Abstract

What if the outputs of inimitable resources are not protected but open to imitation? In the tire industry, tire makers' tread patterns, which endow tires with critical functionality, are the output of innovation capabilities. However, this intellectual property was not completely protected from the industry's birth in the early twentieth century through the 1990s. This leads us to the fundamental research question addressed in this paper. Why was this valuable innovation not protected in full for almost a century? Why did firms finally begin to protect it in the 1990s? To answer this question, we examine the history of the global tire industry and its patent trajectory.

We use two methodologies that complement each other. By unpacking the historical events and longitudinal patent and financial data analysis, we show the shift to more design protections as a response to imitation by makers from emerging economies. This complementary approach helps us better apprehend the dynamism of imitation and innovation.

Our findings suggest that until the late twentieth century, tread designs, a well-known source of competitive advantage, were not fully protected because imitation of the design would hurt the imitators' other resources such as brand identity. However, the entry of emerging economy players who did not bear these imitation costs dramatically changed the patent trajectory. Advanced players that were directly confronted by the threat of imitation were suddenly forced to strengthen the patent portfolio of their designs to protect their key source of competitive advantage.
This study contributes to the resource-based view (RBV) by showing that some assumptions about consistent investment in inimitability can be relaxed. The RBV as a basis for the competitive advantage of a firm suggests the application of a bundle of valuable tangible or intangible resources at the firm’s disposal (Penrose, 1959; Wernerfelt, 1984; Barney, 1991). The RBV explains a firm’s ability to deliver sustainable competitive advantage when resources are managed so that their outcomes cannot be readily imitated by competitors, which ultimately creates a competitive barrier (Mahoney and Pandian, 1992; Smith and Rupp, 2002). Thus, the investment to secure inimitability seems natural as a strategic choice of firms (Lieberman, 1987; Hill, 1988; Barney, 1991). However, we highlight here that firms will invest in protecting valuable resources only when there is a threat to inimitability. On the condition that imitation destroys other resources of an imitator, imitation may not occur. If firms recognize this condition in an industry, investment in inimitability may not be necessary. Once the condition is compromised, however, active protection of valuable resources from imitation should be enforced.
When is Imitation a Threat? The Case of Design in the Global Tire Industry

Introduction

What if the outputs of inimitable resources are not protected but open to imitation? In the tire industry, tire makers’ tread patterns, which endow tires with critical functionality, are the output of innovation capabilities. However, this intellectual property was not completely protected from the industry’s birth in the early twentieth century through the 1990s. This leads us to the fundamental research question addressed in this paper. Why was this valuable innovation not protected in full for almost a century? Why did firms finally begin to protect it in the 1990s? To answer this question, we examine the history of the global tire industry and its patent trajectory.

The global tire industry was extremely stable for much of the twentieth century. Four of the five largest tire makers in the world in 1971 (West, 1984) were the top four players in the global tire industry in 1910. The incremental advancement of product quality along with the development of mass production technology since 1920 sustained the steady domination of large tire makers for more than 60 years (French, 1991; Jovanovic and MacDonald, 1994). However, by the 1960s, new entrants from Japan began challenging the dominance of American and European multinational enterprises (MNEs). Over the next twenty years, these entrants altered the profile of the industry, culminating in radical consolidation in the late 1980s, wherein several of the established firms were acquired.

Another round of global entry began in the 1980s, this time from South Korea. However, unlike Japan in the 1960s, which was by most measures an advanced economy, South Korea in the 1980s was an economy in the early stages of emergence.¹ We argue that global entry by firms

¹ By the 1960s, Japan’s per capita GDP was roughly on a par with those of the major advanced economies of Western Europe (World Development Indicators, World Bank, 2014). In contrast, South Korea’s per
from emerging markets is fundamentally different from the entry of firms from advanced economies. Specifically, whereas advanced economy firms have the capabilities to engage in innovation rivalry soon after entry, emerging market firms have to use imitation as they catch up (Awate et al., 2015). In this paper, we document the nature of the reactions that this imitative entry triggers from the established MNEs.

Our findings suggest that until the late twentieth century, tread designs, a well-known source of competitive advantage, were not fully protected because imitation of the design would hurt the imitators’ other resources such as brand identity. However, the entry of emerging economy players who did not bear these imitation costs dramatically changed the patent trajectory. Advanced players that were directly confronted by the threat of imitation were suddenly forced to strengthen the patent portfolio of their designs to protect their key source of competitive advantage.

This study contributes to the resource-based view (RBV) by showing that some assumptions about consistent investment in inimitability can be relaxed. The RBV as a basis for the competitive advantage of a firm suggests the application of a bundle of valuable tangible or intangible resources at the firm’s disposal (Penrose, 1959; Wernerfelt, 1984; Barney, 1991). The RBV explains a firm’s ability to deliver sustainable competitive advantage when resources are managed so that their outcomes cannot be readily imitated by competitors, which ultimately creates a competitive barrier (Mahoney and Pandian, 1992; Smith and Rupp, 2002). Thus, the investment to secure inimitability seems natural as a strategic choice of firms (Lieberman, 1987; Hill, 1988; Barney, 1991). However, we highlight here that firms will invest in protecting valuable resources only when there is a threat to inimitability. On the condition that imitation capita GDP in the early 1980s was about one-sixth of comparable contemporaneous figures, indicating that it was an economy in the early stages of emergence.
destroys other resources of an imitator, imitation may not occur. If firms recognize this condition in an industry, investment in inimitability may not be necessary. Once the condition is compromised, however, active protection of valuable resources from imitation should be enforced.

Theoretical Background

Inimitability and Isolation Mechanisms

The resource-based view (RBV) contends that the basis for the competitive advantage of a firm lies in the application of a bundle of valuable tangible or intangible resources at the firm’s disposal (Penrose, 1959; Wernerfelt, 1984; Barney, 1991). Transforming a short-term competitive advantage into a sustained competitive advantage requires that the resources are not perfectly mobile in nature (Peteraf, 1993). Effectively, the RBV emphasizes that valuable resources should neither be perfectly imitable nor substitutable without great effort (Barney, 1991). Firms can sustain a strategic position that may result in high profits (Porter, 1980) if they are able to develop and maintain resources and capabilities that cannot be possessed or built up in a similar manner by competitors (Barney, 1991). Therefore, the consistent investment in inimitability seems like an inevitable choice for firms with valuable resources.

The extant literature shows that the reality of competition challenges firms to secure inimitability consistently. As technological and market uncertainties decrease, firms tend to imitate their competitors’ strategic and operational behaviors (DiMaggio and Powell, 1983). This tendency becomes stronger over time, establishing common sources of knowledge and know-how (Prahalad and Bettis, 1986; Pounder and St. John, 1996). Along with strong institutional pressure over time, increasingly stronger dependency on similar partners may further cultivate
the lack of unique resources and capability (Miller and Chen, 1994). As firms advance along the experience curve with widely-accepted routines and processes, their competitive advantage suffers because their originally unique resources become common among competitors in the industry (Porter, 1980; Lieberman, 1987; Hill, 1988). The prevalence of fungible resources and capabilities as an industry ages restricts the breadth and depth of strategic choices (Scherer and Ross, 1990), resulting in similar business practices and products within an industry (Klepper and Graddy, 1990).

The strategic management and innovation literature has identified various isolating mechanisms that help build barriers to imitation (Rumelt, 1984), including causal ambiguity (Lippman and Rumelt, 1982; Reed and DeFillippi, 1990), mobility barriers (Caves and Porter, 1977), inimitable resource positions derived from scale advantages, preferred access to either resources or customers, restrictions on competitors’ options (Ghemawat, 1986), and nontradeable assets such as tacit knowledge and social complexity (Dierickx and Cool, 1989). A firm may take advantage of secrecy for resources and capability of innovation by establishing special procedures to handle trade secrets if the locus of innovation mainly comes from a type of process (Levin, Klevorick, Nelson, and Winter, 1987). However, if the core aspect of innovation is easily noticeable, imitable, and/or reengineered, appropriate formal protections such as a patent may serve better for economic rents. Especially in technology-driven industries, where knowledge creation dominates the growth and prosperity of firms, the protection of valuable intangible resources such as intellectual property (IP) is one of the critical options that secure inimitability (Nelson, 1959; Barney, 1991), possibly leading to a better strategic position (Porter, 1980).

However, even when the protection of competitive IP seems like a logical behavior, investment in inimitability may not always be the norm. If imitation itself is costly (Nelson and
Winter, 1982), the need for proactive protection mechanisms may be low. Imitation may be very costly when customers particularly favor innovators as a criterion for brand selection (Rajan, Volpin, & Zingales, 2000). In firms from advanced economies, managers tend to view imitation as taboo because imitation may compromise their personal reputations (Bolton, 1993; Shenkar, 2010). The stigma of being imitators may de-legitimize a firm in an industry and cause the loss of opportunities for institutional benefits (Meyer & Rowan, 1977). Thus, under the condition that imitation destroys other valuable resources of imitators, innovators do not feel the strong necessity to enforce rigorous isolation mechanisms. The consistent protection of valuable intellectual properties may not necessarily happen.

*Changes in Investments in inimitability: Strategic Group Responding to a Threat*

In a sense that isolating mechanisms shield individual firms from imitation within a particular strategic group (Kor, 2016), the condition of loose protection remains as long as the strategic group does not perceive a threat.

As many studies in the strategic management literature tell, the industry itself can contain subgroups with different dynamics of competition (Amel and Rhoades, 1988; Lee, 2003). Within an industry, a competitor grouping using similar market segments and/or product diversity that differ from those of other industry groups is called a strategic group (Newman, 1978). A strategic group includes the closest industry competitors given that a significant mobility barrier exists (Porter, 1980). This nature of a strategic group facilitates the convergence of organizational behavior because “divergent strategies reduce the ability of the oligopolists to coordinate their actions tacitly... reducing average industry profitability” (Porter, 1979). The
members of a strategic group are likely to respond similarly to a risk that threatens the group in order to defend their status quo (Chen and MacMillan, 1992; Chen, Smith, and Grimm, 1992).

Once a clear threat of imitation in a strategic group of advanced incumbents emerges, the advanced players will ultimately adjust their investments in inimitability in a similar direction. Since group membership emerges with irrevocable structures based on path dependencies (Peteraf and Shanley, 1997) such as a long-term investment in a specific area of research and development (Caves, 1984) and a historical “commitment by selling the output” of the R&D activities (Lee, 2003), firms in a threatened group react to defend their innovations in a similar way.

*Design as a Source of Competitiveness and its Imitation*

The necessity to protect key innovations from imitation culminates in product design. Effective design can improve the functionality of a product while also serving as visible evidence of enhanced product quality from an advanced R&D capability that in turn creates a significant competitive advantage (Kotler and Rath, 1984; Gemser and Leenders, 2001). At the same time, design facilitates customers’ identification of the maker and brand. For example, the unique shape of a product helps customers recognize “the set of properties of an artifact, consisting of the discrete properties of the form” (Luchs and Swan, 2011). As a result, product design can work as a key factor of competitiveness (Hertenstein et al., 2005) by providing a visible guide for customers to recognize and choose a specific maker with favored brand identity. In this sense, firms leverage design to communicate the value of their product via its physical appearance (Beebe, 2010), a critical resource worthy of protection.
On the other hand, the design of a product can be vulnerable to imitation due to its visible nature to competitors. While an effective design is highly valued as an important source of competitiveness (Gemser and Leenders, 2001), design itself can be an easy target of imitation if not carefully protected (Filiz and Tether, 2015). Especially for lagging firms in emerging markets with a weak intellectual property (IP) protection regime, the temptation to copy a valuable IP from industry leaders is real and significant (Brandl, Darendeli, and Mudambi, 2018, Forthcoming) owing to “institutional void” (Khanna and Palepu, 1997) along with cultural disrespect (Bugbee, 1967; Jaffe and Lerner, 2007; Peng, 2013; Robinson, 2016) and a lack of policies that support IP rights (Zimmerman, 2013). Eventually, their vulnerability to imitation and the high tendency of imitation by emerging market players make advanced market players more concerned about protecting their product design.

In summary, while product design as an effective outcome of advanced R&D capability is widely considered a key factor for competitive advantage (Kotler and Rath, 1984), it may not necessarily be protected under the condition of high imitation costs caused by other resources at risk by imitation. This implies that the heightened risk of imitation by lagging firms who do not bear imitation costs can create a significant increase in investment in protection of designs by leading innovators that are directly impacted by this risk. We argue that the phenomenon of sudden transition to more design patents in the tire industry well exemplifies this case. To further examine how the threat of imitation drives the protection trend of innovations to a different path, we conducted a historical analysis of the global tire industry along with a patent analysis of advanced big players and emergent contenders.

**Context and Methods**
The empirical context of this research is the global tire industry, which the innovation literature has studied extensively. While the tire industry has not witnessed disruptive technological innovations since the emergence of the radial tire\(^2\), 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 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 and Simons, 2000). The industry that has been mature and stable for a long time is going through another dynamic era, stirred by the market entry of emerging economy makers, especially from South Korea in the 1990s.

We use two methodologies that complement each other. By unpacking the historical events and longitudinal patent and financial data analysis, we show the shift to more design protections as a response to imitation by makers from emerging economies (Scalera, Mukherjee, Perri, and Mudambi, 2014). This complementary approach helps us better apprehend the dynamism of imitation and innovation (Casson, 1986, 1997; Wilkins, 1996; Jones and Khanna, 2006; Morck and Yeung, 2007; Buckley, 2009).

First, we perform a historical analysis of the tire industry which provides us with background information and the rationales for imitation by emerging economy tire makers. To

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\(^2\) A new 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, and Zingales, 2000). Eventually, 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 and Simon, 2000).
illustrate the trajectory of IP protection and the nature of imitation in the tire industry, we study
the historic events and technological evolution that have shaped the global competition landscape
since its early years, with a noticeable change in the trajectory 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” (Joseph
and Ocasio, 2012; Scalera, Mukherjee, Perri, and Mudambi, 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 expert interviews were performed. Two senior-level executives, two tire sales experts, two
strategic planning managers, and two R&D engineers of global tire makers were interviewed to
discover the rationales of historical business practices in the industry. We also conducted email
interviews with two former executives of Korean automobile makers to augment the historical
analysis.

Second, the analysis of the historical dynamics, supporting the findings of seminal studies
in the strategic management and international business literatures, 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 innovation-based competition. Pakes and Griliches (1984) noticed that a
firm’s “level of economically valuable technological knowledge” can be indicated by the number
of 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) suggested that patents can be considered a good measurement of externally identifiable
“innovative success”. Therefore, patent analysis can illustrate, to some extent, what types of
innovation tire makers in the industry focus on.
We 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 that were collected from the Global CompuStat database.

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, and 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 and Thurik, 2000).

Thanks to a series of product and process innovations, the number of firms in the tire industry dropped, firmly solidifying the market positions of old, big players (Jovanovic and 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).

Meanwhile, Japanese tire makers joined the group of global tire leaders. In the 1960s, Japanese tire makers experienced strong growth thanks to “full-fledged motorization, including increased automobiles on the road and the advent of expressways” (The Japan Automobile Tyre Manufacturers Association, 2016). Japanese tire makers such as Bridgestone, Yokohama, and Sumitomo swiftly followed the innovation path of European tire makers by commercializing radial tire technology, which is today’s tire standard, and engaged in brand-based competition in the 1950s and 60s (Rajan, Volpin, and Zingales, 2000). In this sense, the Japanese tire makers competed as leading innovators head-to-head with European makers. Based on the innovations, the Japanese tire industry supplied original equipment (OE) tires on new Japanese cars that were exported to Europe and, later, the US (Rajan, Volpin, and Zingales, 2000). For instance, Bridgestone and Yokohama entered the US OE market in 1967 and 1969, respectively.

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) though they recognized the superiority and popularity of radial tires (Kovacs and 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 markers 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, and Zingales, 2000), immediate, extensive investment in radial tires was not feasible though the need to catch up was very urgent. As a result, 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, and Zingales, 2000).

Ultimately, the global tire industry became even more concentrated with advanced innovators by the late 1980s (Klepper and 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 and 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, and Zingales, 2000) and its considerable research efforts to catch up with radial technology (Scalera, Mukherjee, Perri, and Mudambi, 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 Design Patents

Starting in the 1990s, the tire industry witnessed another round of global competition, this time from emerging market makers. The once ever-strengthening oligopoly gradually relaxed, allowing mid-tier tire makers to take larger shares. According to Nikkei Asian Review (2015), the biggest tire maker, Bridgestone, 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 such as South Korea have
consistently made inroads into the established players’ market shares. For instance, Hankook Tire (Korea) gained an additional 3.7 percentage points of the global market share (Tire Business cited by Nikkei Asian Review, 2015). Collectively, the Big 3 tire makers (Bridgestone, Michelin, and Goodyear) lost 17.2 percentage points to mid-tier tire makers from emerging economies.

Coincidently, while emergent mid-tier manufacturers were gaining more market share, dominant established players were filing more design patents. Specifically, the patent trajectory in the tire industry changed to protect more tread patterns starting in the 1990s. Tread design refers to the pattern or grooves on the tire’s circumference and determines the effectiveness of traction, anti-hydroplaning, and noise-reduction, which critically influence a car’s maneuverability and longevity (Clark, 1981). Furthermore, since the tread design is unique for each tire brand, it gives a way for automobile makers who well understand the criticality of tread design for tire performance to recognize and select OE tires. In this sense, tread design is a valuable source of competitive advantage.

A few studies have noted the historical increase in protection of tire design. Scalera, Mukherjee, Perri, and Mudambi (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 tire industry, has shown significant growth of design innovation efforts; 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) 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), the recent specific focus on tread design is even more out of the traditional patent trajectory in the industry. Indeed, design patents for tread patterns were rare but are now the norm.

Why was protection of tread design weak before the 1990s? Various other resources at risk of imitation may explain the loose investment in inimitability. First, imitation might have destroyed the mutual benefits that the tire makers headquartered in the Akron area enjoyed. 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) 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 and Kerr, 1996). These players had little motive to hurt this special relationship of mutual benefits by infringing the intellectual properties of their trusted “friends.”

Second, imitation may compromise the reputation of being an innovator, a critical resource to maintain OE market shares. Automobile makers, who are the buyers with the biggest bargaining power, relentlessly pushed tire makers to be technological innovators. To keep up with the evolving performance of cars, being an innovator is an important requirement to be selected for an OE tire supplier (Rajan, Volpin, & Zingales, 2000). An R&D engineer at a global tire maker stated in an interview that automakers sometimes demand tires specifically tailored for their new cars. If a tire maker cannot meet this demand by innovating their tire quality, the relationship cannot last. Another tire R&D engineer further elaborates that automakers “hate to see the image of imitator [i.e., of an imitating tire maker] get stuck with them.” Automakers
carefully keep distant from any stigma which may negatively affect their brand images. Thus, major tire makers carefully cultivate their reputations as innovators (Rajan, Volpin, & Zingales, 2000). Imitation can go against the strategic choice of tire makers.

The nature of design further restricts imitation by major tire makers. Since each tread pattern is uniquely identifiable to its brand and maker, the infringement of design cannot be easily hidden. Since the advanced players from Europe, the US, and Japan have created well-established tread patterns that are uniquely identifiable with their brands, they have not risked copying each other’s designs to sacrifice competitive resources such as their reputation and brand identity.

These contextual circumstances along with the nature of design explain the loose protection of tread patterns without costly legal protection methods until the 1990s. When only advanced players competed in the global tire market, design infringement was hardly imaginable due to the other resources at stake.

However, a threat of imitation from emerging market tire makers finally arrived in the global tire industry. In the late 1980s and early 1990s, tire makers from South Korea made a major entry into the global market. For example, Kumho Tire entered the US OE Market for GM in 1988, and Hankook Tire did so for Volkswagen in 1991. This was a critical moment because of the significance of the OE market. According to Isaacson (1993), a significant portion of OE tires transfer to the choice of individual replacement tire (RE) customers. Interviewees from a major tire maker called this “the rebound effect,” which creates a significant portion of RE sales. Isaacson (1993) reports that 44% of Michelin’s OE tires were selected again when customers needed a new RE tire; Goodyear enjoyed a 39% rebound effect. For the first time in the global
tire industry, South Korean tire makers started to directly compete with long-dominating players from Europe, Japan, and the US by officially entering the OE market.

The emergence of emerging economy makers in the 1990s signaled the imminent threat of imitation to the advanced market players in the tire industry. Firms from emerging economies with weak IP protection tend to engage in IP infringement because of institutional (Khanna and Palepu, 1997), cultural (Bugbee, 1967; Jaffe and Lerner, 2007), and political (Zimmerman, 2013) loopholes. This tendency posed a practical threat of imitation for the tread patterns of advanced makers, which had not been protected for a long time (Warner, 1966). Since players from emerging economies tend to have no or weak brand identity, they do not have much to lose when copying the tread designs of leading, established firms. Design infringement may not necessarily cost the emerging tire makers significantly because they do not carry the reputation of being innovators (Rajan, Volpin, & Zingales, 2000) or managers’ views of imitation as taboo (Bolton, 1993; Shenkar, 2010). They are even free from the risks to mutual benefits and the potential “de-legitimization” (Meyer & Rowan, 1977) that had been supported by the open door policy of the Akron-based makers (Allen, 1949). We argue that the emerging economy players’ low cost of imitation contributed to the major tire makers’ decision to begin protecting tread designs more strongly.

The increasing number of lawsuits related to tread design infringement starting in the late 1990s indirectly supports that the sudden increase in design patenting is not a vain worry. In 1996, Michelin claimed that a Korean tire maker, 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). The judge then granted Michelin’s motion to terminate the investigation. Though 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). 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 cannot secure “the same grip or longevity of performance as an authentic Michelin tire” (Modern Tire Dealer, 2007).

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 an 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).

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”3 copying Bridgestone’s tread patterns for truck and bus tires (Bridgestone, 2014). 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)

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3 “Pre-cured treads” refers to pre-vulcanized tread rubber used in retread tires (Bridgestone, 2014).
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”.

**Major Findings**

Figure 1 presents the cumulative patents 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. Their number of patents over the period 1975 – 2005 increased consistently without a significant sign of slowing down, showing the relentless pressure for innovation in the tire industry (Rajan, Volpin, and Zingales, 2000). Chemical and mechanical utility patents dominated these patents up to the 1970s and 1980s, showing the emphasis on the main core technologies at the time (Scalera, Mukherjee, Perri, and Mudambi, 2014).

There were virtually no design patents filed in 1975, and the number of design patents took off slowly between 1975 and 1990. As Table 1 shows, the increase in design innovation since the 1990s is outstanding. During the 1980s, the ratio between design and utility patents was just 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. Though it is not shown in the Table 1, the number of tire design innovation patents (190) almost matched the number of utility patents (197) in 2015.
The dramatic increase in design patenting activities by the Big 3 makers coincides with the historical context of the greatly increased risk of imitation by emergent tire makers. It has been since the entry of Korean tire makers into the OE market in the 1990s that major makers’ cumulative number of design patents dramatically increased. Goodyear’s design patents have grown most noticeably, outpacing those of Bridgestone and Michelin in total (Figure 2). 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 production of design patents assigned to Goodyear jumped to 44.6 in 1990 – 1994, 85 in 1995 – 1999, and finally 101 in 2005 – 2009. This dramatic surge of Goodyear’s design patents may represent the greater degree of the perceived threat of imitation after the dissolution of the “open door policy” in the late 1980s. As the long-time leader and lone survivor of the Akron-based tire makers, Goodyear must have taken the collapse of the trusted circle more seriously than other major makers. By patenting more tread patterns than any other majors, Goodyear was eager to protect its designs from imitators.

The sudden increase in design patents was not confined to Goodyear. In an analysis of the design patents of the Big 3 players (Figure 3), the race for design protection is clearly visible when the average annual productivity 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 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.
Unlike the Big 3 makers, emerging economy makers started to protect their designs only after the 2000s. As shown in Figure 4, Hankook Tire (established in 1941 in Korea), Kumho Tire (established in 1960 in Korea), Cheng Shin (established in 1967 in Taiwan), and Nexen (established in 1942 in Korea) collectively had no design patents until 2000, a huge delay compared with the patent trajectory of advanced tire makers. While the emergent makers have kept producing patents in innovating chemical and mechanical components, the number of design patents caught up only recently, reaching the cumulative ratio of 0.78 in 2014.

The significantly late patent trajectory of design patents by emerging economy makers seems to support that the development of design capability is a recent phenomenon. Korean tire maker Kumho, which had a design infringement conflict with Michelin in 1996, started to produce design patents simultaneously with its investment in scientific R&D efforts, producing 82 utility patents in the period of 2000 – 2005 alone. Hankook, another Korean tire maker, also started to file design patents in the period 2000 – 2005.

However, Hankook produced increasingly more design patents after 2005, eventually taking over the weak leadership of Kumho in tread design in 2010 (Figure 5). Hankook was granted 6 patents for tread patterns in 2006 and later secured 17 design patents in 2014 alone. By the end of 2014, Hankook had accumulated 64 design patents in total, more than double Kumho’s 31 patents. Another important movement came from Nexen, the third-largest Korean tire maker. Nexen patented an average of 3.7 tread designs per year between 2006 and 2014, owning 33 unique, patented tread designs in 2014. Though Nexen started to engage in design innovation even later than other emerging economy tire makers, its cumulative number of design patents was more than that of former mid-tier leader Kumho as of 2014. Interestingly, Nexen had one and only utility patent in 2003 while creating tread patterns with 33 design patents between
2004 and 2014, showing an absolute dedication of R&D to design innovation. Compared to Korean tire makers, other emerging makers show little footprint in design. For example, Cheng Shin patented only 6 design patents in total.

To understand the impact of tire makers from emerging economies, we estimated a series of fixed effects panel regression on our unbalanced panel dataset controlling unobserved firm-level heterogeneity. As a dependent variable, we 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 to show the impact of the emergence of Korean makers in the global tire market. We also included a variable for the yearly revenue of knock-off tire makers. We define the variable by summating the yearly revenues of tire makers that do not have any patent or license while still manufacturing tires as a proxy of imitators. The yearly number of utility patents controls the R&D intensity for each firm. We also include various control variables for yearly revenues of each maker, the Great Recession period (2007 – 2009), the end of the Klepperian Oligopoly (1975 -1990, Klepper and Simons, 2000) and the yearly number of lawsuit cases about the tread design infringements.

Notably, we use a control variable to incorporate the change in the strength of IP regime. 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, we consider the implementation year of a TRIPS agreement for each county as a proxy for the strengthening in IP regime of a home country. TRIPS stands for the World Trade Organization’s (WTO) Trade-Related Aspects of Intellectual Property Rights (TRIPS). Signing the agreement signals an emerging economy country’s willingness to comply with the minimum

The results of the main regressions can be found in Table 2. We 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. Along with the control variables in Model 5, the positive and significant estimates for Korean makers ($p < 0.001$) indicate that growth in Korean makers’ revenues enhances their efforts to protect their designs. Since Korean tire makers emerged in the OE market where only advanced players had competed, their impact on design protection is significant as expected. On the other hand, the revenue growth of knock-off makers, who generally remain in the RE market, do not influence the trajectory of design patenting.

To further test the impact of Korean tire makers on specific strategic groups, we 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. We defined the advanced players as traditional tire makers that have dominated both 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, South Korea, Kenya, Peru, Sri Lanka, Thailand, Turkey, Myanmar, and Russia. For each group, we regressed the number of design patents on the revenue of Korean tire makers and control variables. The results in Table 3 show that the effect of growth in the revenues of Korean makers is not significant on the emerging players but is significantly positive.
($p < 0.05$) on the advanced players. The impact of the threat of imitation by Korean makers only affects the advanced players in the same strategic group, as expected.

We also performed a sensitivity analysis to better understand the impact of Korean tire makers as the major threat of imitation. We split the dataset before and after 1993, the year after all the Korean tire makers entered the US, which is the biggest tire market in the world. The results in Table 3 confirm that the effects of Korean makers’ revenues after 1993 are significantly greater ($p < 0.05$) in magnitude than those before 1993. The analysis before/after 1995 is also consistent with the finding. The results show that the entry by Korean makers generated a greater impact on the production of design patents, implicating how seriously tire makers responded to the entry by Korean makers.

In summary, we argue that the main source of the big players’ dramatic shift to design patents is the threat of imitation by emerging economy players such as South Korean tire makers. While the trust among competitors in terms of protecting tread patterns and brand identity reduced the need to patent designs until the 1990s, the fear of emergent makers’ attempts to imitate the design of advanced tire makers contributed to the phenomenon of filing more design patents. This threat of imitation from South Korea directly challenged and clearly impacted the group of advanced tire makers. This explains the situation shown in Figure 1 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.

**Discussion and Conclusion**

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

The key findings in this paper are aligned with the extant literature in that the threat of imitation from players in emerging economies can potentially change innovation leaders’ focus of patenting activities to protect the source of their competitive advantage. As a major contribution to the literature, this paper examines a relatively underexplored but critical question regarding innovation in a mature industry: what if the outputs of innovation are unprotected and open to imitation? Before innovators consider employing formal and informal isolating mechanisms, they may not engage in strategic protection of innovations thanks to a specific condition of competition: under the condition that imitation compromises other resources of an imitator such as brand identity, innovators may leave some intellectual properties unprotected because they understand that the high cost of imitation prevents imitation. In this sense, the investment in inimitability is not an inevitable strategic choice of innovators. However, once this condition is compromised, isolating mechanisms finally draw managers’ attention to securing inimitability.

One alternative explanation for the swift change in patent trajectory is the shift in R&D focus by advanced players. If advanced tire makers realized the value of tread design and started to focus on design over other types of innovations during the 1990s, the surge of design patenting may be explained. However, this possibility is slim because the value of tread designs has been widely known from the early years of the industry.
Since the first tread designs in 1908 by Goodyear and Firestone, the importance of tread design has been a key area of innovation (Lief, 1951; O’Reilly, 1983). Tread design is uniquely identifiable to each brand and maker and is directly associated with financial performance (Lief, 1951). For example, individual customers and automobile tire makers responded to Firestone’s non-skid tire with its unique tread design quickly and positively; 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 (Leif, 1951). This is mainly because tread design is one of the most critical determinants for tire quality. For instance, Allbert and Walker (1965) compared various factors that influence effective braking friction on a wet road. They found that while the change in tread materials only shows a variability of 1.5:1, patterned tire versus smooth tire creates a variability of 8:1 and different tread pattern designs do so up to 4:1. It is no wonder that researchers and tire makers have studied different shapes and depths of tread design elements in terms of pneumatic tire mechanics to minimize hydroplaning and maximize snow traction performance from the early period of the tire industry (Allbert and Walker, 1965; Novopolskii and Tretyakov, 1963; Smith and Dough, 1972; Staughton, 1970). Thus, a sudden technological shift of focus on innovation in the 1990s does not fully explain the surge of design patents.

In conclusion, we argue that the main culprit for this surge is the change in the competitive landscape caused by emergent players with low imitation costs. A switch to a different patenting behavior in an innovation-driven industry may not simply occur out of a sudden recognition of the value of a specific type of innovation. It should be apprehended within the historical context of a dynamic competitive landscape. We contend that this change in patent trajectory should be appreciated in light of innovators’ response to the threat of imitation, a threat that aims specifically at valuable but less protected intellectual properties. A formal or informal
protection mechanism for securing the economic rents from innovation (Teece, 1986) may be employed when the protection finally becomes necessary.

Limitations and Future Research Directions

First and foremost, a simple count of different types of patents may not fully capture the trajectory of protection and innovation (Lanjouw and Schankerman, 2004), possibly requiring us to develop other measurements that may better fit the impact of imitation.

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 tells us that some industries have no or gradual (rather than dramatic) shakeouts caused by innovation (Gort and Klepper, 1982; Klepper and Graddy, 1990; Klepper and 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 design patents by emergent manufacturers influence the scope and quality of design innovation by advanced manufacturers?
- If so, how can such a relationship between patent infringement and innovation characteristics be theoretically apprehended and modeled?
Along with the suggested follow-up studies, we hope to understand how imitation by emerging players impacts innovation trajectory by advanced players and what factors moderate the eventual outcome.

Figure 1. Innovation Trajectory of the Big 3 Tire Makers (Goodyear, Michelin, and Bridgestone) in the Period of 1975 – 2014

<table>
<thead>
<tr>
<th>Yearly Period</th>
<th>Utility Patents</th>
<th>Design Patents</th>
<th>Ratio (Design/Utility)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1975 – 1979</td>
<td>1078</td>
<td>96</td>
<td>0.089</td>
</tr>
<tr>
<td>1980 – 1984</td>
<td>896</td>
<td>191</td>
<td>0.213</td>
</tr>
<tr>
<td>1985 – 1989</td>
<td>1066</td>
<td>220</td>
<td>0.206</td>
</tr>
<tr>
<td>1990 – 1994</td>
<td>1111</td>
<td>406</td>
<td>0.365</td>
</tr>
<tr>
<td>1995 – 1999</td>
<td>1762</td>
<td>703</td>
<td>0.399</td>
</tr>
<tr>
<td>2000 – 2004</td>
<td>2102</td>
<td>800</td>
<td>0.381</td>
</tr>
<tr>
<td>2005 – 2009</td>
<td>1761</td>
<td>897</td>
<td>0.509</td>
</tr>
<tr>
<td>2010 – 2014</td>
<td>1922</td>
<td>923</td>
<td>0.480</td>
</tr>
</tbody>
</table>
Table 1. Patents in 5-year Periods from 1975 – 2014 (Goodyear, Michelin, and Bridgestone).

Figure 2. Firm-level Cumulative Design Patents from 1975 – 2014 (Goodyear, Michelin, and Bridgestone).
Figure 3. Design Patents on Average from 1975 – 2014 (Goodyear, Michelin, and Bridgestone).
Figure 4. Innovation Trajectory of 4 Emergent Tire Makers (Hankook, Kumho, Cheng Shin, and Nexen) in the Period of 2000 – 2014

Figure 5. Firm-level Cumulative Design Patents from 2000 – 2014 (Hankook, Kumho, Nexen, and Cheng Shin).
Global Tire Manufacturers: Fixed Effect Panel Regression (Lagging 1 Year)  
Dependent Variable: Design Patents

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
<th>Model 4</th>
<th>Model 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Utility Patents</td>
<td>0.143** (2.99)</td>
<td>0.0977* (2.13)</td>
<td>0.101* (2.16)</td>
<td>0.0715* (1.72)</td>
<td>0.0699* (1.69)</td>
</tr>
<tr>
<td>Logged Revenue of Korean Makers</td>
<td>4.184*** (12.34)</td>
<td>4.253*** (14.16)</td>
<td>3.814*** (15.84)</td>
<td>4.003*** (6.96)</td>
<td></td>
</tr>
<tr>
<td>Logged Revenue</td>
<td>-0.261 (-0.74)</td>
<td>-0.286 (-0.95)</td>
<td>0.199 (1.14)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Logged Sales of Knock-off Makers</td>
<td>0.459 (1.36)</td>
<td>0.416 (1.50)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Great Recession (2007-2009)</td>
<td>2.120* (1.79)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of Tread Design Infringements Per Year</td>
<td>0.446 (1.31)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TRIPS Agreement Implementation</td>
<td>-6.243*** (-7.08)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>End of Klepperian Oligopoly ( - 1990)</td>
<td>0.122 (0.03)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>3.742*** (4.53)</td>
<td>-57.05*** (-10.42)</td>
<td>-55.60*** (-9.15)</td>
<td>-55.59*** (-9.66)</td>
<td>-59.84*** (-16.47)</td>
</tr>
<tr>
<td>Observations</td>
<td>854</td>
<td>806</td>
<td>797</td>
<td>797</td>
<td>797</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.051</td>
<td>0.493</td>
<td>0.499</td>
<td>0.519</td>
<td>0.549</td>
</tr>
<tr>
<td>F</td>
<td>8.927</td>
<td>87.85</td>
<td>76.48</td>
<td>99.26</td>
<td>457.1</td>
</tr>
</tbody>
</table>

$t$ statistics in parentheses  
* $p < 0.10$,  * $p < 0.05$,  ** $p < 0.01$,  *** $p < 0.001$

Table 2. 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

<table>
<thead>
<tr>
<th></th>
<th>[Advanced Makers] Panel OLS Regression</th>
<th>[Emerging Makers] Panel OLS Regression</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Utility Patents</strong></td>
<td>0.0564</td>
<td>0.215</td>
</tr>
<tr>
<td></td>
<td>(1.34)</td>
<td>(1.60)</td>
</tr>
<tr>
<td><strong>Logged Revenue of Korean Makers</strong></td>
<td>3.824*</td>
<td>0.735</td>
</tr>
<tr>
<td></td>
<td>(3.39)</td>
<td>(1.61)</td>
</tr>
<tr>
<td><strong>Logged Revenue</strong></td>
<td>2.151</td>
<td>0.0300</td>
</tr>
<tr>
<td></td>
<td>(1.22)</td>
<td>(0.85)</td>
</tr>
<tr>
<td><strong>Logged Sales of Knock-off Makers</strong></td>
<td>0.597</td>
<td>0.0482*</td>
</tr>
<tr>
<td></td>
<td>(1.28)</td>
<td>(2.43)</td>
</tr>
<tr>
<td><strong>Great Recession (2007-2009)</strong></td>
<td>6.911</td>
<td>0.261</td>
</tr>
<tr>
<td></td>
<td>(1.51)</td>
<td>(1.59)</td>
</tr>
<tr>
<td><strong>Number of Tread Design Infringements Per Year</strong></td>
<td>1.183</td>
<td>0.0615</td>
</tr>
<tr>
<td></td>
<td>(1.63)</td>
<td>(1.11)</td>
</tr>
<tr>
<td><strong>TRIPS Agreement Implementation</strong></td>
<td>0</td>
<td>-0.815</td>
</tr>
<tr>
<td></td>
<td>(. )</td>
<td>(-1.46)</td>
</tr>
<tr>
<td><strong>End of Klepperian Oligopoly ( - 1990)</strong></td>
<td>-0.526</td>
<td>0.195</td>
</tr>
<tr>
<td></td>
<td>(-0.07)</td>
<td>(0.37)</td>
</tr>
<tr>
<td><strong>Constant</strong></td>
<td>-65.00*</td>
<td>-11.63*</td>
</tr>
<tr>
<td></td>
<td>(-3.24)</td>
<td>(-1.78)</td>
</tr>
<tr>
<td><strong>Observations</strong></td>
<td>203</td>
<td>594</td>
</tr>
<tr>
<td><strong>R^2</strong></td>
<td>0.593</td>
<td>0.146</td>
</tr>
<tr>
<td><strong>F</strong></td>
<td>1152.6</td>
<td>17.91</td>
</tr>
</tbody>
</table>

*t statistics in parentheses
+ p < 0.10, * p < 0.05, ** p < 0.01, *** p < 0.001

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

<table>
<thead>
<tr>
<th></th>
<th>[Earlier than 1993]</th>
<th>[Since 1993]</th>
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<tr>
<td></td>
<td>Panel OLS Regression</td>
<td>Panel OLS Regression</td>
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<tr>
<td>Utility Patents</td>
<td>-0.168*</td>
<td>0.0673*</td>
</tr>
<tr>
<td></td>
<td>(-2.55)</td>
<td>(1.96)</td>
</tr>
<tr>
<td>Logged Revenue of Korean Makers</td>
<td>1.695***</td>
<td>4.463*</td>
</tr>
<tr>
<td></td>
<td>(17.98)</td>
<td>(2.57)</td>
</tr>
<tr>
<td>Logged Revenue</td>
<td>-11.09**</td>
<td>0.160</td>
</tr>
<tr>
<td></td>
<td>(-3.61)</td>
<td>(0.87)</td>
</tr>
<tr>
<td>Logged Sales of Knock-off Makers</td>
<td>0.237</td>
<td>0.362</td>
</tr>
<tr>
<td></td>
<td>(1.25)</td>
<td>(1.37)</td>
</tr>
<tr>
<td>Great Recession (2007-2009)</td>
<td>0</td>
<td>1.767*</td>
</tr>
<tr>
<td></td>
<td>(.</td>
<td>(1.95)</td>
</tr>
<tr>
<td>Number of Tread Design Infringements Per Year</td>
<td>-5.792</td>
<td>0.257</td>
</tr>
<tr>
<td></td>
<td>(-1.76)</td>
<td>(1.36)</td>
</tr>
<tr>
<td>TRIPS Agreement Implementation</td>
<td>0</td>
<td>-5.750**</td>
</tr>
<tr>
<td></td>
<td>(.</td>
<td>(-2.81)</td>
</tr>
<tr>
<td>End of Klepperian Oligopoly ( - 1990)</td>
<td>3.897</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(1.45)</td>
<td>(.</td>
</tr>
<tr>
<td>Constant</td>
<td>123.3**</td>
<td>-66.92*</td>
</tr>
<tr>
<td></td>
<td>(3.46)</td>
<td>(-2.42)</td>
</tr>
<tr>
<td>Observations</td>
<td>53</td>
<td>744</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.683</td>
<td>0.176</td>
</tr>
<tr>
<td>F</td>
<td>697407.2</td>
<td>3.337</td>
</tr>
</tbody>
</table>

$t$ statistics in parentheses 

$^{*}p < 0.10, ^{*}p < 0.05, ^{**}p < 0.01, ^{***}p < 0.001$

### Appendix 1. Number of Design Patents for Global Tire Makers in 1975 – 2014

<table>
<thead>
<tr>
<th>Period</th>
<th>Goodyear</th>
<th>Bridgestone</th>
<th>Michelin</th>
<th>Continental</th>
<th>Pirelli</th>
<th>Cooper</th>
<th>Sumitomo</th>
<th>Toyo</th>
<th>Yokohama</th>
<th>Hankook</th>
<th>Kumho</th>
<th>Nexen</th>
<th>Cheng Shin</th>
<th>5-Year Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1975-1979</td>
<td>35</td>
<td>33</td>
<td>28</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1980-1984</td>
<td>52</td>
<td>93</td>
<td>46</td>
<td>0</td>
<td>8</td>
<td>2</td>
<td>47</td>
<td>0</td>
<td>7</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1985-1989</td>
<td>92</td>
<td>84</td>
<td>44</td>
<td>0</td>
<td>20</td>
<td>0</td>
<td>139</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1990-1994</td>
<td>223</td>
<td>77</td>
<td>106</td>
<td>7</td>
<td>13</td>
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<td>62</td>
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