and turn them into a set of proposals. The proposals were reviewed and quickly reflected in the decision-making and investment in tire research and manufacturing. OE tire makers still continue this practice today as a way to achieve and supply innovative OE tires (Kim & Mudambi, 2020). This long-lasting practice represents tire makers' endeavors to guard their OE supplier relationships, a key component to survive and prosper in the tire industry.

On top of tire makers' efforts in the OE market and dedication to tire innovation, the uniqueness and obvious visibility of tread design in tire products added another dimension to the loose protection. Tires of various sizes even within the same tire product line have different specific details of tread design in terms of block sizes, groove widths, tread widths, and other characteristics, making a tire maker and its product uniquely identifiable (Bodziak, 2008). After all, a tread design is unique to each tire maker and brand, resulting in its differential effectiveness. This uniqueness cannot be hidden because the tread area is visibly exposed on the tire surface. Car makers, who well understand tread designs as a source of tire innovation, have strong interests in and expert knowledge of tread designs in each tire brand.

The high visibility of tread design can help other tire makers easily imitate and enjoy its benefits. An imitator can readily emulate the tread patterns simply by measuring shapes and sizes in a picture of tread design. For instance, Michelin accused China Manufacturers Alliance (CMA) of copying its tread design based on a 1997 original illustration of its XLD 70-1 L3T OTR tire in an advertisement. CMA imitated Michelin's XHA OTR tire again in 1999 based on an illustration of the tire in another advertising pamphlet. Since these tread designs were not patented, Michelin had to engage in litigation, using its old advertisement catalogues as evidence (McCarron, 2007).

Because imitating tread design is an effortless task, imitation can bring significant benefits by saving time and resources in developing an effective tread design. Since it is not possible to develop a single tread design that can maximize all the attributes of a tire, the development of a tread design requires comprehensive research capabilities because

of the complicated trade-offs among the many performance factors of a tire (Kovac, 1973). For example, a passenger vehicle in snowy regions may need OE tires with deep grooves and lateral slots, but such tread design may sacrifice high traction on regular roads. Since the various automobile types, uses, and driving conditions demand a careful selection of design features and optimizations whose performance and qualities are appropriate for the desired car performance, OE tire makers have long innovated their knowledge about how to design, fine-tune, and customize tread design elements by selectively prioritizing the desired sets of attributes while meeting the minimum standards of the other parameters. Thus, car makers' strong favor for tire innovators over imitators has been essential and inevitable.

Eventually, car makers' strong preference for innovative OE tire makers and the obviousness of tread design left little room for imitation. An imitation of tread design may signal the maker's incapability or unwillingness to innovate tires tailored to the changing requirements of new vehicles. Litigations due to an infringing imitation of design may delay the OE supplies, which may critically jeopardize a tire maker's brand reputation as an innovator and risk its OE supply relationship with car makers (Rajan, Volpin, & Zingales, 2000). If the attempt to imitate can go undetected, imitation may be an affordable risk. However, a design imitation could be quickly caught due to the obvious visibility of the tread area, making imitation particularly difficult. Since both tire and car makers can closely examine the arrangements of tread blocks of diverse shapes and sizes, imitating tread design was particularly difficult. This is a clear departure from other innovation areas such as tire compounds that may be easily hidden or kept as trade

secrets from competitors. The contextual market structure and nature of innovation in the tire history therefore worked as a double barrier preventing imitation even without active legal protections.

Conclusion

In this research, we revealed a new insight in the study of innovation and imitation by highlighting that it is crucial to understand the market structure as well as the nature of innovation in an innovation-driven industry. By reviewing the historic tire industry, where tread design innovation was a source of competitive advantage, we argue that loose protection of the design was not inaction but strategic adaptation in the competitive reality of the tire industry. While the value of tread design had been clearly recognized since its inception in the early 1900s, legally protecting tread patterns was not the first priority for tire makers despite the clear value and easy imitability of the design. Tread designs are different in nature from innovations such as tire structure or manufacturing process, as they cannot be concealed from competitors and buyers. Furthermore, managing this industry includes dealing with car makers, who are powerful bulk buyers and highly selective for innovators.

We illuminated an intriguing answer to the puzzle of the lack of reliance on institutional protection mechanisms, in particular intellectual property systems. Competitors can reproduce or mimic designs to take advantage of the advanced features of innovative products. When the design of a product creates major competitive advantages at a product and firm level, the legal protection of design offers an intuitive

tool to prevent the proliferation of identical or similar knockoffs. Especially when an industry has emerged through the heavily guarded barrier of intellectual property rights, early players are expected to understand the key role of legal protection and employ it to protect their innovations. In this sense, major tire makers' lack of activity in legal protection offers an interesting puzzle. However, the rare protection of tread patterns has received remarkably little consideration in the literatures of business history, innovation management, and strategic management as a whole.

We reveal that tire makers that had innovative tread designs did not need to depend on the legal protection system due to the competitive market structure and the nature of tread design innovation. The close supply relationship between tire and car makers and its competitive implications in the tire industry posed a high risk of imitation to tire makers. Car makers demanded innovative OE tires customized to new cars and markets, and tire makers had to closely match the requests. Imitation and (possibly resulting) litigations could damage the reputation of tire makers and cause the delay of OE tire supply to car makers, a critical deal breaker for car makers. Since the tread design is unique to each tire brand and visible to tire and car makers, the chance to conceal its imitation was very slim. The market structure and the nature of innovation in competition therefore minimized the need for a legal protection system in the area of tread design for decades.

Despite the conventional wisdom that a legal protection of innovation is necessary, where imitation is relatively easy but provides significant benefits for competitive advantages, a protection strategy may not necessarily rely on intellectual

property rights. Firms leverage their innovations in a specific structure of market and competition. Imitation can be discouraged if the act of imitation significantly harms a firm's market position and advantages in an industry. Effectively, active adaptation to market structure and innovation characteristics can prevent the emergence of imitators and sustain the advantages of innovation without formal activities of protection for an extended period of time.

CHAPTER 3
INNOVATION AND IMITATION:
DESIGN IN THE GLOBAL TIRE INDUSTRY

Introduction

In 1908, Goodyear and Firestone commercialized the “All-Weather Tread” (O’Reilly, 1983) and “Firestone Non-Skid” (Lief, 1951), respectively. These were the first tires with *tread design*. Tread design is the geometric voids and molded elements on the surface of the tire, such as circumferential grooves, transverse sipes, and shoulder blocks. Various configurations and combinations of the elements generate differential traction by expelling water and dirt from beneath the tire (Tire Technology International, 2017). Unlike the prior generation of slick (or pattern-less) or steel-studded tires, tires with tread design had significantly improved traction (Novopolskii & Tretyakov, 1963), braking friction (Allbert & Walker, 1965), longevity (Tretyakov & Novopolskii, 1969), and noise reduction (Clark 1981). Tread design is one of the most critical features in determining tire performance and quality (Clark, 1981), and it has been adopted by all competitors.

Contrary to expectation, however, tread design was not closely protected from imitation at first. The tire industry had only one design patent per year from 1945 to 1965 (Warner, 1966). For instance, after it was developed in 1962, Goodrich did not patent the BFG Big Edge tread design, an innovative design which enhanced tire mileage and safety by elongating the tread edge of the tire. In contrast, tread design has been positioned as a main target of protection since the 1990s; tire makers collectively patented 406 tread

designs in 1991 – 1994, 703 in 1995 – 2000, and 923 in 2011 – 2014. The dramatic increase in patent protection is an interesting puzzle in that the crucial value of tread design innovation has been consistently recognized and advertised throughout tire industry history. This study identifies what mechanism explains the antecedents of change in protection strategy. Why did global tire makers rarely protect these innovations through patenting for decades and eventually began patenting seriously after the 1990s?

The strategic management and technology innovation literatures suggest some possible explanations. First, less protection in early decades may indicate high reliance on secrecy, leveraging causal ambiguity (Arundel, 2001; Reed & DeFillippi, 1990): if various elements and their combination must be emulated for an innovation, the complexity of the task may deter imitation (Rivkin, 2000), relaxing the need for patenting. Second, the intention of innovation diffusion may also substitute for the need for patenting. For instance, standardization aims to diffuse knowledge and maximize network externality rather than build exclusivity (Blind & Thumm, 2004). Lowering imitation barriers may delay the emergence of substitute innovations, sustaining the competitive advantage in an existing technology (Polidoro & Toh, 2011). Furthermore, weak protection of an innovation can induce competitors and other institutional actors to commit to the same knowledge base (Garud, Jain, & Kumaraswamy, 2002; Wade, 1995), providing the benefits of knowledge spillover to both innovators and imitators (Yang, Phelps, & Steensma, 2010). Thus, the strategy for greater network externality may reduce the need for patenting.

However, an in-depth investigation of the global tire industry reveals that these explanations do not convincingly explain the weak protection of innovations followed by a steep shift to aggressive patenting. The tread design itself does not require a complicated process of imitation because each element of the design is clearly visible to competitors. The tire industry neither has clear intention to increase the degree of network externality for tread design nor a substitute to replace it. Unlike tire structure, standardization or dominant design of tread design for network externality has not been formulated at all in the industry. Then what explains the loose protection of these valuable innovations, followed by vigorous patenting in the global tire industry?

In this paper, I highlight the dynamic nature of resource inimitability and protection. Given that some innovations can be critical knowledge-based resources enhancing competitive advantages (Bates & Flynn, 1995; Grant, 1996; Rumelt, 1984), it is a conventional assumption that firms have strong incentives to protect valuable innovations with weak inimitability (Lippmann & Rumelt, 1982). Unlike the conventional assumption, I show that weak inimitability of a key resource does not necessarily trigger protection from imitation. Nor does the link between resource inimitability and imitation protection stay static. Under the condition that imitating a key resource destroys other valuable resources of the imitator, the key resource stays inimitable and the owner firm of the resource does not engage in active protection. Even though the key resource can be easily imitable, competitors still avoid imitating the resource because it can be highly costly when customers particularly favor innovators as a criterion for product selection. The stigma of being imitators may de-legitimize a firm

and cause the loss of opportunities for institutional benefits in an industry (Meyer & Rowan, 1977). However, when the status quo changes with the emergence of competitors that are free from such imitation cost, investment in inimitability finally starts and increases rapidly. This study argues that the incentive to protect a valuable resource depends on not just the difficulty of imitating it in terms of causal ambiguity (Arundel, 2001; Reed & DeFillippi, 1990) or the network externality-related benefits of imitation associated with dominant designs (Suarez & Utterback, 1995) but also on the competitive landscape of the industry.

I support the arguments above by unpacking historical events and longitudinal patent analysis in the global tire industry. I observe that, while firms in advanced economies (like Goodyear and Michelin) invested significant time and efforts in tread design innovation starting from the dawn of the industry in the early twentieth century, they did not actively protect this innovation through patenting until the 1990s. The timing of the active protection in the 1990s coincides with the large-scale entry of tire manufacturers from emerging economies. Of particular interest are Korean tire firms, who entered global markets on the coattails of Korean auto assemblers. I present evidence that tire manufacturers operating in advanced economies were deterred from imitating each other's tire designs since these were viewed as key aspects of a firm's reputation. However, Korean entrants had no reputation cost in global markets and were not deterred from imitating designs. The findings explain why a competitive condition makes a valuable-but-imitable resource inimitable and when firms begin protecting the resource in the context of the global tire industry. Thus, the incentive and timing to

protect a valuable resource depend on not just resource inimitability but also competitive market structure. I contend that the “I” of the VRIO framework (Barney, 1991) is a function of the nature of competitive interaction (Porter, 1985).

This study addresses the oversight of dynamisms and competitive contingencies that extends the resource-based view (RBV) (Priem & Butler, 2001; Sirmon, Hitt, & Ireland, 2007). The findings help deepen the understanding of why firms choose not to invest in imitation protection (Polidoro & Toh, 2011) and the timing when firms finally decide to deter imitation. This research aims to shift the RBV from a static and basic setting in which the link between valuable-but-imitable resources and their protection is established both instantly and stably toward a more dynamic and practical setting in which firms can delay their investment in inimitability and alter their protection strategy according to a newly emerged competitive landscape. The findings will advance the extant literatures on the dynamic relationship between global innovation, competition, and imitation in the long-standing history of the tire industry, which may help managers understand when to invest in imitation protection.

Background

Resource Inimitability and IPR Protection

When and how do firms invest in resource inimitability? Before studying the question, I first visit the definition of resource inimitability. The resource-based view (RBV) defines resource inimitability as an attribute that makes a resource not perfectly mobile to competitors (Penrose, 1959; Wernerfelt, 1984; Barney, 1991). High resource

imitability deters competitors to develop and possess similar or imitative resources, transforming a short-term competitive advantage into a sustained competitive advantage (Barney, 1991; Peteraf, 1993). Effectively, high resource inimitability helps a firm sustain a strategic position that results in high value appropriation. Thus, scholars who subscribe to the classical RBV assume that investment in resource inimitability should be an inevitable choice for firms (Penrose, 1959; Wernerfelt, 1984; Barney, 1991).

As a well-known way to invest in resource inimitability, intellectual property right (IPR) is a clear manifestation of protection strategy (Foss & Foss, 2004; 2005). IPR defines the exclusive relationship between a resource and its owner firm (Waldron, 1988; Heller, 1998; Alexander & Peñalver, 2012) by offering a legal foundation to fight against imitation (Shapiro, 2003). For example, patent assignees can exert IPR via patent litigation to exclude imitators who attempt to copy claims of a patent (Lanjouw & Schankerman, 2001).

Many advantages encourage IPRs for resource owners. IPRs may enhance both value creation and appropriability (Somaya, 2012). Since IPRs can reduce transaction costs in protecting valuable resources, resource owners can limit value dissipation, resulting in higher value creation (Foss & Foss, 2005). The legal exclusivity endowed by IPR helps an owner firm have a revenue channel of protected resources via licensing (Clarkson & Toh, 2010). A thick portfolio of IPR works as an effective tool to prevent the emergence of imitators (Somaya, 2003). When resource owner firms have made large investments in new technologies and ownership rights are widely distributed in a technology market, IPRs can effectively “safeguard the investments in new technologies”

(Ziedonis, 2004, p. 805). Tough IPR enforcements can block knowledge outflow to competitors caused by job-hopping skilled employees (Agarwal, Ganco, & Ziedonis, 2009) and even reduce the probability of employee mobility itself, further curbing knowledge spillover (Ganco, Ziedonis, & Agarwal, 2015). IPRs also help firms strategically create crucial lead time between R&D developments and commercialization against imitators (Rudy & Black, 2018).

Therefore, it is not surprising that IPRs are widely used to protect valuable innovations in many knowledge-driven industries such as semiconductors (Mahoney & Pandian, 1992; Somaya, 2003) and pharmaceuticals (Rudy & Black, 2018). Foss and Foss (2005, p. 543) succinctly state that “a resource owner’s ability to create, appropriate, and sustain value from resources partly depends on the property rights that he or she holds.” Thus, IPR protection gives an innovation its realistic resource inimitability (Linden & Somaya, 2003). Nevertheless, although these prior studies indicate that firms should invest in resource inimitability and IPR protection works as an effective way to enhance resource inimitability, the extant literature fails to propose firm-level antecedents of dynamic changes in investments in resource inimitability via IPRs.

Causal Ambiguity

The strategic management literature suggests some antecedents that may control the investment in resource inimitability and, in turn, IPR protection. First, the notion of causal ambiguity helps explain what triggers investments in resource inimitability. If a key resource involves high causal ambiguity, its owner firm does not have to rely on

explicit reinforcement of resource inimitability. Causal ambiguity originates from a lack of causal relationship of resources with competitive advantages, hampering competitors' ability to emulate the resource and, in turn, erecting a barrier to imitation (Reed & DeFillippi, 1990). The traditional RBV literature implies that the degree of causal ambiguity embedded in resources themselves (Barney, 1991) and in the process of making the resource (Peteraf, 1993) control the need of explicit protection. If a resource consists of a complex combination and configuration of its elements, the high complexity contributes to high causal ambiguity and, in turn, inimitability (Rivkin, 2000). High causal ambiguity may also come from high tacitness (Polanyi, 1966) and high specificity (Williamson, 1985), deterring competitors from figuring out how to copy or reconstruct the key resource. Assuming that a key resource features high causal ambiguity, the owner firm can successfully delay imitation without explicit formal protection mechanisms such as IPRs (Ryall, 2009; Szulanski, 1996).

In this sense, firms whose resources have high causal ambiguity can rationally relax their investment in resource inimitability (Lippman & Rumelt, 1982; Reed & DeFillippi, 1990) because they do not need to protect the resources thoroughly and can avoid some adverse consequences from IPRs. IPR litigations may incur knowledge leakage that will benefit technologically lagging firms (Levin, Klevorick, Nelson, & Winter, 1987) and even result in invalidating IPRs (Besson & Meurer, 2008), two of the reasons why research-intensive firms still prefer causal ambiguity over IPR protection (Blind & Thumm, 2004). However, because the causal ambiguity of an innovation decays over time as competitors better understand relevant technologies and advance their own

R&D capabilities (Ghemawat, 1986), firms may eventually trigger and increase their investment in resource inimitability. Nevertheless, this explanation based on causal ambiguity depends strictly on the existence of conditions such as high complexity, tacitness, and specificity that hinder competitors from figuring out how to copy key resources. If the core nature of an innovation is easily identifiable and/or reengineered, causal ambiguity does not necessarily address the dynamic aspects about when a firm finally starts to invest in inimitability.

Network Externality

Another plausible reason to explain what enables investments in resource inimitability is subject to the concept of network externality. Positive network externality refers to the conditions in which the value of a good increases as the number of adopters rises (Schilling, 2002). An innovation that is widely adopted may confer accumulating returns to innovators, making possible further advancements, pressure for compatibility, and finally establishment of a dominant design (Arthur, 1989; Katz & Shapiro, 1986; Suarez & Utterback, 1995). Thus, a firm strives to position its technology to take up the status of dominant design so that it can maximize the effects of positive network externality.

One representative example of a network externality-based strategy that may lower the need for IPRs is standardization. Standardization aims to establish common interfaces and maximize compatibility across participants (Blind & Thumm, 2004). In particular, the goal of standardization is to achieve high customer acceptance (Salop &

Scheffman, 1983; 1987) as well as wide diffusion of technology (Blind & Thumm, 2004), weakening the need for exclusive ownership of knowledge and technology among the standardized producers. Thus, firms may intentionally lower the barriers to IPRs to facilitate competitors' adoption of an innovation. Furthermore, firms that participate in standardization processes are also likely to reduce internal R&D capacity and, in turn, IPR production by relying more on knowledge transfer from other participants in the standardization process (Love & Roper, 1999). The literature supports this negative association between standardization and IPRs (Blind, 2004; Blind & Thumm, 2004).

A network externality-based strategy may also intentionally constrain IPR production to build a greater knowledge pool. By limiting IPR activities, firms induce competitors to develop similar or even imitative innovations based on original knowledge and technologies, creating a bigger knowledge pool in the same domain of knowledge (Yang, Phelps, & Steensma, 2010). Loose IPR protection can expand the network of knowledge contributors (Levitt & March, 1988; Hansen, 1999) to include government agencies (Scott, 1985) and educational institutions (Heimer, 1985), further strengthening the knowledge pool. As the size of the knowledge pool grows, originating firms produce more innovative outputs because imitative innovations provide originating firms with new ideas and knowledge conducive to technological refinements in the same knowledge domain (Autio, Sapienza, & Almeida, 2000; Yang, Phelps, & Steensma, 2010).

Moreover, firms with imitative knowledge and technologies can form collaborative alliances with originating firms to secure institutional support in the industry (Wade,

1995; Garud, Jain, & Kumaraswamy, 2002). In this sense, originating firms can intentionally delay IPR protection to strengthen their strategic position in an industry.

Finally, a network externality-based perspective suggests another subtle benefit of relaxed IPR protection: reducing the threat of substitution. Recent studies highlight that loose IPR protection can be an effective choice for deterring the emergence of substitution in technology that may compromise originating firms' appropriability (Polidoro & Toh, 2011). Originating firms frequently face competitors that attempt to work around and substitute current innovative knowledge and technology (Peteraf & Bergen, 2003; Newbert, 2007). Especially when the threat of substitution is expected to render considerable risk to the original innovators (Mitchell, 1989; Anderson & Tushman, 1990), they should take strategic actions to curb the emergence of a substituting technology (Lado, Boyd, Wright, & Kroll, 2006). In this context, loose IPR protection can be a strategic choice of innovators. The low barrier to imitation can incentivize competitors to take advantage of the currently available knowledge and technologies rather than to create substituting innovations (Gallini, 1984; McEvily et al., 2000; Lado et al., 2006). Since loose IPRs may recruit wider institutional supports for a specific technology (Wade, 1995; Garud, Jain, & Kumaraswamy, 2002), competitors may further lose the momentum to seek substitutable innovations. Thus, innovative firms may discretionally choose to relax their IPR activities in order to deter the emergence of substitutions as long as possible (Polidoro & Toh, 2011). This strategic relaxation of IPRs to neutralize the threat of substitution is more likely to happen at an early stage of innovation because originating firms may not be able to precisely assess the uncertainty

and threat of substitution that the premature innovation induces (Agarwal, Sarkar, & Echambadi, 2002; Polidoro & Toh, 2011).

Theory

The explanations of the casual ambiguity and network externality perspectives described above hint at a dynamic source of investment in resource inimitability: imitation costs. In essence, resource inimitability originates from how costly and time-consuming competitors find it to imitate resources and capabilities (Barney, 1991; Helfat & Eisenhardt, 2004), though the imitation cost terminology may not be explicit. The notion of causal ambiguity represents such a case in which a resource intrinsically has high imitation cost to imitators due to its complex, tacit, or specific nature (Reed & DeFillippi, 1990; Arundel, 2001), thus relaxing an innovator's concern for protection.

On the other hand, the concept of network externality is somewhat different in that originating innovators intentionally diminish imitation costs to imitators. Positive network externality incentivizes an innovator to strategically relax IPR protection so that competitors (and potential imitators) can engage more in imitative development. As more firms and users adopt and diffuse a certain innovation, its originating innovator can harvest greater benefits of network effects (Katz & Shapiro, 1986). Thus, some originating innovators strive to expand positive network externality to acquire competitive advantages coming from a dominant design (Suarez & Utterback, 1995), a single standard (Swann and Gill, 1993; Swann, 2000), a bigger knowledge pool (Yang,

Phelps, & Steensma, 2010), stronger institutional supports (Wade, 1995; Garud, Jain, & Kumaraswamy, 2002), or a lower threat of substitution (Polidoro & Toh, 2011).

One missing component of prior studies in the extant literature is an imitator's imitation cost caused by damaging other valuable resources internally. An imitation cost itself can vary as the act of imitation influences other resources of imitators. For instance, imitation can be costly to imitators when customers particularly favor innovators as a criterion for product selection (Rajan, Volpin, & Zingales, 2000). In a context where a positive identity of being innovator is a key resource for competition, firms should be extra careful not to compromise the resource by imitating competitors. The stigma of being imitators may de-legitimize a firm in an industry and weaken institutional supports (Meyer & Rowan, 1977). Even at a managerial level, managers from advanced economies tend to view imitation as taboo because imitation may compromise their personal reputations (Bolton, 1993; Shenkar, 2010), leading them to avoid imitative strategies. Thus, under the condition that imitation destroys other valuable resources of imitators and firms recognize this reality clearly, imitation itself may not occur readily due to its high cost. As long as this condition stays stable in an industry, innovators do not need to enforce rigorous protection mechanisms such as IPRs. Once the condition is disrupted, however, firms are finally required to start to invest in resource inimitability.

The imitation cost incurred to an imitator by compromising other resources can be particularly high, especially when the resources at risk are difficult to build. A firm's reputation represents such a case. Firm reputation refers to "the perceptions by a firm's audience about the firm's ability to provide value compared with its peers and rivals"

(Philippe & Durand, 2011, p. 971). Like other intangible resources such as customer loyalty and trust, reputation takes significant time and efforts to develop and is not readily exchangeable in factor markets (Dierickx and Cool, 1989). Forming reputation takes time because it is intrinsically a “signaling process, in which the strategic choices of firms send signals to observers and observers use these signals to form impressions of these firms” (Basdeo, Smith, Grimm, Rindova, & Derfus, 2006, p. 1205). In other words, a reputation builds through a long course in which firms’ behaviors over time shape competitors’ and buyers’ understanding of what the behaviors convey (Fombrun & Shanley, 1990; Heil & Robertson, 1991). Eventually, a reputation delivers a firm’s long-standing identity as the set of interdependent characteristics of the organization that give it specificity, stability, and coherence (Swaminathan, 2001).

Furthermore, a positive reputation can be particularly important when it contributes to higher competitive advantages. Recent studies reveal that firms with a favorable reputation achieve higher performance in competitive markets because a reputation itself is a rare, valuable, hardly imitable and nonsubstitutable resource (Deephouse, 2000). Investors are more likely to invest in the firm with a positive reputation and customers are more attracted to purchase its products or services (Balmer, 1995; Van Riel, 1995). It is not a surprise that a favorable reputation is a strategic resource that requires protection, inasmuch as improved firm-level reputation is associated with a better competitive advantage (Stigler, 1962; Caves & Porter, 1977). If acts of imitation damage such a critical resource, firms should keep distant from imitative behaviors.

The imitator's high imitation costs incurred by compromising valuable resources such as reputation can be closely associated with the timing of investments in resource inimitability. Changes in the competitive landscape, initiated by the emergence of competitors that are free from the condition of imitation costs, ultimately alert incumbents to protect key resources at risk. Prior studies have emphasized that firms dynamically respond to the changes in business environments (Teece, Pisano, & Shuen, 1997; Eisenhardt & Martin, 2000). If a change poses threats to their competitive positions and advantages, firms have a clear motivation to respond accordingly (Grimm & Smith, 1997). In this sense, a change in a competitive landscape can be a key antecedent of firm reaction for protection against imitation. In knowledge-intensive industries where the value of technological differentiation is strategically important and technological competencies are significantly associated with competitive advantage (Dierickx & Cool, 1989; Henderson & Cockburn, 1994), it is a logical response for incumbent innovators to begin to protect their innovations against the emergence of competitors with low imitation costs that are very likely to imitate those innovations. Since inimitability is strongly associated with sustained competitive advantage (Barney, 2001), the investment in resource inimitability will eventually begin. Thus, the emergence of such competitors works as a dynamic antecedent that informs incumbent innovators that they should finally start to protect their innovations against imitation.

All in all, while investment in resource inimitability is taken for granted in the RBV (Barney, 2001), firms do not necessarily protect key innovations all the time. Firms can deter protection under the condition of high imitation costs by which imitation can

critically damage other valuable resources for competitive advantages. This implies that innovators can relax protections if the condition holds, but can also invest in resource inimitability if it does not. The emergence of lagging firms that are free from this condition induces incumbent innovators at direct risk to respond by engaging in and increasing their investment in protection (Chen & MacMillan, 1992; Chen, Smith, & Grimm, 1992). To further examine how the change in the condition shifts the trajectory of protection to a different path, I conducted a historical analysis of the global tire industry along with an analysis of the patent data of advanced incumbents and emergent contenders.

Empirical Context – Global Tire Industry

The empirical context of this research is the global tire industry, which has been a topic of interest in the innovation literature (e.g., see Klepper & Simons, 2000; Sull, 2001). While the tire industry has not witnessed disruptive technological innovations since the emergence of the radial tire,ⁱ some mid-tier tire manufacturers have improved their market shares consistently over the past two decades (Fujimura, 2015). Although the Big 3 players (Bridgestone, Michelin, and Goodyear) still dominate innovation and the

ⁱ A radial tire features cord plies that are arranged perpendicular to the direction of travel, or radially (from the center of the tire). This tire technology provides better maneuverability on rough or wet roads and improves braking and cornering power. Radial tires significantly enhance gas mileage and can last 40,000 miles or more (Rajan, Volpin, & Zingales, 2000). Radial tire technology, which is today's tire standard, helped to shake out technologically lagging tire makers, strengthening the oligopolistic structure of the industry (Klepper & Simon, 2000).

market, they collectively lost 17.2% of market share to mid-tier tire makers in the period of 2003 – 2014 alone. The consistent inroads of mid-tier tire makers are an interesting divergence from the argument in the extant literature that there is a gradual strengthening of an oligopoly by large incumbents through incremental innovation in a mature industry (Schumpeter, 1942; Klepper & Simons, 2000). The industry has been mature and stable for a long time but is going through another dynamic era, prompted by the market entry of emerging economy makers.

Coincidentally, while emergent mid-tier manufacturers were gaining more market share, dominant established players were filing more design patents. More specifically, the patent trajectory in the tire industry changed to mainly protect tread patterns starting in the 1990s. The role of tread patterns is important as the complex configuration and combination of design elements of tread (Figure 1) determine the effectiveness of traction (Novopolskii & Tretyakov, 1963), anti-hydroplaning (Allbert & Walker, 1965), and noise-reduction (Clark 1981), which in turn critically influence a car's maneuverability and longevity (Tretyakov & Novopolskii, 1969). Furthermore, since the tread design is unique for each tire maker and brand, it gives a criterion for automobile makers, who well understand that tread design is critically associated with tire performance, to select original equipment (OE) tires. In this sense, tread design is a main area of innovation and key source of competitive advantage in the tire industry.

Figure 1: Elements of Tread Design

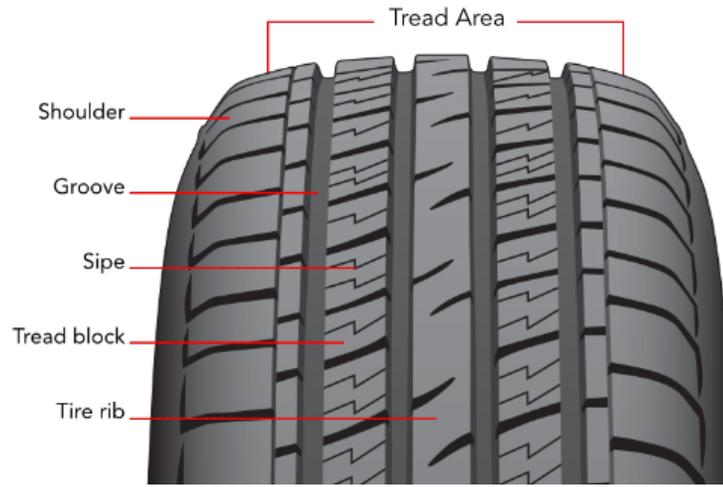


Figure 2: Cumulative Patents of the Big 3 makers (Goodyear, Michelin, and Bridgestone) in the Period of 1975 – 2014

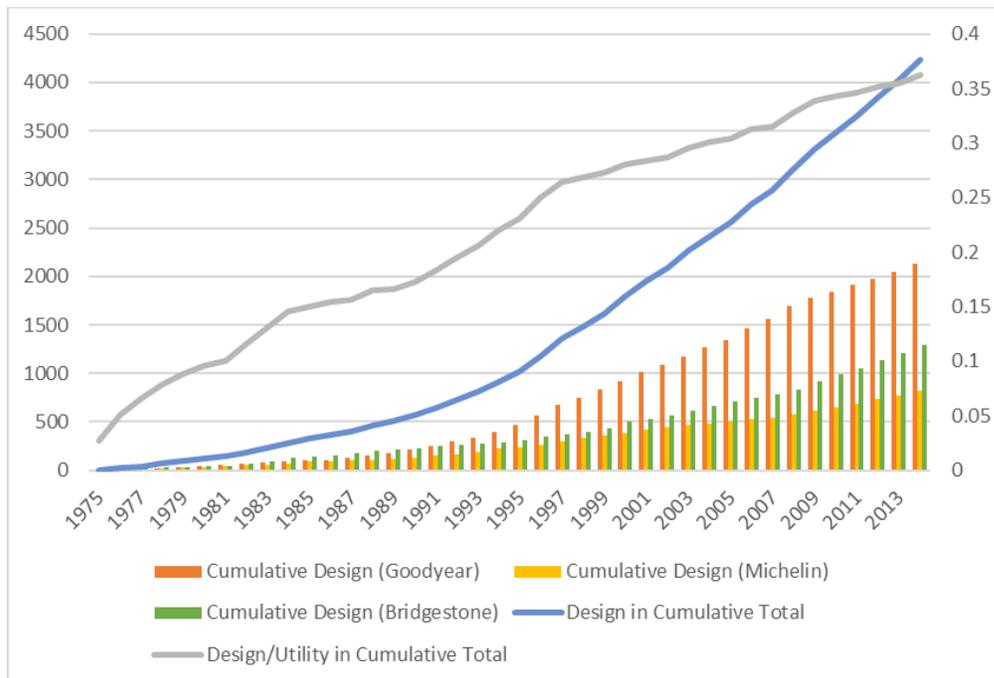


Figure 2 presents the cumulative patents in the period of 1975 – 2014 of the Big 3 makers (Goodyear, Michelin, and Bridgestone), which are the dominant players and innovation leaders in the global tire industry. The Big 3 collectively control more than 50% of the global tire market share and produced more than 75% of the total patents by tire makers. The number of patents they filed over the period 1975 – 2005 increased consistently without a significant sign of slowing down, showing the relentless pressure to innovate in the tire industry (Rajan, Volpin, & Zingales, 2000). Chemical and mechanical utility patents had dominated these patents up to the 1970s and 1980s, showing the strong emphasis on tire materials and manufacturing technologies at the time (Scalera et al., 2014).

There were few design patents filed until 1975, and the number of design patents of major global tire makers took off slowly between 1975 and 1990. As Table 1 shows, however, the increase in the number and share of tread design patents of the Big 3 makers since the 1990s is outstanding. During the 1980s, the ratio between design and utility patents was around 0.2, showing the dominance of chemical and mechanical innovation by the innovation leaders. However, in the 1990s, the production of design patents almost doubled to a ratio of about 0.4 design to utility patents. Eventually, the ratio between design and utility further increased to about 0.5 in the period of 2005 – 2014; the number of tire design innovation patents (190) almost matched the number of utility patents (197) in 2015. Tread designs have evidently become the main target of patent protection in the industry.

Table 1: The Increase in the Number and Share of Tread Design Patents (Goodyear, Bridgestone, and Michelin)

Yearly Period	Utility Patents	Design Patents	Ratio (Design/Utility)
1975 – 1979	1078	96	0.089
1980 – 1984	896	191	0.213
1985 – 1989	1066	220	0.206
1990 – 1994	1111	406	0.365
1995 – 1999	1762	703	0.399
2000 – 2004	2102	800	0.381
2005 – 2009	1761	897	0.509
2010 – 2014	1922	923	0.480

The relatively late increase in design patenting activities does not mean that tire makers have only recently discovered the critical value of tread design. In 1908, Goodyear commercialized the first tread design called “All-Weather Tread.” The design featured “diamond-shaped tread with four-way edges that resisted skids in any direction.” The tread pattern quickly became Goodyear’s iconic design and cemented its reputation as an innovator owing to its significant enhancement of traction (O’Reilly, 1983, p. 23). In the same year, Firestone invented the first angular anti-skid tread design called “Firestone Non-Skid,” generating high customer demand in 1910s. Thanks to its distinctive tread patterns that resulted in improved functionality, 40% of the 105,000 Firestone tires sold in 1909 and 60% of the 168,000 units sold in 1910 were anti-skid (Lief, 1951). The tread design helped the tire maker achieve a profit of more than one million dollars for the first time in Firestone’s history.

In the 1930s, Firestone conceived the first tread patterns for farming tires called Ground Grip that employed the tall length and open spacing of the bars. The tread design ensured that tractors had a larger contact and strong traction with the ground, saving hours for various farming tasks. Subsequently, the demand for Ground Grip tires grew

significantly. “(Ground Grip) pneumatics as original equipment increased from 17,800 out of 118,600 tractors sold in 1935 to 92,400 out of 216,000 in 1937, the percentage growing to 85 two years later” (Lief, 1951, p. 218).

The first asymmetric pattern for passenger cars was invented in 1965 and featured a tread design with “large, closely spaced, interlocking elements on the outboard shoulder for handling and a more wide-open design on the inboard shoulder for traction” that enhanced Michelin’s position as an innovator (Tire Technology International, 2017). The superiority of this tread design was widely recognized throughout the 1970s, especially for racing and rallies where an extreme level of tire performance was required. In later years, the asymmetric design in Michelin’s tread patterns was widely used in OE and replacement (RE) tires (Tire Technology International, 2017).

As tire makers have consistently made efforts to invent effective designs and configurations of tread pattern elements since the first emergence of patterned tires in the early 1900s, they have advertised new tread designs as a main feature of their tires. More specifically, the advertisements steadily attributed their enhanced performances to innovative tread designs. For example, the advertisement for the Goodrich Safety Silvertown Tire Original (1939) argued that the Life Saver tread design “acts like a battery of windshield wipers – sweeps right and left, across a wet surface – leaves a track so dry you can light a match on it.” The advertisement for Goodyear’s Suburbanite in 1955 highlighted the tread design saying “New! Exclusive Goodyear tread grip – for 51% more traction in snow, 17% more traction in mud!” The advertisement for Michelin XAS in 1968 stressed that its asymmetric tread patterns were designed to help cars operate at

210km/h, a speed considered high performance at that time. Armstrong Tires in 1980 advertised the strong traction of the Coronet tire's tread design with the catchy phrase: "the grip is basic for proper control." Even in more recent years, the Goodyear Wrangler Aquatred's tread design was the main feature of its advertisements in 1990, showing its superiority at expelling water underneath. The advertisement for Bridgestone Turanza GR90 in 2010 also called attention to its tread design: "an ultra-efficient tread design featuring rows of low and wide angle grooves and flexible construction deliver better water dispersion for heightened safety." A senior manager from a major global tire maker, who had an email interview with me, acknowledged that the historical efforts of advertisements featuring tread designs show that tread design has been an important part of innovation ever since its invention: "it is reasonable to assume that tread design has figured significantly over time as a tool for controlling grip in rough, wet and snowy conditions." Evidently, tread design has been a consistent part of innovation throughout the history of tires.

Incremental innovations followed the major tread design innovations above. As a clear example, Ground Grip, Firestone's first tread design for tractors which was invented in 1932, was followed by a series of variations throughout the 1930s and 1940s. Firestone also introduced the "Polar Grip" tread design in 1947. This tread had numerous "isocel" particles, or small pores, molded into the tread, working as a "tiny suction cup with biting edges." This tread design had multiple subsequent variations to secure extra traction, with studs implanted in the tread for the Studded Polar Grip and Ground Grip Super-Balloon products sold throughout the 1960s. However, these innovations and variants were not

patented. While major tire makers such as Goodyear, Firestone, Goodrich, Michelin, Dunlop, Continental, and Pirelli have been consistent leaders in the race for tread design innovations throughout the history of tire manufacturing, they did not patent major tread design innovations and following variations at all until the 1960s (Warner, 1966), only slowly starting to patent in the 1970s and aggressively accelerating in the 1990s. This phenomenon presents an interesting puzzle.

Methodology and Data Collection

I use two methodologies that complement each other. By unpacking the historical events and longitudinal patent and financial data analysis, this study shows the steep shift to active design protections as a response to the emergence of emerging economy tire makers in competition (Scalera et al., 2014). This complementary approach helps us better apprehend the dynamism of imitation and innovation (Casson, 1986; 1997; Wilkins, 1996; Jones & Khanna, 2006; Morck & Yeung, 2007; Buckley, 2009).

First, I perform a historical analysis of the tire industry which provides background information and the rationales for imitation by emerging economy tire makers. To illustrate the trajectory of protection and the nature of imitation in the tire industry, I study the historic events and trends that have shaped the global competition landscape since its early years, with a noticeable change in tread design protection in the tire industry since the 1990s. The rich historical analysis is expected to help elaborate the ins and outs of contextual dynamics (Pettigrew, 1990; Siggelkow, 2007) and illuminate causal forces of interest (Siggelkow, 2007; Joseph & Ocasio, 2012; Scalera et al., 2014).

The historic events were collected through various sources such as academic manuscripts, books, magazines, press articles, and corporate websites.

To triangulate the insights from the historical analysis, a series of semi-structured interviews were conducted during June 2018 (Table 2). One senior executive, two tire sales experts, three strategic planning managers, and two R&D engineers working for global tire and car makers were interviewed to collect contextual knowledge of the tire industry. All the face-to-face interviews lasted 45 minutes to 1 hour. I also conducted two email interviews: one with a former executive of a Korean auto maker to learn more about the history of Korean tire-making and one with a senior manager of a global tire maker to hear about the criticality and imitation of tread design.

Table 2: Interview Overview

Name*	Organization Type**	Interviewee's Position	Role
TireBest	Tire Maker	Senior Vice President	Leading corporate strategy planning division
EveryTire	Tire Maker	Senior Manager	Supervising external science and technology programs
GlobalTire	Tire Maker	Sales Director	Overseeing sales of original equipment tires for a specific car maker
GlobalTire	Tire Maker	Assistant Sales Director	Overseeing sales of original equipment tires for a specific car maker
GlobalTire	Tire Maker	Strategic Planning manager	Leading corporate-level strategy formulation
GlobalTire	Tire Maker	Assistant Strategic Planning manager	Analyzing external environments in the tire industry
GlobalTire	Tire Maker	R&D Engineer	Researching and developing tread designs
GlobalTire	Tire Maker	Assistant R&D Engineer	Researching and developing tread designs
QualityCar	Car Maker	Strategic Planning Manager	Establishing the corporate-level strategy
TopCar	Car Maker	Former Head of European Headquarter	Managing the sales in Europe.

* For confidentiality reasons, the names of these companies are fictitious.

** All manufacturers are globally renowned firms exporting products to more than 100 countries.

Second, the analysis of the historical dynamics is followed by a rigorous analysis of patent and financial data. Analysis based on patent data has been widely used in the literature to diagnose protection and competition. Pakes and Griliches (1984) noticed that a firm's level of economically valuable technological knowledge can be indicated by the number of its patents. Patents can also show the trajectory of protection over time, since firms willingly patent the majority of innovative (patentable) ideas and products (Mansfield, 1986). Ahuja (2000) also suggested that patents can be considered a good measurement of externally identifiable innovative success and imitation protection. Therefore, patent analysis can illustrate what types of innovations tire makers protect.

I gathered tire makers' patents via the patent collection compiled by Derwent Innovation Database, which scraped, cleaned, and standardized the universe of granted patent data of the United States Patent and Trademark Office (USPTO) across 1975 – 2015. Then, the patent data were merged with global tire makers' financial data for the period 1975 – 2015 collected from the Global CompuStat database.

Historical Analysis – Global Tire Industry from 1920s to 2010s

*The Tire Industry before the 1990s: Formation of Oligopoly by Tire Makers from
Advanced Economies*

After the introduction of pneumatic tires in the 1920s, the tire industry maintained an oligopolistic structure dominated by large innovators. The first fundamental product innovation of balloon-type tires in the 1920s was coupled with consistent process innovation in tire-manufacturing machines for mass production (Rajan, Volpin, &

Zingales, 2000). Continuous increases in product quality and quantity consistently penalized small or new tire makers while strengthening the dominant position of large makers mainly from Europe and the US until the 1970s (French, 1997). During this period, the longevity of tires increased from 500 miles in the 1910s to 20,000 miles in the 1960s (Jeszeck, 1982), while the tire price index dropped from 7.7 in the 1910s to 0.9 in the 1970s. Tire production rose from 6 million tires in 1913 to more than 200 million in 1968 (Carree & Thurik, 2000).

Thanks to a series of incremental product and process innovations, the number of firms in the tire industry dropped, firmly solidifying the market positions of old, big players (Jovanovic & MacDonald, 1994). By the 1970s, the global tire industry had evolved into a mature oligopoly with a small number of dominant firms, most of which were based in Europe (Michelin, Continental, Pirelli) and the US (Goodyear, Firestone, US Rubber (later Uniroyal), Goodrich, General Tire).

Starting in the 1950s, Japanese tire makers joined the group of major global tire leaders. Japanese tire makers such as Bridgestone, Yokohama, and Sumitomo swiftly adopted the innovations of European tire makers by commercializing radial tire technology, which is today's structural standard of tires, and engaged in brand-based competition throughout the 1950s and 1960s (Rajan, Volpin, & Zingales, 2000). The Japanese tire industry supplied OE tires that were exported to Europe and, later, the US (Rajan, Volpin, & Zingales, 2000). As a result, Japanese tire makers joined the competition as leading innovators head-to-head with European and US makers.

Reluctance to adopt the new radial tire standard was fatal to US tire makers. Goodyear and most US tire makers made a sub-optimal choice by adopting “belted bias ply” technology in the late 1960s (Denoual, 1980; O’Reilly, 1983; Sull, 2001) even though they recognized the superiority and popularity of radial tires (Kovacs & Rodgers, 1994). The deviation of the US tire makers from the dominant innovation trend invited detrimental consequences starting in the 1970s. When the demand for radial tires could no longer be ignored, the “radial-lagging” US tire makers experienced major financial troubles. Since radial tires require more costs for labor and materials and different production facilities than bias ply tires (*Rubber World*, November 1965, cited by Rajan, Volpin, & Zingales, 2000), immediate, extensive investment in radial tires was not feasible though the need to catch up was very urgent. Consequently, unlike European and Japanese makers, major US tire makers were not able to supply the necessary quality and quantity of radial tires to automobile manufacturers (Rajan, Volpin, & Zingales, 2000).

By the late 1980s, the global tire industry became even more concentrated in advanced innovators (Klepper & Simons, 2000). Through aggressive acquisitions by European and Japanese innovators, old, big US tire makers that had dominated the global tire industry for six decades exited (Ito & Rose, 2002). For example, Continental (Germany) bought General Tire (US) in 1987; Bridgestone (Japan) acquired Firestone (US) in 1988; Pirelli (Italy) bought Armstrong (US) in 1988; Yokohama (Japan) acquired Mohawk (US) in 1989; and Michelin (France) acquired Uniroyal-Goodrich (US) in 1990. Goodyear survived as the only major US tire maker thanks to its dominant (and “somewhat inertia bound”) position in the US replacement (RE) tire market (Rajan,

Volpin, & Zingales, 2000, p. 66) and its considerable research efforts to catch up with radial technology (Scalera et al., 2014). According to Ito and Rose (2002), the five major oligopolists (Goodyear, Bridgestone, Michelin, Continental, and Pirelli) took up more than 75% of the global market share as a result of the late-1980s consolidation.

The Tire Industry Since the 1990s: Relaxed Oligopoly and Tread Design Protection

Starting in the early 1990s, the tire industry witnessed a new round of global competition, this time from emerging economy tire makers. The once ever-strengthening oligopoly gradually relaxed as mid-tier tire makers in emerging economies increasingly took larger shares. According to Fujimura (2015), Bridgestone, the biggest tire maker, lost 3 percentage points between 2004 and 2013. Michelin and Goodyear lost 5.5 percentage points and 8.3 percentage points, respectively, during the same period. Meanwhile, mid-tier players from emerging economies consistently made inroads into the established advanced players' market shares. For instance, Hankook Tire (Korea) gained an additional 3.7 percentage points of the global market share during the same time period (*Tire Business*, cited by Fujimura, 2015). Collectively, the Big 3 tire makers (Bridgestone, Michelin, and Goodyear) lost 17.2 percentage points to mid-tier tire makers from emerging economies.

Coinciding with the entry of these mid-tier players, the industry witnessed a sharp increase in protection of tread designs. A few studies have reported the phenomenon. Scalera et al. (2014) find that Goodyear's number of design patents increased dramatically starting in 1992, eventually outnumbering its yearly utility patents in

chemical and mechanical classes. Mudambi, Mudambi, Mukherjee, and Scalera (2017) report that design patenting activity in the Akron area, the heartland of the US tire industry, grew significantly; the percentage of design patents in 1975 – 1979 was only 4.79% but reached 25.39% in 2000 – 2004. This is an interesting departure from Warner’s (1966, p. 276) report of “[only] one design innovation per year” in the tire industry in the period between 1940 and 1965. If we consider that the design innovations of those years included all the aspects of tire design such as “the tire’s diameter, tread design, fabric ply composition” and some “cosmetic” ornaments (Warner, 1966, p. 277), the recent dominant focus on the protection of tread designs is even more out of the traditional patent trajectory in the industry.

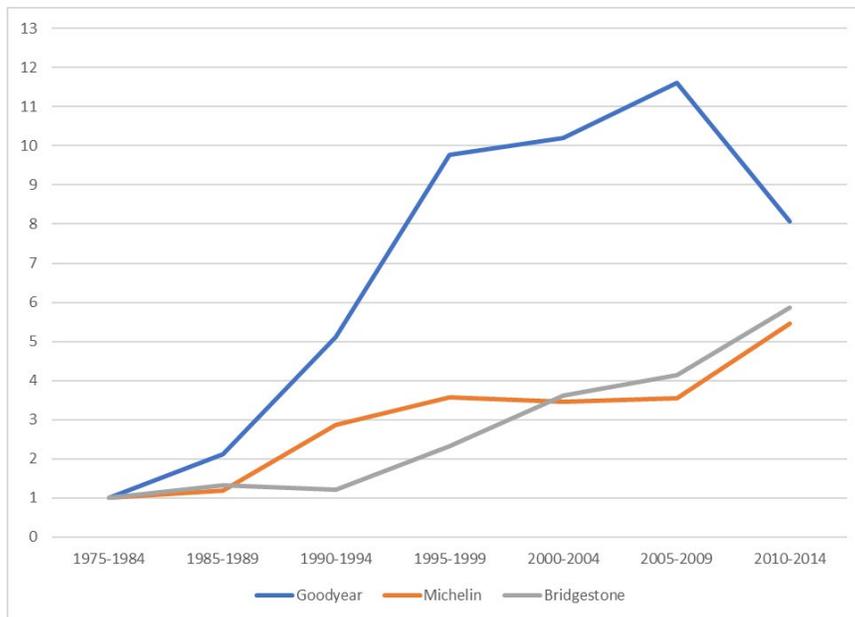
Our patent analysis is well aligned with recent studies, showing that Goodyear’s tread design patents have grown most noticeably (Table 3). Goodyear patented 2,127 designs, which is 2.6 times more than Michelin (817), and 1.6 times more than Bridgestone (1292) as of 2014. The average yearly number of tread design patents assigned to Goodyear jumped to 44.6 in 1990 – 1994, 85 in 1995 – 1999, and finally 101 in 2005 – 2009. The sudden increase in the design patents was not confined to Goodyear. In the patent analysis of the Big 3 players (Figure 3), the race for tread design protection is clearly visible when the average annual number of design patents in 1975 – 1984 is set to 1 as a baseline for each player. While Goodyear shows the steepest increase in design patents in 1990 – 1994 and 1995 – 1999, Michelin also jumped to file and was granted 2.86 times more design patents than its baseline in 1990 – 1994, 3.57 times more in 1995 – 1999, and eventually 5.46 times more in 2010 – 2014. Though Bridgestone initially

stayed calm until the early 1990s, the Japanese tire maker secured 2.32 times more design patents in 1995 – 1999 than its baseline, finally reaching 5.87 times more than the average in 1975 – 1984.

Table 3: Number of Design Patents for Global Tire Makers in 1975 – 2014

Period	Goodyear	Bridgestone	Michelin	Continental	Pirelli	Cooper	Sumitomo	Toyo	Yokohama	Hankook	Kumho	Nexen	Cheng Shin	5-Year Total
1975-1979	35	33	28	0	0	0	0	0	0	0	0	0	0	96
1980-1984	52	93	46	0	8	2	47	0	7	0	0	0	0	255
1985-1989	92	84	44	0	20	0	139	0	3	0	0	0	0	382
1990-1994	223	77	106	7	13	0	62	1	20	2	0	0	0	511
1995-1999	425	146	132	5	7	0	73	3	55	1	4	0	0	851
2000-2004	444	228	128	2	12	1	52	12	56	3	4	0	0	942
2005-2009	505	261	131	6	27	4	110	114	38	18	20	21	0	1255
2010-2014	351	370	202	1	12	78	129	119	106	45	8	14	6	1441
Grand Total	2127	1292	817	21	99	85	612	249	285	69	36	35	6	5733

Figure 3: Firm-level Efforts to Protect Design Patents from 1975 – 2014 (Goodyear, Michelin, and Bridgestone)



Why Major Tire Makers Delayed Tread Design Protection

Why did major tire makers not fully invest in the protection of tread designs before the 1990s? My interviews with the industry experts suggest that the loose investment in inimitability can be associated with key resources threatened by imitation of tread design. Imitation of tread design may compromise the reputation of being an innovator, a critical resource to specifically maintain OE market shares. Automobile makers, who are the buyers with the biggest bargaining power (Kim & Mudambi, 2020), relentlessly pushed tire makers to be technological innovators. A seasoned tire veteran stated, “You just can’t stand still with those boys [the automobile manufacturers]. ... Your tires have to carry heavier loads, last longer and go faster. The smaller firms cannot afford the kind of R&D operation this entails” (Rubber World, January 1966, cited by Rajan, Volpin, & Zingales, 2000, p. 58). To keep up with the evolving performance of cars, being an innovator is an important requirement for selection as an OE tire supplier. In an interview, an R&D engineer from GlobalTire stated that automakers sometimes demand tires specifically tailored for their new cars or markets. If a tire maker cannot meet this demand by innovating their tire features, the relationship cannot last. A strategic planning manager from GlobalTire further elaborated that automakers “hate to see the image of imitator [i.e., of an imitating tire maker] get stuck with them.” Automakers carefully select reputed innovators over imitators for their cars. Thus, major tire makers cultivate their reputation as innovators to continue their OE supplier relationship with automakers. Premature imitation is not a logical choice for tire makers.

Especially with tread design, global tire makers in OE markets had sought to avoid imitation. In the interview, the R&D engineer from GlobalTire noted that because each tread pattern (unlike chemical compounds, etc.) is clearly visible to automakers and uniquely identifiable to its tire maker and brand, the infringement of tread design cannot be readily hidden. Since the advanced players from Europe, the US, and Japan have created well-established tread patterns that are uniquely associated with their brands, they have avoided copying each other's designs in order not to sacrifice their reputation as an innovator. This condition of high imitation cost that may occur to imitators by damaging their reputation as innovators explains the loose protection of tread patterns without explicit legal protection methods until the 1990s. When only advanced playersⁱⁱ competed in the global OE tire market, design infringement was hardly imaginable because their well-established reputations as innovators were at stake. A senior manager at EveryTire supported, “[the imitation cost to risk the supplier relationship with carmakers] is significant to major and reputable [tire] companies.”

However, the appearance in the market of emerging economy makers in the 1990s disrupted the imitation-proof comfort zone of advanced incumbents in the OE market of the tire industry. Firms from emerging economies with weak IP protection tend to engage

ⁱⁱ For instance, the tire makers in the US OE market in 1980 were Goodyear (28%), Firestone (21.5%), Uniroyal (24.4%), General (10.8%), Goodrich (10.3%), and Michelin (5%) (1980 Tire Industry Facts, 1981). Ten years later in 1990, the OE market was still populated only by advanced tire makers without any design infringement: Goodyear (36.5%), Bridgestone/Firestone (17.3%), Uniroyal Goodrich (17.0%), Michelin (15.7%), General (12.0%), and Dunlop (1.5%) (1992 Tire Industry Facts, 1993). While the RE market witnessed a number of cases of infringements, the OE market has stayed relatively free from knock-off makers.

in IP infringement because of institutional (Khanna & Palepu, 1997), cultural (Bugbee, 1967; Jaffe & Lerner, 2007), and political (Zimmerman, 2013) loopholes. This tendency posed a practical threat of imitation for the tread patterns of advanced tire makers, which had not been protected for a long time. While the players from emerging economies tend to have no or weak reputations as innovators, they still can supply OE tires to their national automakers that export to the global market. The emerging tire makers thus do not have to worry much about damaging their reputation when they copy the tread designs of leading, established firms. Furthermore, design infringement was not a taboo to emerging tire makers because their managers did not necessarily view imitation as evil (Bolton, 1993; Shenkar, 2010). The emerging firms were even free from the risks to mutual benefits and the potential “de-legitimization” (Meyer & Rowan, 1977) that had been supported by the open-door policyⁱⁱⁱ of the Akron-based makers (Allen, 1949). The emerging economy players’ low cost of imitation alerted the major tire makers to begin protecting tread designs strongly.

The increasing number of lawsuits related to tread design infringement starting in the late 1990s indirectly supports that the sudden increase in tread design patents is not a vain worry of incumbent tire makers. In 1996, Michelin claimed that a Korean tire maker,

ⁱⁱⁱ Akron-based tire makers such as Goodyear, Goodrich, Uniroyal, Firestone, and General Tire had been collocated from the early days of the industry, developing a strong sense of trust. Allen (1949, p. 167) reports that they “did not worry too much about patents and trade secrets,” collectively “pooling ideas” and building improvements based on each other’s innovations. This reciprocally-benefitting “open-door policy” facilitated the atmosphere of active joint R&D projects among Akron-based tire makers (O’Reilly, 1983; Blackford & Kerr, 1996).

Kumho, had copied its tread design (Miller, 1996) on three tire models (XZA-1, XZA+1, and XZA2) protected by its US Patent No. 4,480,671. Kumho's tire, named 962 steer tire, was said to imitate Michelin's "narrow shoulder rib configuration", which the patent seeks to protect (Miller, 1996). Michelin wanted the United States International Trade Commission (ITC) to order Kumho to cease and desist the import and sale of the allegedly copied tire model to the US based on section 337 of the Tariff Act of 1930 that bans imports and sales of products that infringe on a US patent (Federal Register, 1997). In January 1997, Michelin withdrew the complaint after the judge ordered Michelin to reveal some "sensitive and highly-sought after information" (Federal Register, 1997: para. 5). The judge then granted Michelin's motion to terminate the investigation. Although the lawsuit ended with Michelin's withdrawal to prevent further imitation, the cases of tread design infringement continued.

In 2005, Michelin sued Dynamic Tire Corp. (Dynamic Tire) and its president, Robert Sherkin. This was the third lawsuit related to Aeolus Tire (Aeolus) in China. The suit claimed that Dynamic Tire distributed "knock-offs" of Michelin tires manufactured by Aeolus. Specifically, Michelin claimed that its proprietary tread designs of XDE M/S and XDA-HT tires were closely copied and infringed. The spokesperson for Michelin, Lynn Mann, stated that "the three separate lawsuits from last June to December shows how aggressively we're willing to pursue distributors that sell knockoffs of our tires. ... From a Michelin North America standpoint, filing actions against the distributor is the most direct path to stopping this problem" (Nguyen, 2005: para. 4). Also in 2005, Michelin alerted its more than 5,000 dealers about many "look-alike tires from Asia,"

copying the tread design of its truck and off-the-road (OTR) tires. The long-time tire maker argued that such imitations may not secure “the same grip or longevity of performance as an authentic Michelin tire” (*Modern Tire Dealer*, 2007: para. 6).

Michelin recently filed a lawsuit against a Thailand-based tire maker, Svizz-One, and an American distributor, Atturo, for tread design infringement (US Patent No. D483,322) (Powell, 2016), stating that the infringement “irreparably harms it [Michelin], for example, by circumventing its right to exclude others from making or selling products that are covered by the tire tread patent.” Michelin also added that the patent infringement should be considered as a willful act from the emergent tire maker “because it occurs despite an objectively high likelihood that their conduct infringes the patent” (Powell, 2016; *Michelin v. Atturo and Svizz-One*, 2016, p. 6).

The imitation risk of tread patterns impacted other advanced tire makers as well. In 2014, the US International Trade Commission (ITC) forbade the import of certain kinds of automotive tires from China and Thailand, because they violate design patents held by Toyo Tire Holdings of America Inc (United States International Trade Commission, 2014). According to Kossov (2014), eight tread design patents (D487,424; D610,975; D610,976; D610,977; D615,031; D626,913; D458,214; D653,200) were infringed by a group of Asian tire makers including Hong Kong Tri-Ace Tire (Hong Kong), Weifang Shunfuchang Rubber & Plastic (China), Svizz-One (Thailand), and six other Chinese makers as well as related importers and US distributors. Toyo claimed that by infringing those patents, the alleged infringers damaged the Toyo and Nitto brands that featured Toyo’s original tread and side wall designs. Eventually, in July 2014, ITC

issued “a limited exclusion order forbidding the import and sale of tires that violate Toyo’s patents” (Kossov, 2014).

Bridgestone secured a favorable ruling in 2011 against two Chinese tire makers, Jianxin and PT Beststone. The Chinese makers were accused of “manufacturing and selling pre-cured treads”^{iv} copying Bridgestone’s tread patterns for truck and bus tires (Bridgestone, 2014: para. 2). In 2014, the Zhengzhou Higher People’s Court in China ruled that the two Chinese tire makers violated Bridgestone’s design rights and ordered the makers to compensate the incurred damage to Bridgestone. After a few more lawsuits against tread design infringements, Bridgestone (2017: para. 4) stated that it will continue to deal with such infringement to protect “the safety and quality associated with its products ... [for] maintaining and enhancing its hard-earned brand value”.

Among the emerging economy tire makers that actively imitate advanced players due to low imitation costs, I argue that the dramatic increase in design patenting activities by global tire makers is closely associated with the entry of Korean tire makers in particular. This is mainly because Korean makers are the first and only^v large-scale entry into the OE market that directly threatens global tire makers. According to the interview

^{iv} “Pre-cured treads” refers to pre-vulcanized tread rubber used in retread tires (Bridgestone, 2014: para. 5).

^v According to the annual records of tire shipments, tire pricing, distribution, commercial business, plant capacities, and other import data published by *Modern Tire Dealer* since 1980, no emerging economy tire makers other than Korean tire makers have entered the US OE tire market. Thus, there has been no shift of OE auto companies from major tire makers such as Goodyear and Michelin to Chinese or emerging economy players other than Korean makers.

with the sales director and assistant sales director, Korean tire makers first entered the US OE tire market as an OE supplier for Korean car makers in the early 1990s. For instance, Kumho Tire, the second biggest Korean tire maker, became an OE tire supplier in the US market with the made-in-Korea cars called Festiva in the early 1990s. Korean global automakers such as Hyundai and Kia Motors have used Korean tires for their export cars since the 1990s. *Modern Tire Dealer* (2017) reports that cars manufactured by Hyundai and Kia and exported to the US have been predominantly equipped with Korean tires (71% as of 2016) until recently. As South Korean automakers exported over one million cars to major international markets across six continents in the mid-1990s (Korea Automobile Manufacturers Association (KAMA), 2005), Korean tire makers such as Hankook Tire (the biggest Korean tire maker), Kumho, and Nexen (the third biggest in Korea) quickly became global OE tire suppliers.

The large-scale entries of South Korean firms into the global OE market along with emerging economy firms' attempts to imitate tread designs signaled a clear change in the competitive landscape, urging a change in incumbents' protection strategy. Entry to the global OE market is particularly critical in that a significant portion of OE tires transfer to the choice of individual replacement tire (RE) customers. In our interview, a strategic planning manager called this "the rebound effect," which creates a significant portion of RE sales. For instance, Quelch and Isaacson (1994) report that 44% of Michelin's OE tires were selected again when customers needed a new RE tire, and Goodyear enjoyed a 39% rebound effect. For the first time in the history of the global tire industry, emerging economy tire makers finally started to directly compete with the

group of long-dominating players from Europe, Japan, and the US by officially entering the most value-creating OE market. The strategic response with stringent protection of innovations by the established OE tire makers became essential to defend their innovations and market shares.

Longitudinal Analysis of Patent and Financial Data

To understand the impact of tire makers from emerging economies with low imitation costs, I estimated a series of fixed effects panel regression on our unbalanced panel dataset controlling unobserved firm-level heterogeneity. As a dependent variable, I employed the yearly number of USPTO design patents in 1975 – 2015 for all the global tire makers identified by the Global Industry Classification Standard (code: 25101020 (Tires & Rubber)) in the Global CompuStat database.

The main independent variable is the yearly revenue of Korean tire makers (*Revenue of Korean Makers*) to show the impact of the emergence of tire makers that are relatively free from the prior condition of imitation costs and who had entered the global tire market. I also included a variable for the yearly revenue of other emerging economy tire makers (*Sales of Emerging Economy Makers*), defined by summing the yearly revenues of tire makers from emerging economies such as China, Russia, India, Indonesia, Pakistan, Poland, Peru, Sri Lanka, Turkey, Myanmar, and Tunisia. These tire makers have not entered the global OE market before. The yearly number of utility patents (*Utility Patents*) controls the R&D intensity for each firm. I also include variables such as yearly revenues of each maker (*Revenue*) and the Great Recession period (2007 –

2009) to control the impact of financial performance on the number of design patents.

The yearly number of patent produced in each country (*Country-level Number of Patents Per Year*) is included to control the national-level R&D intensity. The yearly tire sales (in million units) of the biggest tire market, the US market, is employed to control the overall ups and down in tire industry sales (*US Tire Market*).

The analysis includes some industry-specific control variables. First, the period of Safeguard in the tire industry is used to control the industry-specific condition of tire export (*Safe Guard*). In June 2009, the US International Trade Commission (ITC) applied a special Safeguard clause to China to determine the market disturbance facts for China's PCR (Personal Car Radial) and LTR (Light Truck Radial) tires. This was based on the provision that World Trade Organization (WTO) member states could apply a special Safeguard on imports from China for 12 years (2001 ~ 2013) after China's entry into the WTO. Finally, President Obama announced additional 35%, 30%, and 25% surcharges annually for the next three years beginning September 2009. The US Steel Workers Union (USW), which had requested the United States to restrict imports of Chinese tires in 2009, asked the US Department of Commerce again in June 2014 to impose countervailing duties and anti-dumping duties on imported tires from China. The Safeguard was a great opportunity for Korean tire manufacturers, who enjoyed great profits thanks to the additional tariffs imposed on US tires from China. The annual average growth rate of exports to China from 2009 to 2012 reached 35.5%. This binary variable is set to 1 during the Safeguard period to control the unexpected boon for Korean tire makers and the indirect impact for other tire makers. Second, the yearly number of

lawsuit cases related to tread design infringements (*Number of Tread Design Infringements Per Year*) is also employed to control overall prevalence and simple threat of imitation in tread designs in the global tire industry.

Notably, I use a control variable to incorporate the change in the strength of IPR regime (*TRIPS Agreement Implementation*). As a home country of a tire maker adopts a global IP protection standard, the maker's patenting strategy and behavior may change to adapt to the new IP protection environment. To account for this, I consider the implementation year of the WTO's Trade-Related Aspects of Intellectual Property Rights (TRIPS) for each country as a proxy for the strengthening in IPR regime of a home country. Signing the agreement signals an emerging economy country's willingness to comply with the globally recognized standards for IPR protection (Peng, Ahlstrom, Carraher, & Shi, 2017; Brandl, Darendeli, and Mudambi, 2019).

The results of the main regressions can be found in Table 4. I examine the relationship of design patents with the global revenues of Korean tire makers and find that the protection of designs is strongly and positively associated with the global revenues of the Korean players. Model 1 indicates the impact of overall control variables on the design patents. Most of the variables except for *Country-level Number of Patents Per Year* are significantly associated with the number of design patents. The firm-level control variables such as *Utility Patents* (for R&D intensity) and *Revenue* (for economic performance) also show significant impact on the dependent variable in Model 2. When I plug in the revenue of emerging economy players (*Sales of Emerging Economy Makers*) in Model 3, the variable is clearly associated with the number of design patents, implying

that the global emergence of these tire makers seems to increase the investment in tread design protection. However, once the main variable, *Revenue of Korean Makers*, is included in Model 4, the result shows that the independent variable is positively and strongly significant ($\beta = 5.01, p = 0.003$), while making the impact of *Sales of Emerging Economy Makers* insignificant ($\beta = 0.290, p = 0.298$). This result indicates that growth in the global revenues of Korean makers (not others) enhances efforts to protect the tread designs. The main result is as expected since only Korean tire makers among emerging economy players that are relatively free from high imitation costs caused by damaging the identity of being an imitator emerged in the OE market where advanced players had competed. On the other hand, the revenue growth of other emerging tire makers, which remain in the RE market, do not necessarily influence the trajectory of design patenting.

Table 4: Fixed Effects Panel Regression of Yearly Revenue of Korean Tire Makers on Design Patents

Global Tire Manufacturers: Fixed Effect Panel Regression (Lagging 1 Year)
 Dependent Variable: Design Patents

	Model 1	Model 2	Model 3	Model 4
Utility Patents		0.0970079 [0.031]	0.0724116 [0.021]	0.0652123 [0.077]
Logged Revenue of Korean Makers				5.005076 [0.003]
Logged Sales of Emerging Economy Makers			0.7597591 [0.057]	0.2896624 [0.298]
Logged Revenue		0.39608 [0.034]	0.2794635 [0.053]	0.238045 [0.232]
Great Recession (2007-2009)	5.315319 [0.021]	5.273449 [0.026]	3.678833 [0.010]	2.040593 [0.046]
Number of Tread Design Infringements Per Year	1.563485 [0.004]	1.5629 [0.003]	1.916454 [0.010]	0.1620928 [0.494]
TRIPS Agreement Implementation	-6.582886 [0.005]	-6.894335 [0.008]	-4.669219 [0.006]	-5.928442 [0.003]
Country-level Number of Patents Per Year	0.000002 [0.694]	0.000002 [0.712]	-0.000004 [0.225]	-0.000005 [0.123]
US Tire Market	0.1405549 [0.028]	0.1284167 [0.035]	0.0348183 [0.025]	0.0240011 [0.082]
Safe Guard (2009 – 2012, 2005)	7.940711 [0.004]	7.647473 [0.004]	6.050279 [0.016]	0.2122469 [0.796]
Constant	-34.81226 [0.062]	-36.27259 [0.060]	-20.6786 [0.049]	-79.29153 [0.005]
Observations	826	774	739	739
Within R^2	0.1912	0.2362	0.1746	0.2148
Between R^2	0.3039	0.3405	0.2980	0.0980
Overall R^2	0.0163	0.2742	0.2351	0.1250
F Statistics	2.65	2.42	2.85	2.63

Table 5: Subgroup Analysis for Advanced vs. Emerging Economy Makers: Fixed Effects

Panel Regression of Yearly Revenue of Korean Tire Makers on Design Patents

Global Tire Manufacturers: Fixed Effect Panel Regression (Lagging 1 Year)

Dependent Variable: Design Patents

	[Advanced Makers] Panel OLS Regression	[Emerging Mak Panel OLS Regr
Utility Patents	-0.000603 [0.991]	0.2238601 [0.098]
Logged Revenue of Korean Makers	11.04614 [0.002]	0.9303388 [0.097]
Logged Sales of Emerging Economy Makers	0.9439017 [0.393]	-0.0217855 [0.665]
Logged Revenue	3.516651 [0.172]	0.0356354 [0.306]
Great Recession (2007-2009)	4.73004 [0.337]	0.3104396 [0.095]
Number of Tread Design Infringements Per Year	-0.4773436 [0.630]	-0.0699309 [0.333]
TRIPS Agreement Implementation	0 (omitted)	-0.8557481 [0.124]
Country-level Number of Patents Per Year	-0.0000726 [0.043]	0.0000001 [0.799]
US Tire Market	-0.0009848 [0.989]	0.0082593 [0.023]
Safe Guard (2009 – 2012, 2005)	-1.739401 [0.689]	-0.2204024 [0.383]
Constant	-170.3934 [0.011]	-15.52131 [0.089]
Observations	161	578

To further test the impact of Korean tire makers on a group of advanced incumbents in the industry, I performed a subgroup analysis to better understand the threat of imitation across the different groups in context (Venkatraman, 1989). We divided the dataset into two sets of subgroups: advanced and emerging economy players. I define the advanced players as traditional tire makers that have dominated OE (and RE) markets in the global tire industry. This subgroup includes tire makers from the US, France, Italy, Japan, and Finland. The group of emerging players includes other makers from developing economies such as China, Indonesia, Taiwan, India, Pakistan, Poland, Kenya, Peru, Sri Lanka, Thailand, Turkey, Myanmar, and Russia. For each group, I regressed the number of design patents on the revenue of Korean tire makers and control variables. The results are presented in Table 5 and show that the effect of growth in the revenues of Korean makers is not significant on the emerging players ($\beta = 0.930, p = 0.097$) but is very significantly positive ($\beta = 11.046, p = 0.002$) on the advanced players. The impact of the Korean makers only affects the group of advanced OE players, as expected. This is a clear contrast with other emerging economy players that stay in RE markets.

Finally, I performed a sensitivity analysis to better understand the impact of Korean tire makers. I split the dataset before and after 1993, which is a few years after all the Korean tire makers entered the US OE market riding on the back of Korean car exports. The results in Table 6 confirm that the effects of Korean makers' revenues after 1993 are significantly greater in magnitude ($\beta = 4.700961, p = 0.006$) than those before 1993 ($\beta = 1.120274, p = 0.036$). I had a similar finding that the effects were greater in

magnitude after 1995 in the analysis before/after 1995. The results show that the entry by Korean makers increasingly generated a greater impact on the protection of design patents as time goes.

Table 6: Sensitivity Analysis before vs. after 1993: Fixed Effects Panel Regression of Yearly Revenue of Korean Tire Makers on Design Patents

Global Tire Manufacturers: Fixed Effect Panel Regression (Lagging 1 Year)
Dependent Variable: Design Patents

	[Earlier than 1993] Panel OLS Regression	[Since 1993] Panel OLS Regression
Utility Patents	0.0388696 [0.858]	0.0417525 [0.253]
Logged Revenue of Korean Makers	1.120274 [0.036]	4.700961 [0.006]
Logged Sales of Emerging Economy Makers	0.4737677 [0.184]	0.196666 [0.500]
Logged Revenue	-19.49416 [0.044]	0.2302754 [0.201]
Great Recession (2007-2009)	0 (omitted)	1.627608 [0.054]
Number of Tread Design Infringements Per Year	-6.734344 [0.018]	0.0871081 [0.733]
TRIPS Agreement Implementation	0 (omitted)	-5.119993 [0.008]
Country-level Number of Patents Per Year	0.0002087 [0.141]	-0.000006 [0.088]
US Tire Market	-1.1546772 [0.384]	0.0149951 [0.245]
Safe Guard (2009 – 2012, 2005)	0 (omitted)	-0.0851993 [0.929]
Constant	220.7024 [0.092]	-70.58268 [0.013]
Observations	53	721

In summary, I argue that the main source of the big players' dramatic shift to tread design protection is the threat by emerging economy players such as South Korean tire makers. While the high imitation cost of damaged reputation of an innovator reduced the need to patent designs until the 1990s, the emergence of tire makers who were free from such constraints promoted the phenomenon of filing more tread design patents to protect the innovations. This threat from the competitive entry to the formerly imitation-proof market directly challenged and clearly impacted the group of advanced tire makers. This explains the situation shown in Figure 2 and Table 1 in which the pace of protection in tread designs becomes faster and the proportional share of tread designs relative to utility patents becomes larger as time goes on.

Discussion

Since the first tread designs were created by Goodyear and Firestone in 1908, tread design has been a key area of innovation (Lief, 1951; O'Reilly, 1983). Tread design is uniquely identifiable to each maker and brand and is directly associated with tire performance (Lief, 1951). Since tread design is one of the most critical determinants of tire quality (Clark, 1981), tire researchers and makers have long studied different combinations of shapes and depths of tread design elements to not only minimize hydroplaning and noise but also maximize snow traction and longevity from the early period of the tire industry (Novopolskii & Tretyakov, 1963; Allbert & Walker, 1965; Staughton, 1970; Smith & Dough, 1972). Thus, the long-lasting loose protection of tread

design followed by a sudden shift to active protection around the 1990s is an interesting puzzle.

This study presents evidence that innovative tire manufacturers were deterred from imitating each other's tread designs since imitation was associated with reputation. Since infringing tread design can be easily caught due to its visibility, the imitation may destroy a firm's reputation as an innovator, which is a critical resource to maintain the OE supplier relationship with automakers. However, when emerging entrants with no or weak reputation entered the global markets and were not deterred from imitating designs, advanced incumbents finally had a strong incentive to protect their designs.

Based on the in-depth qualitative and quantitative analyses, I suggest a subtle but dynamic antecedent of firm-level investment in resource inimitability: the emergence of firms that can readily imitate but may not suffer from high imitation costs. This dynamic antecedent can motivate innovation leaders' efforts to invest in inimitability to protect the source of their competitive advantage. The finding from the tire industry is aligned with the extant literature, in which competitors engage in strategic initiatives that challenge the status quo of the market process and focal firms respond in turn (Ferrier, Smith, & Grimm, 1999). Responding to "specific and detectable competitive moves initiated by a firm to defend or improve its relative competitive position" (Smith, Grimm, Gannon, & Chen, 1991, p. 61), firms' actions on IPR protection may change accordingly. Therefore, the change of IPR protection as a manifestation of investment in resource inimitability can be associated with the threat of imitation by competitors. When there is no practical threat of imitation by competitors, the efforts to deter imitation can be minimized. More

specifically, the threat of imitation relies on the condition that imitation destroys other valuable resources of the imitator. If this condition holds among all the competitors in an industry, imitation may not readily occur, and IPR protection may not be essential. Once the condition is compromised by the emergence of competitors that are free from the condition, however, active protection of valuable resources from imitation should be enforced.

This study makes two major contributions. First, it addresses the oversight of dynamisms and competitive contingencies and extends the RBV (Priem & Butler, 2001; Sirmon, Hitt, & Ireland, 2007). The findings help deepen the understanding of why firms choose not to invest in imitation protection (Polidoro & Toh, 2011) and the timing when firms finally decide to deter imitation. This study adds dynamism to the link between innovation and IPR protection by arguing that firms invest in protecting valuable resources if there is a threat to inimitability. My argument aims to shift the RBV from a static and basic setting in which the link between valuable-but-imitable resources and their protection is established both instantly and stably toward a more dynamic and practical setting in which firms can delay their investment in inimitability and alter their protection strategy according to a newly emerged competitive landscape. This insight helps managers understand when to invest in imitation protection. Second, this study contributes to the international innovation literature in which the strategic management and international business disciplines intersect by sketching the dynamic relationship between global innovation, competition, and imitation in the long-standing history of the tire industry. The historical context of innovation in tires helps scholars understand the

subtle nature of imitation costs as a driver to a different path of protection trajectory, an interesting piece of the puzzle of global competition in a technology-driven industry.

I acknowledge that this study has limitations. First and foremost, a simple count of different types of patents may not fully capture the trajectory of protection and innovation (Lanjouw & Schankerman, 2004), possibly requiring the development of other measurements that may better fit the impact of imitation.

Second, due to the nature of an in-depth study within a single industry context, limited generalizability is another major limitation. Future research may be benefited by longitudinal studies clustering relevant industries. In particular, the extant literature reveals that some industries have no or gradual (rather than dramatic) shakeouts caused by innovation (Gort & Klepper, 1982; Klepper & Graddy, 1990; Klepper & Simons, 2000). These different contexts of competition may react differently with the threat of imitation, resulting in different speed, strength, and direction of response to the threat. Understanding the sources of the institutional differences related to imitation can be another interesting research avenue to pursue.

Some follow-up research questions regarding imitation and its impact on innovation are presented to guide future researchers:

- Does infringement on tread design patents by emergent manufacturers influence the scope and quality of design innovation by advanced manufacturers?
- If so, how can such a relationship between infringement and innovation characteristics be theoretically apprehended and modeled?

Along with these suggested studies and follow-up questions, I hope to understand how imitation by lagging emergent players impacts protection and innovation trajectory by advanced players and what factors moderate the eventual outcome.

Conclusion

I argue that the main culprit for the surge in the number of design patents by established firms is the change in the competitive landscape caused by emergent players with low imitation costs. A switch to active protection in an innovation-driven industry may not simply occur due to the resource characteristic of weak inimitability. The dynamic change in investment in inimitability should be apprehended within the historical context of a dynamic competitive landscape. This study contends that this change in protection trajectory should be appreciated in light of innovators' response to the threat of imitation, a threat that comes from new entrants who are not concerned about compromising other key resources by imitation. A formal protection mechanism for securing economic rents from innovation (Teece, 1986) may be employed when the protection finally becomes necessary in a competitive landscape. After all, resource inimitability (Barney, 1991) is a function of the dynamic nature of competitive interaction (Porter, 1985).

CHAPTER 4
AN ECOSYSTEM-BASED ANALYSIS OF DESIGN INNOVATION
INFRINGEMENTS: SOUTH KOREA AND CHINA IN THE GLOBAL TIRE
INDUSTRY^{vi}

Introduction

Why do emerging economy governments sometimes fail to curb continuous intellectual property (IP) infringements by local firms? Prior studies have identified various factors such as history, culture, and social norms that may influence ongoing IP infringements (North, 1990). These heterogenous factors may have precluded local firms from building complementary assets (Teece, 1996), causing them to lag in key innovations in an industry. For example, the failure to develop a culture of IP protection may contribute to an environment where intellectual property rights (IPR) are violated (Alford, 1995; Suttmeier & Yao, 2011). Zimmerman (2013) argues that conflicts between state and private ownership in some emerging economy countries can be another cause of continuous infringements. However, there are many cases and studies that suggest that a country's culture, social, and political systems may not be the determining factors in IP infringements (Peng, 2013; Yu, 2014).

IPR systems are known to be another key factor. More specifically, weak formal IPR systems in emerging economies are thought to induce frequent IP infringement (Coriat & Weinsten, 2002; North, 1990). Indeed, a stringent IPR regime can increase the

^{vi} This study is based on previous work published in the Journal of International Business Policy (Kim & Mudambi, 2020).

transaction costs of imitation (North, 1990; Williamson, 1985), potentially leading to less infringement. This conventional explanation based on legal and regulatory frameworks implies that a reduction in IPR violations results from stronger enforcement.

However, a strong IPR system does not necessarily control ongoing infringements by emerging economy firms. This is clear in the context of the tire industry. Under the aegis of strong global agreements such as the World Trade Organization's Trade-Related Aspects of Intellectual Property Rights (TRIPS), Chinese tire makers have been repeatedly accused of IP infringements, often resulting in litigation. While adopting TRIPS signifies the willingness and preparedness of a country to protect IPR for domestic and foreign firms (Peng, Ahlstrom, Carraher, & Shi, 2017; Brandl, Darendeli, & Mudambi, 2019), it does not necessarily lead all domestic firms to adjust their strategies away from infringements. Rather, it seems that Chinese tire makers have chosen to stay imitation-driven and, in turn, infringement-prone, even though the strengthened IP regime gives leverage to advanced foreign firms to sue IP infringers in China. By contrast, infringements by South Korean tire makers effectively ceased after the TRIPS agreement. Given the common policy framework adopted by these two countries, what explains the difference in IP infringements by their constituent tire firms?

To answer this research question, I employ the lens of the business ecosystem to understand the divergent behaviors of domestic tire makers in China and South Korea. I argue that policy makers should understand that the healthy existence and alliance of keystone organizations in the ecosystem increases the willingness to innovate and the benefits of innovation by embedded firms, effectively reducing IP infringements. A keystone organization is the leading firm in a business ecosystem that forms a common strategic vision for all other embedded firms (Iansiti & Levien, 2004; Nambisan & Baron, 2013). As such, it offers key knowledge and market information to other actors that may

impact their strategic choice between innovation and imitation (Adner & Kapoor, 2010; Iansiti & Levien, 2004). Hence, the role of a keystone organization within an ecosystem is vital because it provides stronger incentives for member firms to innovate, with the additional benefit of avoiding IP infringements.

To support the arguments, I examine the design patent infringements of Chinese and South Korean tire makers after a strong IP standard – TRIPS – was enacted and enforced in the 1990s and 2000s. I focus on the case of two emerging countries to highlight the clear difference resulting in a divergent outcome. The qualitative analysis of the IP litigations of design infringements offers rich contextual knowledge of an underexplored phenomenon (Eisenhardt, 1989; Yin, 2009) within comparable empirical settings (Edmondson & McManus, 2007).

This study makes two contributions. First, I offer another perspective on the recent debate about IPR protection in China (Verbeke, Ahlstrom, Carraher, Peng, & Vertinsky, 2017). Long-term institutional pressure caused US firms and stakeholders to favor a strong IP standard over time (Peng et al., 2017). China seems to have followed a similar path as Chinese firms accumulate IP stocks (Peng, 2013), eventually adopting strong formal IP standards (Maskus, 2000). However, Brander, Cui, and Vertinsky (2017) argue that China may not necessarily follow the US path toward IPR protection. IP infringements continue to occur in China (Li, 2004) and compromise its global leadership in innovation (Brander et al., 2017). Thus, a strong IP system does not guarantee that Chinese companies will start innovating rather than continuing to imitate. I argue that the ecosystem perspective offers an important lens to better explain the issue of IP infringements.

Second, while the ecosystem perspective has recently gained more popularity in policy-making (Adner & Kapoor, 2006), it has not been used to explain firms' orientation

toward IP infringement. This study suggests that the transition to stringent IP protection standards in developing countries does not necessarily mean the end of policymakers' role in curbing IP infringements by domestic firms. Policy actors should facilitate domestic firms' pro-innovation orientation (Nelson, 1993) based on an understanding of the criticality of keystone organizations and alliances with them (Iansiti & Levien, 2004; Adner & Kapoor, 2010). I argue that there may be a reduction in IPR violations not because there is a change in enforcement (heavier stick), but because of increased benefits of innovation in the ecosystem (sweeter carrot).

The next section begins with a brief overview of the literature on IPR, infringement, and business ecosystem perspectives. The subsequent section presents cases of design infringements in the global tire industry after TRIPS was implemented in China and South Korea. Following the analysis from the ecosystem point of view, I suggest the implications for policymakers, discuss the limitations of our study and propose a future research agenda to build on the findings.

Theoretical Background

Imitation and IPR Protection

Protection of IPR is critical in the resource-based view (RBV; Foss & Foss, 2005). IPR defines a legally defensible relationship between an intangible knowledge resource and its owner firm (Alexander & Peñalver, 2012). It can be used to prevent competitors from imitating the valuable resource. The exclusivity endowed by IPR helps an owner firm fully appropriate the economic rents created by the resource. Thus, Foss and Foss (2005, p. 543) succinctly state that “a resource owner’s ability to create, appropriate, and sustain value from resources partly depends on the property rights that he or she holds.”

Thus, IPRs such as patents work as a main barrier to imitation (Mahoney & Pandian, 1992; Somaya, 2003). IPR provides the owner of knowledge and technology with the foundation to legally fight against infringements (Shapiro, 2003). For example, patent assignees can appeal to IPR in patent litigation to exclude imitators who attempt to copy claims of a patent (Lanjouw & Schankerman, 2001). In this sense, litigation enabled by an IPR protection system gives an innovation realistic inimitability (Beukel & Zhao, 2018).

Nevertheless, an IPR system is not a bullet-proof protection mechanism. First, while an owner of knowledge and technology has the right to engage in litigation, which is also considered an effective tool to threaten potential imitators (Somaya, 2003), winning is not always guaranteed (Ayres & Klemperer, 1998). Second, the publicized knowledge contained in an IPR can result in knowledge leakage, a weakness that may make firms choose secrecy in some cases (Levin, Klevorick, Nelson, & Winter, 1987).

The Eventual Movement to a Strong IP Standard

In spite of the inherent weakness described above, a stringent IPR system as a critical tool to prevent imitation and resultant infringements is widely preferred. In particular, advanced multinational enterprises (AMNEs) favor a strong IP regime to protect their knowledge and innovations (Hennart, 2009). A strong IP standard can facilitate local activities for knowledge creation (Cantwell & Mudambi, 2005) and knowledge transfer within AMNEs to produce more innovations (Branstetter, Fisman, & Foley, 2006). Advanced players may even leverage litigation to enhance marketing exposure (Galasso & Schankerman, 2014) and limit emerging market competitors' intentions to imitate (Somaya, 2003).

Support for a strong IPR system is not confined to AMNEs. Peng, Ahlstrom, Carraher, and Shi (2017) argue that emerging economy firms and stakeholders are likely to eventually see the advantages of a strong IP standard. Though an emerging economy may initially disrespect IPR, the situation changes as its innovation capacity grows and its firms begin to develop world-class, high-quality products (Comin & Ferrer, 2018). Economic development helps domestic players and stakeholders within a weak IP regime align their interests with those of foreign innovating firms (Khoury & Peng, 2011). In other words, the maturation of the economy leads to “institutional transition” from initially favoring a weak IP regime to the eventual implementation of a stronger IP system (Peng, Ahlstrom, Carraher, & Shi, 2017).

However, this progress toward strong IPR does not necessarily eliminate IP infringements. While an economy with a weak IP system is expected to adopt a high IP standard over time (Peng, Ahlstrom, Carraher, & Shi, 2017), long-established imitation-based competition may continue to fuel infringement litigation even when innovation capacity matures among competitors (Cuervo-Cazurra & Annique, 2010). Prevalent imitation-based competition may even rekindle the preference for a weak IP system (Kim et al., 2012), delaying the implementation of strong IPR protection. In this case, firms in a developing country may continuously risk high litigation costs (Mazzoleni & Nelson, 1998; Schliessler, 2015). In the long run, continuous infringements and litigations can significantly lower future growth and revenues in the country (Bessen & Meurer, 2008).

The extant literature on IPR protection suggests some possible explanations for IP infringements by firms in emerging economies. Some scholars argue that some cultures and traditions seem to approve imitation. For example, Alford (1995) argues that the traditional Chinese social and ethical system influenced by Confucianism contributes to weak intellectual property rights. Suttmeier and Yao (2011) also suspect that the lagging

development of the culture for IP recognition may deter the effective protection of intangibles, as in the case of Chinese companies' persistent insensitivity to the value of software. Zimmerman (2013) further argues that political systems in emerging economies can be another cause of IP infringements because of the conflicts between state and private ownership of IPR.

However, it should be noted that the arguments about cultural and political impacts on IP infringements are inconclusive. There are plenty of cases and studies that suggest that cultures and politics may not be the determining factors underlying the tendency for IP infringements (Peng, 2013). While IP infringements have prevailed in a wide variety of cultures from ancient Asia and Europe (Bugbee, 1967; Jaffe & Lerner, 2007) to modern countries (Hill, 2007; Yu, 2008), it is difficult uncover common characteristics of culture to which these can be attributed. Further, state ownership does not clearly explain the prevalence of counterfeited products (Yu, 2014).

The Business Ecosystem Perspective and Its Implications for IPR Protection

The business ecosystem perspective provides useful insights about why IP infringements may continue after the implementation of a strong IP standard. The term "business ecosystem" was first coined by Moore (1993) to refer to a business network in which firms not only compete but also collaborate and coevolve (Moore, 2006). The actors embedded in this network consist of various participants such as focal firms, complementors, suppliers, and customers who create value by complementing one another. These interdependent relationships that flexibly adapt to changing innovation landscapes can determine focal firms' innovation capability (Adner & Kapoor, 2010; Casadesus-Masanell & Yoffie, 2007) and economic success (Iansiti & Levien, 2004; Moore, 2006; Moore, 1993).

Business ecosystems are related to global value chains (Gereffi, 1999, Mudambi, 2008) in that they encompass interrelated firms that are involved in producing a common product or service in which innovation is a strong motive force (Cano-Kollmann, Cantwell, Hannigan, Mudambi & Song, 2016). However, ecosystems are looser in terms of both coordination and organization, often refer to an entire class of products and include competing firms. Hence ecosystems are more general and relevant to the policy context that I examine in this paper.

The critical impact of interdependent relationships on innovation in the business ecosystem perspective offers a vital implication for imitation and infringements. While the conventional RBV sees inimitability as a property of a resource and as a matter of a firm's effort to exclude others with IPR, the business ecosystem view tells us that a firm's interest and investment in innovation over imitation may stem from its interdependency with other firms. The relationships of actors in a well-functioning ecosystem can explain the high production of quality innovations because they impact the overall performance of a system wherein the actors operate complementarily (Smits & Kuhlmann, 2004). A weak ecosystem discourages investment in innovations because embedded firms see little potential for success from innovation within the ecosystem (Adner, 2006). In this sense, the ecosystem perspective can highlight why embedded firms focus on imitation rather than innovation even when a strong IP standard is enacted and, in turn, why infringements continue.

More specifically, the business ecosystem perspective elucidates the role of a keystone organization for innovation (Iansiti & Levien, 2004). The leading firm provides a technological platform on which embedded firms can build their technologies and innovations. This role is critical because technological leadership controls the innovation trajectory and enhances the value customers place on the products and services produced

within the ecosystem (Adner & Kapoor, 2010). For example, Microsoft and Walmart offer common services, tools, and technology to the firms embedded in their ecosystems. Over time, the embedded firms have made strategic investments in R&D and marketing standards, relying on their relationships with Microsoft and Walmart (Iansiti & Levien, 2004). Effectively, the keystone organizations that lead an ecosystem encourage other actors to share a common future vision and invest more in innovations in the same strategic direction (Iansiti & Levien, 2004; Nambisan & Baron, 2013). In this sense, the existence of an effective keystone organization is a significant differentiator for a pro-innovation orientation and outcome in an ecosystem. Innovative keystone organizations can engage in boundary spanning (Schotter, Mudambi, Doz & Gaur, 2017) and incentivize embedded actors to shy away from imitation and instead pursue innovation.

Oversight of Policy in the Ecosystem Perspective

In general, policymakers' initiatives tend to focus on enhancing local economies within their own geographical jurisdictions (Capello, 2002). For example, when an identified innovation system is located within a cluster, policymakers may easily consider devising a policy to increase cluster density and cultivate a stronger local network (McDonald et al., 2007; Porter, 2000). However, since business ecosystems are often identified and organized by actors who share strong interdependencies across different industries and geographical locations (Iansiti & Levien, 2004), policies to strengthen them may not be obvious. When innovation activities are scattered across multiple locations and regions, policymakers may not see a clear need for policy instruments.

Nevertheless, policymakers' attention to initiatives for an ecosystem can be highly valuable. According to Clarysse et al. (2014), the overall innovation within a business ecosystem still depends on local knowledge creation. Even when many actors in

an ecosystem are dispersed across multiple locations, knowledge creation can center around domestic keystone players, a critical source of IP production. Clarysse et al. (2014) further noted that financial support for the ecosystem frequently comes from public administrations and agencies. This financial support can endow policymakers with considerable power to influence how an ecosystem is structured and operated. Public policies have been shown to have a strong effect on the R&D trajectory in a nation-level innovation system (Mowery and Rosenberg, 1999), indicating that policymakers can act as crucial change agents for the ecosystem and, in turn, on the choice between innovation and imitation.

Methodology

In this study, we document that South Korean and Chinese firms in the global tire industry engaged in design imitation that sometimes resulted in IPR violations even after TRIPS was implemented in each country. The cases of these two emerging countries show clear differences that led to divergent outcomes. Our qualitative analysis of the IP litigations of design infringements will help us gain rich contextual knowledge of an underexplored phenomenon (Eisenhardt, 1989; Yin, 2009) within comparable empirical settings (Edmondson & McManus, 2007).

More specifically, I narrow the scope of analysis to patents (rather than other types of IPRs such as trademarks) and their litigations because this study focuses on tread design in the tire industry. Tread design is the geometric voids and molded elements on the surface of the tire, such as circumferential grooves, transverse sipes, and shoulder blocks. Various configurations and combinations of the elements generate differential traction by expelling water and dirt from beneath the tire (Tire Technology International,

2017). Tread design is one of the most critical features in determining tire performance and quality (Clark, 1981), and it has been adopted by all competitors since its invention in 1908 (Lief, 1951; O'Reilly, 1983). Tread design is known to be protected mainly by design patents in the industry. For example, the big 3 tire makers (Goodyear, Bridgestone, and Michelin) collectively patented 406 tread designs in 1991 – 1994, 703 in 1995 – 2000, and 923 in 2011 – 2014. Because the design is obviously visible to competitors once it is commercialized, trade secrecy is excluded as a means of protection. The lack of an industrial design standard for tread design makes each tire maker further depend on patenting rather than standardization. Accordingly, we focus on design patents and relevant litigations in this context.

The details of design infringements after global IP standardization were collected through various sources such as academic manuscripts, books, magazines, press articles, and corporate websites. To triangulate the insights from the analysis, a series of semi-structured interviews were conducted during June 2018 (Table 7). One senior-level executive, two tire sales experts, three strategic planning managers, and two R&D engineers working for global tire and car makers were interviewed to collect contextual knowledge of the tire industry. I also conducted email interviews with a former executive of a Korean automaker to learn more about the history of South Korean tire-making. All the face-to-face interviews lasted 45 minutes to 1 hour.

Table 7: Interview Overview

Name*	Organization Type**	Interviewee's Position	Role
TireBest	Tire Maker	Senior Vice President	Leading corporate strategy planning division
GlobalTire	Tire Maker	Sales Director	Overseeing sales of original equipment tires for a specific car maker
GlobalTire	Tire Maker	Assistant Sales Director	Overseeing sales of original equipment tires for a specific car maker
GlobalTire	Tire Maker	Strategic Planning manager	Leading corporate-level strategy formulation
GlobalTire	Tire Maker	Assistant Strategic Planning manager	Analyzing external environments in the tire industry
GlobalTire	Tire Maker	R&D Engineer	Researching and developing tread designs
GlobalTire	Tire Maker	Assistant R&D Engineer	Researching and developing tread designs
QualityCar	Car Maker	Strategic Planning Manager	Establishing the corporate-level strategy
TopCar	Car Maker	Former Head of European Headquarter	Managing the sales in Europe.

* For confidentiality reasons, the names of these companies are fictitious.

** All manufacturers are globally renowned firms exporting products to more than 100 countries.

Design Infringements and the Global Tire Industry

Background: TRIPS Agreement and Implementation

There is a significant body of literature on weak IP protection in both the academic and policy areas. Rodrik (2000) suggests that the institutions for IP protection in developing countries are either non-existent or malfunctioning. Khanna and Palepu (1997) describe lagging IP regimes as “institutional voids.” To remedy the frequent cases of illegal imitation (counterfeiting, piracy, etc.) fueled by weak IP protection, an international initiative to transition to strong global IP standards has been promoted since the mid-1990s (Yang & Sonmez, 2013).

All the member countries of the World Trade Organization (WTO) agreed to set IP protection standards matching the level of strong IPR in advanced countries (Taubman, Wager, & Watal, 2012). The WTO’s Trade-Related Aspects of Intellectual Property Rights (TRIPS) agreement was signed in 1994 by all members, including 60

developing countries (Li, 2008). Signing the agreement signals a developing country's willingness to comply with the minimum standards for IP protection for both foreign and domestic firms in the country (Peng, Ahlstrom, Carraher, & Shi, 2017; Brandl, Darendeli, & Mudambi, 2019).

The transition to high IP standards was expected to involve considerable complexity and costs, and significant increases in administrative costs, royalty fees, and penalties were indeed reported across the signatories of the TRIPS agreement (Deere, 2008; McCalman, 2001). To mitigate the burden of the transition, the TRIPS agreement allowed flexibility for individual countries along two dimensions. First, participating countries could implement the agreement within a 10-year period. Countries were free to choose the length of time till they were in full compliance with TRIPS within the maximum allowed period of 10 years. Some countries chose to comply with the agreement immediately, while others (including the largest emerging economies – China and India) chose to take the full 10 years. The grace period until full implementation gave countries time to prepare relevant legal infrastructures incrementally and spread out the costs over the time span (Deere, 2008).

Second, countries could amend the original TRIPS standard to fit their own legal and institutional context (Deere, 2008; Li, 2008). While TRIPS amendments by a signatory country are considered a slightly weaker form of the original TRIPS text (Brandl, Darendeli, & Mudambi, 2019), rigorous amendment processes such as legislation research and drafting required by the WTO (Lybbert, 2002) control the degree of the modification to ensure a high standard for international IP protection.

South Korea was one of the first countries to ratify the TRIPS agreement and implemented it almost immediately. Instead of taking incremental steps before full implementation, South Korea adopted the original TRIPS text as its national IP

legislation in 1996. This swift transition was made possible thanks to the preceding movement toward high IP standards in South Korea. The growth of innovation capability during the 1980s produced considerable IP stocks to protect, making South Korea eager to comply with strong IP harmonization (Kim, Lee, Park, & Choo, 2012).

As we have noted, China took advantage of the full grace period of 10 years, ratifying TRIPS with amendments in 2005 (Brandl, Darendeli, & Mudambi, 2019). Delayed implementation with amendments was a logical choice for China. The weak innovation capability of domestic Chinese firms meant that in order to follow the upcoming IP standardization, they needed more time to prepare and less stringency (Ramamurti, 2005). Domestic firms in emerging economies tend to be heterogeneous: the local subsidiaries of advanced country MNEs tend to favor rapid implementation of stringent IP standards so that they can leverage the IP stocks of their parents to buttress their competitive advantage in local markets. In contrast, the local firms want to postpone the establishment of high IP standards (Brandl, Darendeli, & Mudambi, 2019). As a result, China took the maximum allowed time to adopt the TRIPS regulation (Deere, 2008).

Implications of Tread Design in the Global Tire Industry

The tread of a tire is the rubber part around its circumference that contacts the road or the ground. Here, tread design indicates the pattern of geometric voids on the surface of the tire molded into the tread. If roads were always dry and clear of dirt and snow, it would not be necessary to have sophisticated tread patterns. This is not the case, so tires on cars and trucks intended for regular driving (as opposed to racing) normally include features to maximize driving maneuverability. The tread design is one of the most critical components of innovations that determine tire quality and performance (Allbert &

Walker, 1965; Novopolskii & Tretyakov, 1963; Smith & Dough, 1972; Staughton, 1970). Accordingly, the protection of their unique tread designs is an IPR consideration for tire companies. In interviews conducted as part of our study, tire company R&D engineers designing tread patterns supported the key value of tread design as a main source of functional differentiation (Clark, 1981):

Tread design offers differential performance measures such as traction, braking friction, longevity, and noise reduction (R&D Engineer from GlobalTire).

Furthermore, because tread design involves complicated tradeoffs, tire makers do not allow competitors to imitate an effective tread design. The assistant R&D engineer from GlobalTire stated:

While the deeper patterns of tread may secure better safety on wet or snowy roads, a simpler design may attenuate roadway noise and save manufacturing costs. Thus, it is very tricky to balance each performance measure to satisfy both customers and manufacturers.

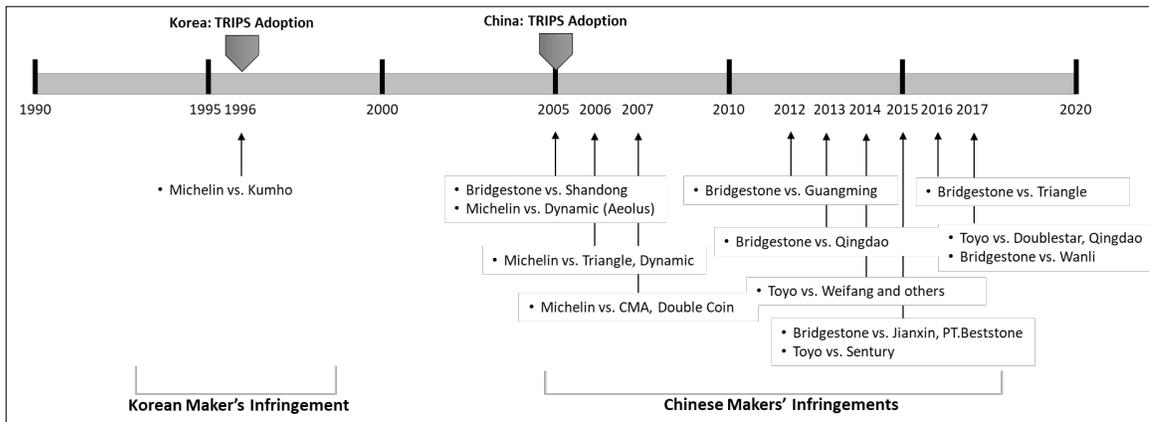
It is not surprising that the protection of tread design is more emphasized than any other innovation area in the industry (Scalera et al., 2014).

The Different Situations after TRIPS implementation: South Korea vs. China

Given the criticality of innovation in tread design and its protection, South Korean and Chinese tire makers show a significant departure in their infringement activities after implementing TRIPS in 1996 and in 2005, respectively (Figure 4). In South Korea, there has been only a single patent litigation regarding patent design since TRIPS implementation. In 1996, Michelin claimed that Kumho, a Korean tire maker, copied its tread design on three tire models (XZA-1, XZA+1, and XZA2) protected by its US Patent No. 4,480,671. Kumho's tire, named the 962 steer tire, was argued to imitate Michelin's "narrow shoulder rib configuration" which the patent seeks to protect (Miller, 1996).

Michelin wanted the United States International Trade Commission (ITC) to order Kumho to cease and desist the import and sale of the allegedly copied tire model to the US based on section 337 of the Tariff Act of 1930 that bans imports and sales of products infringing a US patent (Federal Register, 1997). In January 1997, Michelin withdrew the complaint after a judge ordered Michelin to reveal some “sensitive and highly-sought after information” (Federal Register, 1997). Nevertheless, since this patent litigation, South Korean tire makers have not been involved in any similar design infringements.

Figure 4: Korean and Chinese Tread Design Litigations in 1990 – 2017



As opposed to South Korean tire makers, Chinese tire makers continue to be subject to litigations regarding tread design (Figure 4). Chinese makers had a full 10 years to prepare before the implementation of TRIPS, which is a strong standard intended to curb imitative behaviors that infringe on the IP of other firms. However, contrary to expectations, China’s slow implementation of TRIPS did not give domestic tire makers a buffer zone to catch up and build innovation capability (Kumaraswamy, Mudambi, Saranga, & Tripathy, 2012). Evidently, Chinese tire makers continued to compete by means of imitative activities (Awate, Larsen, & Mudambi, 2012) even though the TRIPS agreement has made IP infringements more difficult.

In 2005, Michelin sued Dynamic Tire Corp. (Dynamic Tire) and its president, Robert Sherkin, regarding Aeolus Tyre (Aeolus) in China. The suit claimed that Dynamic Tire distributed “knockoffs” of Michelin tires manufactured by Aeolus. Michelin claimed that its proprietary tread designs of XDE M/S and XDA-HT tires were closely copied and infringed. The spokesperson for Michelin, Lynn Mann, stated:

The three separate lawsuits from last June to December show how aggressively we’re willing to pursue distributors that sell knockoffs of our tires. ... From a Michelin North America standpoint, filing actions against the distributor is the most direct path to stopping this problem. (Nguyen, 2005)

Also in 2005, Michelin alerted its more than 5,000 dealers about many “look-alike tires from Asia” that were copying the tread design of its truck and off-the-road (OTR) tires. The long-time tire maker argued that such imitations cannot secure “the same grip or longevity of performance as an authentic Michelin tire” (Modern Tire Dealer, 2007).

Two years later, Michelin pursued another lawsuit against China Manufacturers Alliance (CMA), a wholly owned subsidiary of China’s Shanghai Tire & Rubber Co. Ltd. (Modern Tire Dealer, 2007). CMA imported and distributed its brands such as Double Coin, Blue Star, Dynacargo and Warrior tires in North America, where they were less well-known than Michelin brands. In the lawsuit, Michelin complained that CMA imported and sold “the Double Coin RT606 and the DynaTrac RS330 tires, both of which utilize unauthorized copies of the patented Michelin XZE tread pattern” (Modern Tire Dealer, 2007), arguing that “it created and published an original illustration in 1997 of its XLD 70-1 L3T OTR tire” and that CMA violated “the copyright by allegedly imitating the illustration in its advertisement materials” (McCarron, 2007). Michelin also argued that CMA violated Michelin’s copyright of “a 1999 original illustration of its XHA OTR

tire” in a Michelin advertisement. It was an interesting twist for Michelin to claim copyright infringement rather than patent infringement. Michelin’s spokesperson later revealed that the reason for this was that “either the patents on the designs have expired or they were not able to be patented” (McCarron, 2007). In Spain, the Netherlands, France, and Algeria, the Double Coin tires at issue faced legal disputes with Michelin, with the company publicizing that “unauthorized copies of Michelin tread patterns can be found in the (global tire) market – notably under the Double Coin brand” (McCarron, 2007).

Chinese tire makers continue to engage in infringing imitation. In September 2016, Bridgestone achieved a favorable ruling in a lawsuit alleging infringement of the company’s tread design rights against Chinese manufacturer Triangle Tyre. Within a year, Bridgestone won another tread design infringement lawsuit against Guangzhou South China Tire & Rubber and Guangzhou Fengli Rubber & Tire (referred to collectively as “Wanli Tire”) in the Shanghai Intellectual Property Court (Tyrepress, 2017). Wanli Tire was alleged to manufacture and sell tires that imitate tread patterns of Bridgestone’s Dueler A/T REVO 2 tires for sport utility vehicles. This favorable ruling for Bridgestone ordered Wanli Tire to discontinue the manufacturing and sales activities related to the tires at issue, to dispose of the related molds of tires, and to compensate \$88,000 to Bridgestone (Tyrepress, 2017).

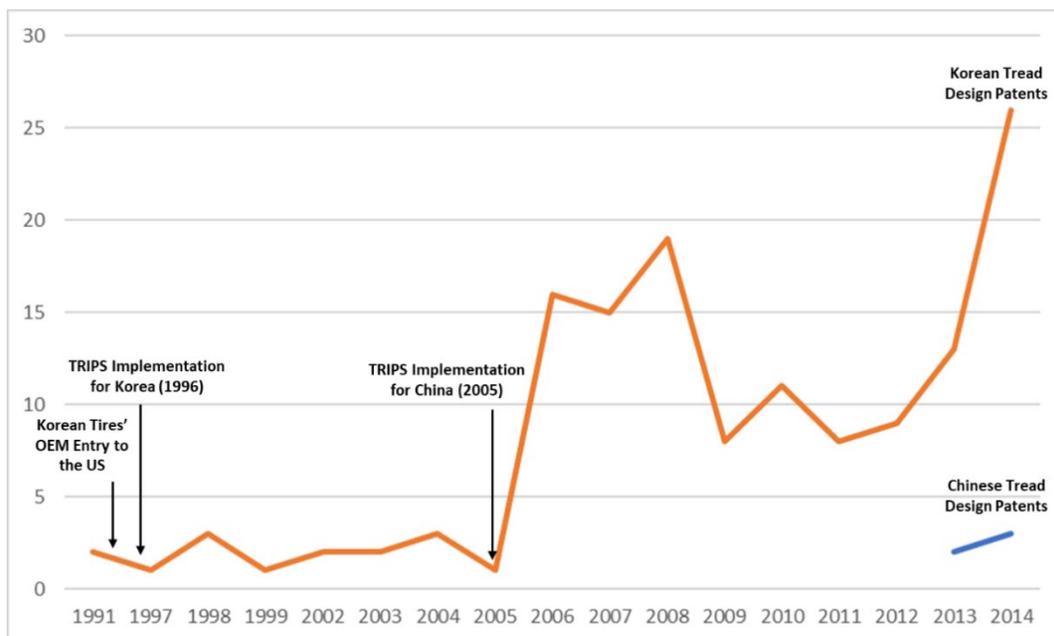
This clear departure between South Korea and China is significant in that there was no known tread design-related litigation involving Korean or Chinese tire makers before TRIPS was implemented. Only after the TRIPS agreement was enacted did I find

relevant litigation cases. This may be because the IPR regime strengthened by TRIPS finally made it possible for the infringees (advanced tire makers such as Michelin) to sue the infringers (Korean and Chinese tire makers) (Taubman, Wager, & Watal, 2012). However, I still assume that both South Korean and Chinese tire makers engaged in imitative behaviors before TRIPS, though the degree of imitation intensity might vary, because of the general absence of tread design patents before TRIPS (Figure 5). Chinese tire makers had zero tread design patents before TRIPS; Korean tire makers owned only two. This means that the tire makers had commercialized tires without patenting their own designs for a long time. When we consider the critical value and weak imitability of tread design in the context of the tire industry, supported by numerous documents (e.g., Clark, 1981) and interview results, it is highly likely that imitation was prevalent before 1995 among all emerging economy tire makers.

It is notable that Chinese infringements continue in other industries as well. China's 2015 White Paper on IPR protection reports that Chinese local courts "accepted 109,386 civil IP cases of first instance," showing a yearly increase of 14.49% (State Intellectual Property Office (SIPO) of the People's Republic of China, 2016, p. 9). Among the first instance cases, there were 11,607 (10.6%) patent-relevant cases, "up by 20.3% year on year" (SIPO, 2016). Recognizing the growing number of IPR cases of dispute, China established three IP-specialized courts in Beijing, Shanghai, and Guangzhou in late 2014 (Guo, 2015) and four new IP-specialized tribunals in Nanjing, Suzhou, Chengdu, and Wohan in early 2017 (Li, Xu, & Zhang, 2017). These new IP courts and tribunals try "[IPR] cases involving patents, technical secrets, computer

software, new plant varieties, integrated circuit layout designs, and cases regarding recognition of well-known trademarks and antitrust issues” (Li, Xu, & Zhang, 2017: para. 4). Though more institutional concern about imitation in China may be good news for advanced tire makers, the high IP standard of TRIPS implementation in China does not seem to have prevented ongoing infringements.

Figure 5: Chinese and Korean Tread Design Patents Trajectory (1991 – 2014)



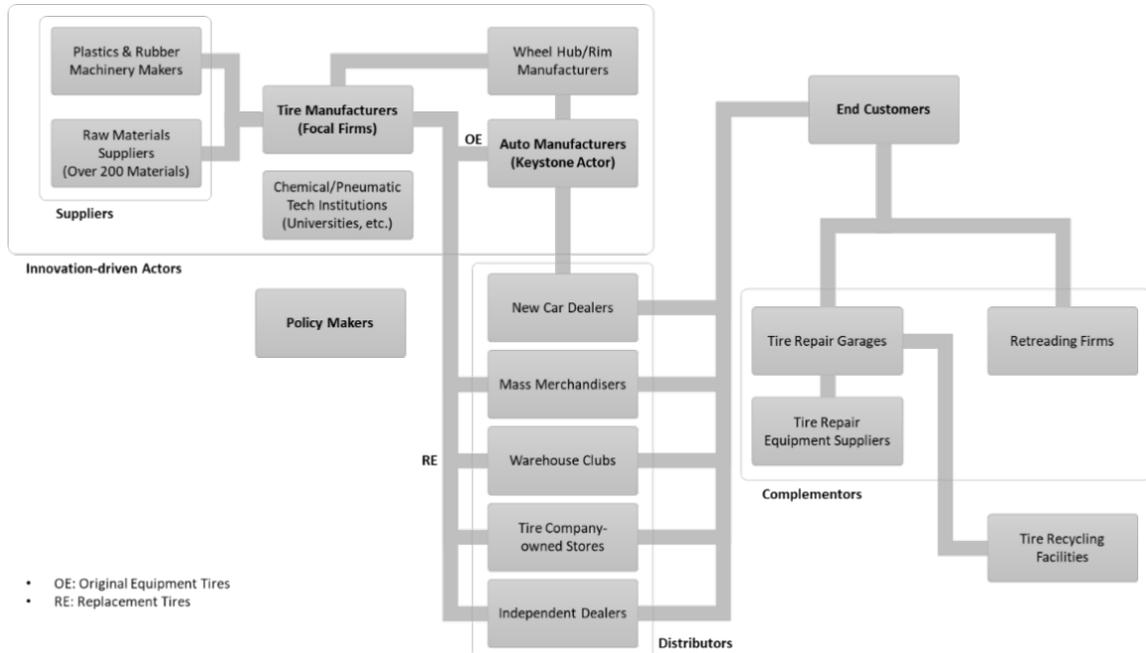
Ecosystem Explanations about Continuous Infringements by Chinese Tire Makers

What explains the fact that consistent IP infringements of domestic tire makers continued in China but not in South Korea after TRIPS was implemented? The clear difference between Chinese and Korean tire makers is the existence of globally successful automakers in the latter country. The major Korean automakers like Hyundai and Kia have a close relationship with Korean tire firms like Kumho and Hankook as well as other support firms in the tire ecosystem (Figure 6). Global automakers in the tire

ecosystem function as keystone organizations and encourage tire makers to innovate.

This encouragement is based on their need to achieve and retain competitiveness in the global car market. Tires are critical components that affect a car’s performance.

Figure 6: Global Tire Ecosystem



A car’s maneuverability, comfort, longevity, and safety are dependent on tires, which provide the only contact point between the car and the road (Clark, 1981). Tire makers also need detailed specifications of car performance and characteristics to maximize tire performance while controlling the tradeoffs between tire innovations and manufacturing costs.

In this sense, tires necessarily coevolve with cars. For example, Goodyear, a US-based tire maker, focused its research and development efforts on technological areas mainly in the “mechanical and chemical” classes of patents (Scalera et al., 2014). This innovation trajectory was necessary to match the dramatic increase in weight and speed of US automobiles over the decades (Rajan, Volpin, & Zingales, 2000).

Global automakers' demanding attitude about innovation is well known. A seasoned tire veteran stated, "You just can't stand still with those boys [the automobile manufacturers]. ... Your tires have to carry heavier loads, last longer and go faster. The smaller firms cannot afford the kind of R&D operation this entails" (Rubber World, January 1966, cited by Rajan, Volpin, & Zingales, 2000). To respond to automakers' drive to innovate, tire makers that supply original equipment (OE) tires should pay close attention to their innovation needs. In the interviews with R&D engineers and sales directors held for this study, participants commented that global automakers frequently demand tires specifically tailored to their new cars in each international market. If a tire maker cannot meet this demand by innovating their tire quality, the relationship cannot last. Being an innovator is a key requirement for being selected as an OE tire supplier, as described by Rajan, Volpin, and Zingales (2000).

Global automakers also care seriously about innovation for brand reputation. Using imitative components may compromise the hard-earned reputation of a car's brand image, a critical resource for automakers to compete in the global market. A strategic planning manager from GlobalTire further elaborated that automakers "hate to see the image of imitator [i.e., of an imitating tire maker] get stuck with them." Global automakers carefully keep distant from any stigma which may negatively affect their brand values. Thus, major tire makers that supply OE tires also cultivate their reputations as innovators (Rajan, Volpin, & Zingales, 2000). It is their connections with global automakers that push tire makers to strategically choose to be innovators rather than imitators.

However, this is not a unilateral but a complementary relationship. Tire makers must collaborate with automakers to develop innovative tires. For instance, Michelin recently launched a joint R&D project with Hyundai to develop tires for Hyundai's next generation of electric vehicles (EV) by 2020 (Ahn, 2017). As a part of the alliance deal, Michelin engineers expect to learn car development information specific to EVs in terms of their driving range and mileage (Ahn, 2017). In order to meet the technological need for tire innovations in future, tire makers also need to maintain a close relationship with automakers.

Tire makers that focus on replacement (RE) tire markets do not necessarily feel pressure from automakers. RE tire makers deal with other actors, such as independent tire dealers, warehouse clubs, tire company-owned stores, and miscellaneous outlets for individual customers. The main concerns of these actors are pricing and accessibility due to the commoditization of tires in the modern era. While OE tire makers advertise their products' innovative features, resulting in higher prices as national brands, RE tire makers compete in a price-sensitive market (Rajan, Volpin, & Zingales, 2000). Likewise, tire makers that are only connected to domestic or prematurely globalized automakers do not face much pressure for innovation because of the automakers' less need to adapt to different road conditions, customer needs, quality regulations, and brand reputation in global markets. In this circumstance, an innovation strategy may not be the best option for the tire makers. Considering the price-sensitivity of customers in RE markets and the large financial investment required to implement new technology (Dixit & Pindyck,

1994), an imitation strategy may work better for tire makers without globally competitive automakers in their national ecosystem.

In this regard, the presence of successful global automakers in the South Korean tire ecosystem is crucial. The automakers' coevolving relationship with Korean tire makers explains their inclination toward innovation. For instance, Korean automakers such as Hyundai and Kia Motors have long used mostly Korean tires for both domestic and export cars. Modern Tire Dealer (2017) reports that cars manufactured by Hyundai and Kia and exported to the US are predominantly equipped with Korean tires (71% of the total as of 2016). As Korean automakers have dramatically increased their new car exports to global markets since the late 1980s, Korean tire makers' innovation capability had to advance correspondingly. As Korean automakers exported over one million Korean-branded cars to major car markets across six continents in the 1990s (Korea Automobile Manufacturers Association (KAMA), 2005), Hankook Tire, one of the biggest Korean tire makers, became a global OE tire supplier, supplying OE tires for Volkswagen in 1991, Ford in 1999, Volvo and Mitsubishi in 2001, GM in 2006 and so on (Table 8). This signaled that its orientation toward innovation was being recognized globally. As pressure from Korean automakers drives Korean tire makers to innovate, their innovation capability enabled them to expand sales beyond the national boundary to become global OE suppliers (Kim & Suh, 2013). Our paper provides strong anecdotal evidence that the role of keystone organizations in an ecosystem is critical.

Table 8: Hankook Tire (Korea) – Original Equipment Supply*

Hankook Tire's OE Tire Supply		
Year	Automaker	Automobile
1991	Volkswagen	
1999	Ford	
2001	Volvo, Mitsubishi	
2003	Ford	F-150
2004	Ford	Econoline, Mondeo
2006	GM, Volkswagen	Chevrolet, Golf
2009	Volkswagen, Audi	New Beetle, Jetta, A3
2010	Ford	Lincoln MKZ
2011	BMW, Toyota	Mini Cooper S/I Series, IQ
2012	BMW, Mercedes Benz	3-Series, E-Class
2013	Honda, Toyota, Nissan, Mercedes Benz, BMW	Civic, Corolla, Altima, S-Class, 5-Series/X5
2014	BMW, Mercedes Benz, BMW, Audi, Mercedes Benz	4-Series, C-Class, Mini Models, TT, TTS, LCV V-Class
2015	Ford, Ford, Porsche, Mercedes Benz, Volkswagen	Mustang, F650, F750, Macan, HCV Actro/C350e, Touran
2016	Ford	Tacoma/Lincoln MKX

* Source: Media reports.

In China, however, the lack of such relationships with globally competitive automakers ruled out the coevolving path by which Chinese tire makers could be innovators. For example, Aeolus Tyre, which is one of the biggest Chinese tire makers, did not reap the benefits of coevolution with Dongfeng Motors, which is Aeolus' main OE buyer and China's second-largest automaker. Dongfeng has been consistently weak as an automaker in the global market (Thun, 2006). While Dongfeng mainly assembles foreign branded cars for the Chinese market based on joint ventures with global

automakers (Zhang & Alon, 2010), its global market entry is a relatively recent achievement and is mostly limited to a few countries in South East Asia (China Daily, 2010) and the Middle East (China Daily, 2013).

It should also be noted that the timing of design patenting by Korean tire makers closely coincided with their entry to US markets as an OE supplier for Korean car makers. According to the interview with the sales director and assistant sales director, Korean tire makers first entered the US OE tire market in the early 1990s, and the first tread design patents by Korean tire makers were filed in 1991 (Figure 5). This further supports our argument that car makers, as keystone organizations in the ecosystem, facilitated Korean tire makers' transition to innovation.

A coevolving relationship between global automakers and tire makers is common for other innovation-driven tire makers. For example, Japanese tire makers like Bridgestone and Yokohama supplied OE tires for Japanese domestic and export cars from the early years of the Japanese auto industry. They quickly adopted and innovated radial tire technology, which is today's tire standard established by Michelin in the 1950s (Rajan, Volpin, & Zingales, 2000). Their innovation capability made it possible for Bridgestone and Yokohama to enter the US OE market in 1967 and 1969, respectively, as Japanese automakers such as Honda entered the US automobile market. Subaru still predominantly uses Japanese tires (67%) in the US market, as does Toyota (38%; Modern Tire Dealer, 2017), retaining the momentum for innovation. The existence of global automakers and the close alliance with them in the tire ecosystem are critical factors in tire makers' positioning as innovators and global competitors (Rajan, Volpin, & Zingales, 2000).

The findings on the dichotomous behaviors of Korean and Chinese tire makers suggests two lessons for policymakers about the essence of IPR infringement: facilitation

of keystone organizations and active relationships between keystone organizations and embedded firms.

Facilitation of Keystone Organizations

First, policymakers should consider the cultivation of keystone actors in an ecosystem. An ecosystem may consist of several actors from a wide range of industries that share common strategic goals led by keystone organizations (Iansiti & Levien, 2004; Nambisan & Baron, 2013). For the ecosystem to evolve and progress as a value network of interdependent actors, it must have a strategic direction (Adner & Kapoor, 2010; Pierce, 2009), and this is often provided by keystone organizations.

In particular, the existence of innovative keystone organizations and the establishment of their leadership is the basis for the transition from infringement to innovation. Firms are constantly required to make sizable investments in new technologies in the face of technological and market uncertainties (McGrath, 1997; Mitchell & Singh, 1996). A premature investment in new technology and innovation may incur a financial loss. In contrast, a late commitment may result in lagging innovation capability, likely resulting in imitative products and services that infringe on others. An innovation leader in an ecosystem can mitigate this troubling trade-off by providing technological guidelines and platforms (Adner & Kapoor, 2010; Iansiti & Levien, 2004; Teece, 2007).

In this sense, it is critical for policymakers to identify the keystone actors in an ecosystem and encourage them to be innovative. Policymakers must understand the targeted ecosystem in terms of the interdependencies of knowledge and investment flows in the relationship between keystone organizations and embedded firms, then identify and resolve hindrances that prevent the emergence of innovation leaders in an ecosystem. A

policy that simply implements strong IP protections may not reduce infringement without the emergence of keystone organizations that serve as the innovation engines of ecosystems.

Facilitation of Relationships Between Keystone Organizations and Embedded Firms

Second, policymakers should support active collaborations between keystone and embedded organizations. Successful innovation and economic appropriation do not solely derive from the existence of innovative keystone organizations. Success requires embedded actors to work complementarily to commercialize products or services (Adner & Kapoor, 2010). Close cooperation between innovation leaders and other actors is required to adapt to the changing realities of technology and markets (Casadesus-Masanell & Yoffie, 2007; Teece, 2007). Mutually beneficial collaborations reduce the financial risk resulting from a large investment in new innovation, increasing the incentive to engage in innovation.

Facilitating alliances between keystone and embedded organizations should be the main concern of policymakers. Prior studies have shown that allied firms can reap economic success if the collaboration exhibits high flexibility (Borys & Jemison, 1989). Because an alliance relationship tends to protect the independence of individual firms while adding small bureaucratic costs, it tends to create significant economic rents (Teece, 1996). By exchanging research and market information and sharing financial burdens, firms in an alliance can improve both adaptation and innovation (Dyer, Kale & Singh, 2004). The creation of inimitable products out of complementary efforts is particularly marked when alliances result in a series of subsequent collaborations (Lippman & Rumelt, 1982).

Dyer (1996) provided evidence of this in the long-term alliance relationship between Toyota as an innovation leader (keystone organization) and its suppliers. Mitchell and Singh (1996) also showed that alliances in the hospital software industry result in more efficient and effective commercialization when they engage in complementary collaboration. This results in better payoffs from investments in new products.

Thus, policymakers should encourage alliances between keystone organizations and embedded actors in the ecosystem by devising instruments that minimize the adverse effects of an alliance. For instance, policymakers should consider modifying the legal and regulatory frameworks to reduce the risk of opportunistic appropriation (Gulati & Singh, 1998).

Discussion

This study contributes to the recent debate on IPR protection in China (Verbeke et al., 2017; Peng et al., 2017) by adding a new perspective to understand the issue. Peng et al. (2017) suggested that China, like the US, is beginning to favor stronger IPR protection. The US was an IP violator in the nineteenth century but is now a leading IP advocate (Maskus, 2000). As a developing country develops its innovation capability and accumulates IP stocks, the institutional transition to a stringent IP regime seems natural (Li, 2008). Thus, the enactment and enforcement of the TRIPS agreement can be considered the beginning of a developing country's decision to adhere to a high standard of IP protection facilitating innovation rather than imitation in the economy. However, the implementation of TRIPS does not necessarily reduce IP infringement. When focusing on design innovations in the context of the tire industry, Chinese firms continue to be infringing imitators, as argued by Brander, Cui, and Vertinsky (2017), while South

Korean firms have stopped engaging in infringing imitation, as evidenced by the disappearance of litigation after the ratification of TRIPS.

The case of Chinese and Korean tire makers shows that there may be a reduction in IPR violations not because there has been a change in enforcement (heavier stick) but because of the increased benefits of innovation (sweeter carrot). In particular, the presence of an alliance with a keystone organization in a business ecosystem can explain divergent orientations to innovation for emerging economic firms. The keystone organization offers carrots to innovators and pushes embedded actors to invest in innovation activities (Iansiti & Levien, 2004). The interdependent relationship with a keystone organization increases the likelihood that embedded actors will overcome financial barriers and innovate new products and services rather than continue with imitative strategies (Adner & Kapoor, 2010) that may result in IP infringement.

The ecosystem perspective may look less appealing, as this study focuses on the specific relationship between tire makers as focal actors and global car makers as keystone organizations. Because ecosystems are networks of interdependent stakeholders that are linked together in complementary value-creating relationships, prior studies that have taken an ecosystem perspective tend to investigate collective dynamics among various actors. For example, management scholars analyze the role and impact of suppliers and complementors on focal firms (Adner & Kapoor, 2006; Pierce, 2009).

However, the ecosystem perspective is not necessarily confined to the inclusiveness of collective actors. Moore (1996) characterizes an ecosystem as the system of firms and markets under the guidance of community leaders. The leadership in an ecosystem formulates governance mechanisms that provide actors with incentives and visions for shared goals (Iansiti & Levien, 2004). The leading firms in an ecosystem affect other actors, and interconnections coevolve together in positioning and capabilities

to achieve shared goals. This study focuses on this characteristic of the ecosystem perspective. As supported in this study, global car makers match the role and impact of keystone organizations in an ecosystem (Iansiti & Levien, 2004). Global car makers not only offer physical platforms and critical knowledge to supplying and complementing actors but also interact according to rules that they have shaped. Rather than listing all other possible interdependencies with various actors such as suppliers, distributors, consumers, governments, processes, products, and competitors, this study focuses the discussion on the issue of keystone players and their relationships with focal actors in an ecosystem.

Understanding the issue of keystone organization in an ecosystem is significant. As Moore (1993) specified, actors in an ecosystem coevolve over time, aligning with strategic intentions established by central firms. The leadership of the central firms may change, but their key function is consistently valued. This is because the close alignment with the leadership facilitates collaboration across the system, lowers the cost of production, reaches new customers, and accelerates learning processes for innovation (Iansiti & Levien, 2004; Moore, 1993; Nambisan & Baron, 2013).

The emphasis on keystone organizations also complements the traditional findings of the “learning by supplying” strand of the global supply management literature. For example, Alcacer and Oxley (2014) point out that customers of suppliers are the source of learning and argue that suppliers’ technological capabilities increase as their supply experience accumulates. Therefore the nature of an OEM firm’s buyers matters a great deal. These findings are observed in other studies as well as anecdotal examples (Bartlett & Ghoshal, 2000; Khanna & Palepu, 2004). The studies in the literature basically look at the issue of how a firm climbs up a value curve to become an

independent participant in the industry. The scholars assume that the goal of an OEM supplier is to evolve into a branded producer.

This study, however, highlights a more fundamental aspect of firm behaviors: the strategic choice between innovation and imitation (as measured by infringement). The choice can be considered to precede or follow the achievement of enhanced technological capabilities. Some firms have successfully transitioned from imitation to innovation. Others persist in imitation, sometimes resulting in IPR violations. I argue that the source of this transition can be traced back to the existence and collaboration with keystone actors in each ecosystem. The ecosystemic view provides the foundation to understand the incentive to be an innovator over the punishment for being an imitator. Prior studies in the global supply management literature do not necessarily address this strategic choice issue of innovation versus imitation. Furthermore, unlike the cases described by Alcacer and Oxley (2014), emerging market tire makers may have no buyers other than their local carmakers. In this situation, our study offers insights about the context where the role of policymakers is critical.

This study further contributes to advancing the policy approach to innovation. The classic view of policy innovation argues that alliances decrease the incentive to innovate. A repeated buyer-supplier relationship may hurt the incentives to innovate compared to market-based contracts (Williamson, 1985). However, complementary relationships between a keystone organization and embedded actors can be an innovation driver in the context of the tire industry and result in high returns from investments in innovations (Kapoor & Lee, 2013). Thus, the role of a keystone organization as a facilitator of innovation in an ecosystem should be highlighted in the course of policymaking. Policymakers should facilitate domestic firms' pro-innovation orientation in a country or industry (Nelson, 1993) based on understanding the criticality of keystone organizations

and their alliances (Adner & Kapoor, 2010; Iansiti & Levien, 2004). This policy approach may eventually address IP infringement.

Based on the findings, we recommend that policymakers pursue policies to help keystone organizations emerge in an ecosystem. As described in the design innovation case in the tire industry, alliances with complementary keystone automakers have effectively induced tire-making firms to avoid imitation and invest in innovation (Kapoor & Lee, 2013; Rajan, Volpin, & Zingales, 2000). This advantage can be greater when technological uncertainty is high (Nickerson & Zenger, 2004). As in the case of the tread design that requires a complementary understanding of both upstream and downstream knowledge, the role of the keystone organization has become more important for innovation. Along with the policy for a high IP standard that addresses the systemic inefficiency in IP protection (Smits & Kuhlmann, 2004), a different set of policies to encourage the emergence of globally competitive keystone organizations can help prevent imitation and promote innovation. Fostering the growth of keystone organizations and coevolving alliances with focal actors should be at the core of policies focused on ecosystems. Such policies are likely to motivate an imitation-driven ecosystem to be more focused on innovation. Once healthy alliances between keystone and embedded actors are functioning, the need for governmental interventions may subside as the ecosystem becomes sustainable (Peltoniemi & Vuori, 2004).

This study has a few limitations. I acknowledge that informal factors such as history, culture, and social norms (North, 1990) in China and South Korea may have had various influences on IP infringement after the TRIPS agreement, although their influence is still considered ambiguous (Peng et al., 2017). Subtle national differences in development levels (Park, 2008) and trade activities (Yang & Sonmez, 2013) may also have affected management and innovation after TRIPS, resulting in different outcomes in

terms of infringement. Furthermore, because the transition from developing players to advanced players in an industry must consider various contingent factors, such as strategic intention, industry type, and capability (Hobday, Rush, & Bessant, 2004), it may not be feasible to pinpoint one determinant of the issue of IP infringement.

Among the possible contingent factors, the existence of business groups may create an interesting complication. The South Korean ecosystem consists of chaebols, which are large and resource rich conglomerates. The difference between China and South Korea could be simply the presence of these business groups because the role of Korean chaebols seems comparable to keystone organizations. Indeed, Korean automakers were controlled by the chaebols, who are linchpins of the South Korean National System of Innovation (NSI) (Etzkowitz & Leydesdorff, 2000). However, while chaebols are known to advantage their affiliates by sharing technical knowledge and financial resources and by promoting innovation (Chang, Chung, & Mahmood, 2006), Korean tire makers have not been affiliates or subsidiaries of the carmakers. For example, the biggest Korean tire maker, Hankook Tire, was established in 1941 and remained a specialized tire manufacturer. In this sense, the ecosystem of tire makers in South Korea is distinct from the country's dominant chaebols.

That being said, I still cannot fully rule out the indirect influence of the chaebols in this context. As the NSI literature suggests, the financial support and strong drive toward innovation by chaebols may have advantaged other national actors and structures (Asheim, Lawton Smith, & Oughton, 2011). The close relationship between Korean chaebols and the government may eventually affect tire makers' change of positioning with regard to IPR infringements. However, I do not have clear evidence to support this position.

In this context, Chinese automakers' joint venture relationships with global automakers are relevant. Chinese car makers have been state-owned since their inception, but they dramatically scaled up production in JVs with global car makers, manufacturing parts and foreign-branded cars for domestic sales from semi-complete knock-down kits. For example, Dongfeng Motor created the Dongfeng Peugeot-Citroen Automobile Co. in 1992. Until 2000, Dongfeng Motor owned 31% of the company, with the Chinese Bank owning 39%, PSA Peugeot-Citroen owning 26.9%, and the International Bank owning 3.1%. Later in the 2000s, Dongfeng and PSA Peugeot-Citroen incrementally increased their shares and equally divided the ownership to 50-50. Dongfeng subsequently launched other JVs such as Dongfeng Honda and Dongfeng Renault in the 2000s and 2010s.

Though global car makers partly own Chinese JVs, domestic tire makers supplying OE tires to these Chinese JVs still engage in imitation as in the case of Aeolus Tire. The partial ownership of global car makers has not meaningfully transferred to exercising pressure on domestic OE tire suppliers for innovation. The factors in the JVs that offset the pressure for innovation coming from global car makers in JVs and how the increase in ownership by global automakers may have influenced Chinese car makers (e.g., Dongfeng Motor) and their OE tire suppliers (e.g., Aeolus Tire), resulting in any changes in continuous IR infringements, have not been studied. These issues require further in-depth investigation of the decision-making rights and processes inside the Chinese JVs.

Therefore, I call for future researchers to build on the integrative framework that includes the ecosystem perspective, which has not been addressed in prior studies of ongoing infringement. The phenomenon of imitation and resultant infringements by emerging economic players requires a comprehensive framework that first identifies

endogenous and exogenous antecedents and consequences in continuous IP infringements and then considers the complex dynamics originating from interactions between firms, institutions, and the ecosystem to illuminate why and how emerging economic firms continue to engage in imitation and infringement.

In addition, to devise effective policies to address continuing infringement after TRIPS, policymakers and scholars should consider that governments and public institutions are subject to imperfect information (Coriat & Weinstein, 2002). It may be risky to conclude that technological and financial assistance from a government promotes the success of a firm. As Braguinsky and Hounshell (2016) noted, many cases exist in which government assistance has failed to generate the intended influence on firm and industrial performance. In particular, public support for potential keystone organizations may not be easy to gain because complex and power-struggling relationships of the embedded actors complicate the ability of policy instruments to support an ecosystem properly (Fiori, 2002). From the perspective that considers a business ecosystem to be a self-governing organism (Peltoniemi & Vuori, 2004), policymakers' intentions and guidance for an innovative ecosystem can be viewed as ineffective. In this regard, future research should include issues related to understanding the adoption mechanisms of policies in an ecosystem and enhancing the effectiveness of policymakers in changing the behaviors of other actors in innovation and global competition.

Conclusion

Why have South Korean tire makers successfully transitioned from imitation to innovation, whereas Chinese tire makers persist in imitation, sometimes resulting in IPR violations? My answer is that the presence of keystone organizations matters because they enforce innovation in an ecosystem. The adoption of a strong IPR system alone does

not explain a reduction in IP infringement. The existence of successful automakers as keystone organizations and their complementary collaboration with domestic tire makers encourages tire makers to be innovators rather than imitators. In this sense, the effectiveness of a high IP protection standard critically depends on an ecosystem orientation toward innovation. If this paper has one message, it is that policymakers should devise policy instruments to facilitate the growth of keystone organizations and their close alliances with embedded actors to build a critical mass of innovation capability and IP stocks. It is vital to keep in mind that IPR violations in South Korea have been reduced not because of a change in enforcement (heavier stick) but because of the increased benefits of innovation in the ecosystem (sweeter carrot).

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APPENDIX A

INTERVIEW SUMMARY

To triangulate the insights from the analysis on tread design with academic manuscripts, books, magazines, press articles, and corporate websites, a series of semi-structured interviews were conducted during June 2018. One senior-level executive, two tire sales experts, three strategic planning managers, and two R&D engineers working for global tire and car makers were interviewed to collect contextual knowledge of the tire industry. We also conducted email interviews with a former executive of a Korean auto maker to learn more about the history of Korean tire-making. All the face-to-face interviews lasted 45 minutes to 1 hour.

	Question Category	Questions
1	Value of Tread Design	<ol style="list-style-type: none"> 1. How important are tread designs in tire performance? 2. How tricky is it to create and/or innovate tread designs? 3. Why have tire makers started patenting more often? 4. Has your firm commercialized an unpatented tread design ever? Why?
2	Relationship of Tire Makers with Car Makers	<ol style="list-style-type: none"> 1. Do automobile makers recognize unique tread patterns? Why? 2. If a car maker finds that its original equipment (OE) tire maker copied the tread designs of others, would it affect the OE partnership? Why? 3. Since when have your tires been equipped on (exported) automobiles? 4. It is known that OE tires transfer to the purchase of the same tire brand for replacement (RE) tire. Does it still work that way? Why?

The interviewees were asked to describe two main issues in the history of tires: the value of tread design and the relationship of tire makers with car makers. The interviewees from tire makers confirmed that tread design for tire performance is one of

the key sources of functional differentiation (Clark, 1981). For example, tread design offers differential performance measures such as traction (Novopolskii & Tretyakov, 1963), braking friction (Allbert & Walker, 1965), longevity (Tretyakov & Novopolskii, 1969), and noise reduction (Clark 1981). Furthermore, the interviewees reported that the tread design requires complex trade-offs among the different performance measures, thus giving each tire a unique quality. These interviewees stated explicitly that litigation regarding tread design infringements cannot be treated as minor. A tread design infringement is a major attempt to imitate the core product performance of advanced tire makers and is a strategic action to catch up with advanced players in the tire industry.

Another key implication of the interviews concerns the relationship of tire makers with car makers. The role of car makers as innovation drivers is clear. The R&D engineer who researches tread design stated that car makers request a set of specific tire features for a new car 2-3 years before its commercialization. Tire makers then research and develop a tire tread design that satisfies the requirements of the new car, sometimes collaborating with the car maker. The development of tread design requires complicated trade-offs among the performance measures, mandating a high R&D capability to keep up with car makers' standards.

The former head of European operations at a Korean automobile maker stated that when Korean cars were initially exported to the US in the late 1980s, they were NOT equipped with Korean tires. Only in the early 1990s did Korean auto manufacturers finally equip their exports to the US with Korean tires. The sales director and assistant sales director corroborated the fact that the timing of Korean tire makers as OE suppliers

to their US-exported cars was around the early 1990s (they stated the first year when this happened as either 1992 or 1993).

All in all, the interviews imply the following:

1. Tread design is one of the key innovations for tire performance.
2. In the process of R&D on tread design, car makers are an innovation driver.
3. Korean tire makers started to supply their tires to US-exported Korean cars in the early 1990s, which coincides with when they began patenting their own innovations.