A longitudinal study of MNE innovation: the case of Goodyear

Vittoria Giada Scalera
Department of Management, Economics and Industrial Engineering, Politecnico di Milano, Milano, Italy
Debmalya Mukherjee
Department of Management, The University of Akron, Akron, Ohio, USA
Alessandra Perri
Department of Management, Ca'Foscari University of Venice, Venice, Italy, and
Ram Mudambi
Department of Strategic Management, Fox School of Business, Temple University, Philadelphia, Pennsylvania, USA

Abstract

Purpose – The purpose of this article is to provide insights into the innovation trajectory, and knowledge pipelines of mature industry multinational enterprises (MNEs). The ability to innovate constantly amidst a turbulent and competitive environment is often the key force behind MNE survival and dominance.

Design/methodology/approach – This study conducts an in-depth longitudinal study of the Goodyear Tire and Rubber Company, a global manufacturing company in the tire and rubber industry. The findings are based on USPTO patent and trademark data from 1975-2005.

Findings – The analysis reveals three crucial trends: the major role of continuous investment in innovation in the firm's survival and turnaround; the evolution of the firm's innovation network from a headquarters-centric model toward more geographical dispersal; and the changing mix of innovation from traditional "hard" science-based research toward a greater emphasis on "softer" competencies in design and trademarks. This third trend, in particular, opens up important new avenues for research on MNE innovation practices.

Originality/value – This study integrates historical analysis of a single firm in the context of its changing industry environment. The historical analysis is enriched by a detailed longitudinal quantitative analysis using a variegated dataset of patents and trademarks to investigate innovation.

Keywords Longitudinal study, Multinational enterprises, Firm resilience, Global tire industry, Innovation trajectory, Upstream and downstream innovation

Paper type Research paper

Introduction

Multinational enterprises (MNEs) – organizational entities configured through globally scattered subsidiary units – often use innovation to create new markets and to mitigate threats stemming from their rivals in a highly complex and uncertain global marketplace (Cantwell and Mudambi, 2005, 2011). In fact, leveraging knowledge and competencies across space and time to spur innovation has been recognized as the next frontier in the international business (IB) literature (Mudambi and Swift, 2011).

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However, the pathway to innovation is not straightforward. MNEs face a particularly difficult challenge in this respect. By definition, these companies operate in multiple countries. Thus, they experience threats emanating from competitive actions of rival MNEs as well as from local firms.

Traditionally, R&D has remained among the least internationalized and most centralized value chain activities of many MNEs (Huggins *et al.*, 2007; UNCTAD, 2005). However, an increasing number of firms have begun to recognize the potential of globally dispersed knowledge clusters and have set up competence-creating global innovation centers in such locations (Andersson *et al.*, 2002; Cantwell and Mudambi, 2005, 2011; Lehrer and Asakawa, 2002). Similarly, while in the past the upstream end of the innovation value chain (i.e. research and design) was considered to be the main source of value-added over the last few years there has been increasing recognition of the central role played by downstream innovation (i.e. innovation arising from marketing knowledge and capabilities) (Mudambi, 2008). Accordingly, closely studying the innovation trajectory at both ends of the value chain can inform IB theorists and practitioners about the organization of MNE activities over time and space (Mudambi and Swift, 2011).

While there is considerable research on the global dispersal of R&D activities of MNEs, very little of this research takes a longitudinal perspective. Further, there is little research that simultaneously examines MNE innovative activities at both ends of the value chain. To fill this crucial void in the IB literature, this paper explores the innovation trajectory of a major US-based MNE operating in a dynamic competitive environment, the Goodyear Tire and Rubber Company. This enables us to address three interrelated research questions:

RQ1. What was Goodyear's innovation trajectory in the face of turbulence in its external environment?

RQ2. How has the geography of Goodyear's innovative activity changed over time?

RQ3. How have the upstream and downstream ends of Goodyear's innovation value chain evolved over time?

To answer these questions we rely on a longitudinal dataset of utility patents, design patents and trademarks drawn from the US Patent and Trademark Office (USPTO). These research questions, their respective conceptual underpinnings and the major findings of this study are presented in Table I.

The context of our study is compelling for several theoretical and practical reasons. First, traditional models of innovation and strategy posit that R&D efforts tend to focus on (exploratory) product innovation during an industry's early years followed by (exploitative) process innovation during maturity (Abernathy and Utterback, 1978). However, as the technology threshold rises, firms may continue to pursue exploratory innovation as they "make the leap" to newer generations of a product (Mudambi and Swift, 2014). Second, over the past several decades, MNEs in advanced economies, like the USA, have come under increasing pressure from imitators in emerging market economies. Little is known about whether and how MNEs in advanced economies change their models of innovation in response to these threats. The research questions in this paper address both these critical issues.

Table I.
Summary of research design and findings

Research question	Conceptual underpinnings	Major findings
RQ1: Innovation trajectory	Innovation as the key to the firm's resilience	Continuous investment in innovation Increased modularity
RQ2: Geography of innovation	Geographic distribution of innovation	Leverage on foreign innovative capabilities
	Linkages between MNE headquarters and foreign subsidiaries	Competence-creating subsidiary Positive spillover on the local economy
RQ3: Value chain evolution	Upstream and downstream innovations	Increasing role of design Complementary function of design and marketing knowledge for differentiation

The analysis also allows us to illustrate the idea of *resilience* as a firm-specific characteristic in the face of a turbulent environment. The survival and turnaround of Goodyear is more striking when we delve deeper into the industry context. Around 1970, the five biggest US tire manufacturers held 80 per cent of their domestic market. By 1980, this dominance was under tremendous pressure, and, by the early 1990s, the extant tire oligopoly had completely disappeared. Uniroyal and BFGoodrich had pooled their tire operations in a joint venture subsequently sold to France's tire giant, Michelin. The Japanese MNE Bridgestone acquired Firestone and Germany-based Continental acquired General Tire. Among the big five, only Goodyear remained independent.

From a theoretical slant, we heed the call for papers examining the local context in global business (Meyer *et al.*, 2011). Most research in the domain of MNE innovation has focused on location-specific intangible resources and knowledge attributes that attract firms to relocate their value chain activities to foreign locations (Graf and Mudambi, 2005). In addition, most extant research has concentrated on examining relocation decisions with regard to low value-added peripheral activities as opposed to high value-added functions such as R&D. Thus, with some exceptions (Jensen and Pedersen, 2011; Rugman *et al.*, 2011), there is a distinct paucity of research on how firms approach high value-added activities, such as R&D, organize their global value chain and create value while remaining rooted in their local cluster (Kumar *et al.*, 2009; Mudambi, 2008; Mukherjee *et al.*, 2013). Our analysis is one of the first to attempt a joint analysis of an MNE's R&D re-configuration and local cluster evolution in an in-depth longitudinal study.

Finally, from a methodological perspective, the longitudinal analysis of a single company provides us with a laboratory to understand the dynamics of the interaction between a company's external environment and its strategic choices. In addition, we use a blend of conventional business history and industrial dynamics, complemented by rigorous patent and trademark data analysis, all within an overarching IB framework. This blended approach is in accordance with the call for using historical analysis to better capture the evolution of firms' strategic choices in the context of a dynamic environment (Buckley, 2009; Casson, 1986, 1997; Jones and Khanna, 2006; Morck and Yeung, 2007; Wilkins, 1996). Indeed, by adopting this novel integrated analytical approach, we hope to stimulate further scientific conversation along this line of inquiry in the fields of IB and management (Birkinshaw *et al.*, 2014).

The paper begins with a short overview of the evolution of MNE R&D strategy that gives rise to competence-creating subsidiaries and global centers of excellence. The next section addresses changes in the global business environment that have given rise to more dispersed R&D networks for MNEs. Then, following a discussion of the research methodology, the study findings are discussed in the context of the research questions. The paper concludes with theoretical and managerial implications and further research directions.

MNEs, innovation and the evolution of innovation networks

While "entrepreneurship theory has become a confusing mix of different elements, plagued by misunderstanding and disagreements" (Casson, 2014, p. 8), at its root is the idea that it involves using judgment to grasp perceived opportunities characterized by Knightian uncertainty. "Corporate entrepreneurship" (Guth and Ginsberg, 1990, p. 5) underlies the production of innovative outputs by established firms, and these are the basis of strategic renewal. In other words, the exhibition of resilience in the face of changes in its external environment is a firm-level capability stemming from corporate entrepreneurship. Such firms are able to maintain innovative outputs when opportunities arise, even during periods of weak financial performance (Mudambi and Swift, 2014). This capability is particularly important in multinational firms that face turbulence in a wide range of markets, but also have innovative opportunities arising from multiple contexts (Meyer *et al.*, 2011).

Three interrelated streams of IB literature analyze the processes whereby MNEs benefit from globally dispersed R&D activities. Hymer (1976) argues that the internationalization process of the firm is determined by leveraging firm-specific advantages into a bigger market. Internalization theory argues that MNEs make decisions regarding international intra-firm activities on the basis of the associated transactions costs (Buckley and Casson, 1976, 1993). The eclectic paradigm contends that firms internalize ownership- and location-specific advantages in foreign locations (Dunning, 1977). Although these perspectives view the MNEs from different (but related) vantage points, all three underscore the importance of hierarchy and control. This may be taken to imply that high value activities, such as R&D, should be kept close to MNE headquarters. Early IB literature, both theoretical and empirical, developed the *hub and spoke* model of MNE organization in which knowledge and innovation flowed from the central headquarters to peripheral subsidiaries. Later work emphasized the significance of a multi-hub differentiated network model in which each entity of an MNE creates new knowledge drawing from its own external environments (Bartlett and Ghoshal, 1990; Ghoshal and Nohria, 1997).

The local roots of an MNE play a crucial role in the development of competencies and knowledge assets as well. Specifically, the strong local linkages help the MNE establish "the home base of the MNE international competitiveness by drawing on the home country location-bound assets" (D'Agostino and Santangelo, 2012, p. 253). Indeed, studies exploring this area of research have underscored the importance of MNE home location as a key source of tangible and intangible assets that can be successfully exploited on a global scale (D'Agostino and Santangelo, 2012; Rugman and Verbeke, 2004). Empirical evidence focusing on sub-national locations shows that there is a link between the technological capacities of the home region and the innovativeness of an

MNE that has its headquarters in that region (Cantwell and Iammarino, 2003; Santangelo, 2000).

Similarly, foreign subsidiary embeddedness in host locations enables the entire system to benefit from host country location-bound knowledge assets because the subsidiary assimilates and applies new external knowledge, and then transfers it within the MNE network (Andersson *et al.*, 2002; Mudambi *et al.*, 2013). Thus, the innovation centers or offshore subsidiaries influence the conversion of location-bound knowledge assets into ownership advantage for the whole MNE (D'Agostino and Santangelo, 2012; Rugman and Verbeke, 2001). The contribution of foreign R&D units in creating new technological competence at home through the leveraging of host-location specific knowledge assets is also well-documented in the literature (Cantwell and Mudambi, 2005; Rugman and Verbeke, 2001).

Building a foreign innovation network with strong local roots

Collectively, this body of literature proposes that MNEs and their networks of subsidiaries and R&D centers evolve over time and space. Many modern MNEs possess competence-creating subsidiaries – entities that have been selected by headquarters for the creation of distinct new knowledge in specific fields (Cantwell and Mudambi, 2005; Forsgren *et al.*, 2000). Such innovation centers are part of larger MNE networks that aim to source global human capital and establish linkages with partner companies and specialized suppliers with superior capabilities (Adenfelt and Lagerström, 2008). They engage in extensive high value-added research, scan technological developments in foreign markets and may enrich the technological capabilities of the focal firm by providing access to foreign talent bases (Lehrer and Asakawa, 2002; Reger, 2004).

Researchers agree that this trend will continue as firms worldwide continue to disperse their global value chains over multiple locations (Cantwell and Mudambi, 2000; Contractor and Mudambi, 2008; Kumar *et al.*, 2009) and the human talent required to perform these complex tasks will need to be sourced globally (Kedia and Mukherjee, 2009). Such instances are abundant in manufacturing as well as in service industries. For instance, Goldman Sachs set up a back-office service center in Bangalore in 2004 with 250 people to primarily provide technology and analytical research support to its global operations (Lampel and Bhalla, 2008). Today, the center is the firm's third-largest office, employing more than 1,200 people, including software designers, and increasingly highly skilled analysts who produce modeling and other data that appear in Goldman research reports. Similarly, Shell operates five offshore captive R&D centers located in Malaysia, UK, Poland, the Philippines and Guatemala. These examples are archetypal – today virtually all major MNEs have significant foreign R&D centers. The core competences of these centers may be grounded in more specialized capabilities that are combined with unique local resources at different locations. Thus, globalization of these centers "may locate sales close to markets, production facilities where costs are lowest, logistics units in a transportation hub or R&D units in a technology cluster" (Meyer, 2006).

The choice of location in relocating or expanding R&D units is not a straightforward one. Each location presents a different combination of strengths and weaknesses, and MNEs often respond by spreading their R&D units over a broader and balanced portfolio of regions and countries (Vestring *et al.*, 2005). The national institutional systems (e.g. educational systems and industry systems) shape distinct trajectories of differential knowledge development (Bartholomew, 1997; Hansen and Løvås, 2004). Considering this variety, MNEs are inclined to enlarge the scope of geographical diversity to expand their technological dimensions and increase the likelihood of new combinations that can generate innovation.

In summary, for MNEs, the globalization of R&D and innovation that translates into the emergence of centers of excellence or research hubs around the world is a strategic response to the globalization of markets, increased competition, technological advancements and the emergence of high-quality human capital in many new locations around the world. To further explore how such factors drive an MNE's global connectivity, internationalization of R&D and innovation outputs, we conducted a longitudinal study of Goodyear's innovation activities over time and space.

Research methodology

In-depth single-company case studies help develop theories and are particularly suitable for understanding phenomena that are dynamic in nature (Eisenhardt, 1989). In addition, a longitudinal case study can often better capture firm dynamics over time (Pettigrew, 1990; Siggelkow, 2007). In fact, it has been argued that such in-depth case studies enable researchers "to get close to the theoretical constructs and causal forces of interest" (Joseph and Ocasio, 2012, p. 637). To this end, in this study, we adopt a blended approach that integrates historical analysis of a single firm in the context of its changing industry environment. Moreover, we buttress this historical analysis with a detailed longitudinal quantitative analysis of patents and trademarks filed by the focal firm. In so doing, we embrace the intellectual movement that calls for bringing "history back into IB" (Buckley, 2009; Casson, 1986, 1997; Jones and Khanna, 2006; Morck and Yeung, 2007; Wilkins, 1996). Scholars have successfully employed this method in the extant MNE literature (Sun, 2009).

Patents and trademarks as proxies for innovation

To explore Goodyear's innovative activity, we employed two types of data, namely, patents and trademarks. Patents represent an established proxy for innovation, as widely asserted by prior research in this field (Griliches, 1990). We included in our analysis both utility and design patents, which in our research framework represent two different aspects of upstream innovation. The USPTO (2005) clarifies that:

> […] "utility patent" protects the way an article is used and works, while a "design patent" protects the way an article looks. The ornamental appearance for an article includes its shape/configuration or surface ornamentation applied to the article, or both.

Searching for sources of innovation is a problem-solving activity (Nelson and Winter, 1982); that is, firms solve problems by combining knowledge elements and, thus, create new products. Because a patent describes a technical problem and its solution, patent data offers a detailed and consistent chronology of how firms solve problems and the manner in which they search for solutions. A patent creates a legal title that indicates the name of the inventors or inventing firm, the relevant technology types (Griliches, 1990) and the technological antecedents of the focal knowledge.

Like patents, trademarks are intellectual property rights (IPRs). They confer on the owner the exclusive right to utilize a mark to identify goods or services, or monetize its value by means of licensing. The USPTO (2005) describes a trademark as "a word, phrase, symbol or design, or a combination thereof that identifies and distinguishes the source of the goods of one party from those of others". Due to the increasingly crucial role of innovation for economic growth and the consequent need to improve our assessments of innovation performance, researchers have proposed the use of trademarks as an additional indicator of firms' innovative activity (Mendonça *et al.*, 2004). In fact, as they are costly to register and maintain[1], trademarks are likely to reflect meaningful events in a company's life (Giarratana and Torrisi, 2010). Although these events are only partially associated with the introduction of new offerings on the marketplace[2], trademarks are critical aspects of marketing innovations, as they help companies accomplish the objective of differentiating their products and services from those offered by other firms (Mendonça *et al.*, 2004). In summary, trademarks reflect the outcome of a firm's marketing efforts and competencies (Fosfuri and Giarratana, 2009). Therefore, by analyzing the dynamics of a firm's trademarking activity, we can gain considerable understanding of its innovative capabilities in marketing. Accordingly, we use trademarks as an indicator of firms' downstream innovation output.

Data sources

The USPTO provides access to both patent and trademark data. The timeframe for the research is 1975-2005. Trademark data is accessible through the USPTO online TESS database, which allows for Boolean search. In addition, in 2013, the USPTO released a comprehensive dataset (the Trademark Case Files Dataset) covering 7.4 million trademarks filed or registered between January 1870 and January 2014. Since it contains detailed information on trademarks – such as trademark characteristics, ownership, classification[3], renewal and other significant events – we employed this dataset to collect the universe of trademarks filed by Goodyear between 1975 and 2005. For each year in our observation window, we reconstructed the company's trademark portfolio by accounting for new registrations, changes in marks' ownership and for trademarks that had been cancelled, abandoned or expired.

USPTO patent data includes the classification of the invention, the location of inventors and the ownership of the intellectual property (IP) created by the invention. The challenges involved in the collection of patent data are well-documented. Some of the difficulties have been lessened by the accessibility of public databases, such as that of the National Bureau of Economic Research (NBER) (Hall *et al.*, 2001). We relied on the Harvard Patent Network Dataverse (DVN), which is a product of the Harvard Business School and the Harvard Institute of Quantitative Social Science (Li *et al.*, 2014). The DVN work draws on both raw data from the USPTO and processed data from the NBER set to create disambiguated patent-inventor observations from 1975 through to 2010 (Li *et al.*, 2014). The full database contains information on over 9.1 million patent inventors, comprising more than 1.3 gigabytes of information (Li *et al.*, 2014).

Accessing the DVN dataset represents a valuable first step. From this data, we extracted Goodyear patents filed between 1975 and 2005. The DVN database has a substantial number of missing design patents for the period 1975-1998. Hence, we complemented the DVN database by extracting this information directly from USPTO to have the universe of Goodyear design patents.

Inventor innovation network and local context

Knowing the name of the inventors, their locations and the number of their patents, provides a rich and personal view of the drivers of innovation. Within the patent data set, we can identify the inventors who lived in Akron (and more generally in Ohio) and also those who lived elsewhere in the USA and in foreign countries. This helps us highlight the geographical distribution of Goodyear's inventors and map their relationship with the two main innovation centers of the firm. In particular, we classify Goodyear patents as Akron- or Luxembourg-based if at least one listed inventor was located near the Akron or Luxembourg innovation center, respectively. These data can be used to assess the levels of local and global collaboration on research, and identify the major differences and commonalities between the innovative activities carried out in Goodyear's R&D centers.

An overview of the Goodyear tire and rubber company

Headquartered in Akron, Ohio, USA, Goodyear was founded by Frank and Charles Sieberling in 1898. Currently, it is the third largest manufacturer of tires in the world after Bridgestone and Michelin and the biggest in North and Latin America, with around 72,000 employees worldwide. Currently, Goodyear serves most regions in the world with 52 plants in 22 different countries. Apart from tires, Goodyear also produces rubber-based industrial products.

The company grew rapidly in its early years, and by 1916, was the largest tire company in the world. By 1960, it had a one-third share of the domestic market (French, 1987; Sull *et al.*, 1997). Innovative activities of the company were spurred by a series of external events. During World War I, Goodyear supplied airships and balloons to the military, and in the 1970s, Apollo 14 mission, the company supplied the first tires on the moon. Currently, Goodyear has three innovation centers. The Goodyear Innovation Center at Akron, Ohio, (GIC*A) was started in 1978 and is the main R&D center of the company. It coordinates with the other centers and oversees the R&D efforts in the North and South American markets. GIC*A is involved in core tire technology innovation and serves as new product engine for Goodyear. The Goodyear Innovation Center in Colmar-Berg, Luxembourg, (GIC*L) conducts R&D activities related to building and testing of new tires for passenger cars, light and medium trucks and farm vehicles for the European, African and Asian-Pacific markets. A team of 900 engineers, scientists and technicians work on new raw materials, tread designs and on rubber quality. One of the innovation objectives of this center is to obtain original equipment approval on their tires from vehicle manufacturers. Finally, the development center in Hanau, Germany, was inherited as part of its acquisition of Dunlop in 1997. The innovation activities of the Hanau center are closely integrated with the Colmar-Berg center in Luxembourg and, thus, have been included as part of the Luxembourg-based innovations for analytical purposes.

Our period of study (1975-2005) witnessed major turbulence in the global tire industry. Therefore, at this point, it is important to understand the major dynamics of the tire industry and the local and the global context in which Goodyear has operated.

The dynamics of the USA tire industry and the Akron region cluster

The tire industry in the USA was centered in Akron, Ohio, to such an extent that it used to be called the "rubber capital of the world". All the major tire manufacturing companies had a presence in this cluster. Four of the five biggest tire companies in the world – namely, Goodyear, BFGoodrich, General Tire and Firestone – had their headquarters in Akron. Collectively, plants in the Akron cluster produced 65 per cent of the tires manufactured in the USA (Sull, 2001).

These companies were responsible for the major tire industry–related innovations in the early part of the twentieth century. Between 1900 and 1937, these companies generated a slew of innovations in raw materials and tire design, which considerably increased overall tire performance (Sull, 2001). For instance, the average tire manufactured in 1900 lasted approximately 500 miles, while the typical tire produced in the mid-1930s lasted more than 20,000 miles (Sull *et al.*, 1997). The early innovations were not limited to tire performance. The average price of a tire declined by over 80 per cent between 1913 and 1933 (USA Bureau of Labor Statistics, 1934, cited in Sull, 2001). Such radical improvement in the product and process resulted from a steady stream of incremental innovations in design that cumulatively increased tire performance and production.

While changes in tire design offered the potential for improved performance, realizing this potential required a host of innovations in complementary technologies (Rosenberg, 1979), especially the raw materials needed to construct a tire, i.e. chemical additives, steel wire and textiles. Thus, the Akron region became a hub of related industries as well. The region was further fueled by the flourishing steel industry in Pittsburgh, Pennsylvania, and the automotive industry in Detroit, Michigan. Consequently, Akron remained an important and highly concentrated industry cluster, and the tire companies maintained strong local roots.

The local roots of these companies went beyond the location of their headquarters. The top executives of Goodyear, Firestone, BFGoodrich and General Tire had deep local connections. Sull (2001, p. L2/L3) describes this connection succinctly:

> An Akron native led Goodyear as either president or chairman of the board continuously between 1940 and 1983. In 1972, between one-third and two-thirds of the executives at Goodyear, Firestone and General Tire were Akron natives; between one-third and one-half had risen through the ranks of the domestic tire industry; and a significant percentage had followed in their fathers' footsteps as executives in the same company. Industry insiders referred to these homegrown executives as "gum-dipped," in reference to the production process developed by Firestone in the 1920s in which fabric strips were dipped in rubber and thereafter took on a uniform shape. Most of these executives lived within a five-block radius of one another, socialized at the Portage Country Club and relied on the Akron Beacon Journal for their news.

Goodyear's competitors and technological turbulence in the tire industry

The Akron industrial cluster and the Akron-based tire MNEs retained their dominance until the 1960s. However, they faced an unprecedented competitive shock in the mid-1960s known as the "radial revolution" (Sull *et al.*, 1997) from the French tire company, Michelin. Radial tires had significantly improved performance. Sull (2001, p. L5) reports that radial tires:

> […] reinforced the tire's plies with steel wire, increased the tire's useful life from 20,000 to 40,000 miles, reduced a driver's gasoline consumption by 5-10 per cent, improved handling and dramatically reduced the likelihood of a catastrophic tire failure, known as a "blowout".

These pioneering features helped Michelin capture a significant portion of the European market and the Akron-based companies also lost significant market share in a continent they had dominated since the end of the First World War.

Goodyear's major rivals – Firestone, Uniroyal, General Tire and BFGoodrich – responded differently when faced with the "radial innovation". Sull *et al.* (1997) describe these different responses in detail. As the new radial technology offered substantial benefits over the prevailing "bias ply" technology, major automakers in the Detroit area embraced the change and adopted radial tires. Sull *et al.* (1997) note that while the improved radial technology was profoundly beneficial for car owners, the change proved disastrous for the tire manufacturers. Making radial tires required huge capital expenditure because existing manufacturing infrastructure did not support the switch and building greenfield plants meant added costs. Notwithstanding these difficulties, Firestone, Uniroyal and General Tire continued to invest in building new plants that could produce radial tires. The then Goodyear CEO and Chairman at that time, Charles Pilliod, was a huge advocate of radial tires and the company invested "every penny" in converting the existing plants to support the new technology (Sull *et al.*, 1997). Unfortunately, despite these huge investments, the Akron companies continued to report very weak earnings (Sull, 1999; Sull *et al.*, 1997). This led to plant closures in the Akron area and in other parts of the USA. From the early to the mid-1980s, all five tire makers faced acquisition threats. Goodyear remained independent by "putting its oil and aerospace businesses on the block, and borrowing heavily to buy back over half its stock" (Sull *et al.*, 1997, p. 494). BFGoodrich, after forming a joint venture with Uniroyal, sold its tire business to the latter and left the tire industry. Uniroyal was later acquired by Michelin. Firestone did not survive either, as the Japanese giant Bridgestone acquired it and gained its network of 1,500 automobile service centers in the USA (New York Times, 1988). During the same period, General Tire sold its tire business to the German firm, Continental.

Thus, with the exception of Goodyear, none of the Akron-based tire companies survived the shocks they suffered in the radial revolution. During the 1970s, they all experienced catastrophic declines. The Akron region also witnessed major decline. The waning of steel, auto and tire production in the 1970s in this region has been attributed to internal factors such as local mismanagement and high union labor costs (Braunerhjelm *et al.*, 2000) and external factors such as globalization and overseas competition.

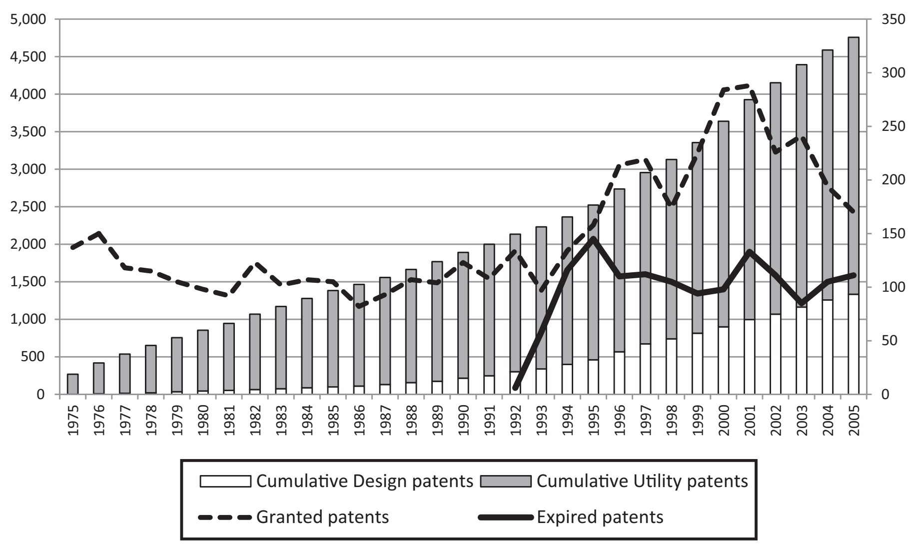
The transition from bias-ply technology to radial design for passenger tires and the changing fortunes of one of America's best known industrial centers provide a rich historical example of environmental and technological changes that had a profound impact on incumbent firms in a mature industry. These changes in the industry provide the backdrop to our analysis of Goodyear's patents. Below, we dig deeper into the innovation responses of Goodyear during the 1975-2005 period and attempt to delineate how global innovation connections and local context spurred a revival (Bathelt *et al.*, 2004). In particular, unlike its Akron-based competitors, Goodyear maintained its innovative output even in periods of weak financial performance, displaying the resilience that enabled it to remain the sole survivor in the formerly dominant industry cluster.

Major findings

RQ1. What was Goodyear's innovation trajectory in the face of turbulence in its external environment?

Figure 1 depicts the cumulative number of utility and design patents over the period 1975-2005, combined with the number of new patent applications[4]. The cumulative number of patents steadily increases throughout these years, demonstrating the firm's consistent commitment to technological progress. The trend of new patent applications is also mainly positive, although it shows a slight decline in the latter part of the 1970s and in the early 1980s. It could be argued that the slowdown of Goodyear's innovation in this period is at least partially related to the complexity of catching-up with the radial breakthrough. Throughout the 1980s, the number of patent applications remained relatively constant, in line with the findings of previous studies of decline in the US-based tire industry over this period (Sull, 2001). In 1995, the innovative performance of Goodyear took off as the firm sought to revive its firm's knowledge-based capabilities by renewing its patent portfolio, which by that time had started to shrink due to the increasing number of patents getting close to expiration. Figure 1 shows that from 1996 onwards the number of new patent applications is substantially higher than the number of expired patents, indicating the growth of Goodyear's innovation portfolio. Hence, while its competitors were collapsing in the face of technological changes and takeover threats, the company engaged in the build-up of a solid base of technological capabilities that enabled it not only to react to the major changes spurred by the radial revolution but also to push the technological threshold in its industry.

A comparison between the dynamics of new patent applications and the company's financial performance offers additional insights into the firm-level conditions under which Goodyear's innovation trajectory developed and influenced its competitive advantage. Table II demonstrates that while innovation shows an increasing trend, the company's R&D/Sales ratio remains quite stable, indicating an increase in R&D productivity. Moreover, the positive pace of new patent applications was sustained



Note: *Cumulative design and utility patents and granted patents by application year. Expired patents by expiration year

Figure 1.
Evolution of Goodyear patent portfolio (1975-2005*)

Year	Return on equity	Return on total assets	R&D/Sales	Number of patents[a]
1980	0.103	0.082	0.021	98
1981	0.111	0.084	0.023	92
1982	0.110	0.084	0.027	123
1983	0.112	0.078	0.026	102
1984	0.133	0.092	0.027	107
1985	0.123	0.087	0.031	105
1986	0.038	0.041	0.032	82
1987	0.319	0.128	0.027	93
1988	0.181	0.081	0.028	107
1989	0.099	0.056	0.028	104
1990	−0.018	N/A	0.029	123
1991	0.040	0.037	0.030	108
1992	−0.283	−0.046	0.028	134
1993	0.183	0.073	0.027	97
1994	0.222	0.091	0.028	134
1995	0.201	0.095	0.028	158
1996	0.031	0.051	0.029	214
1997	0.167	0.095	0.029	219
1998	0.191	0.106	0.033	174
1999	0.065	0.112	0.035	225
2000	0.011	0.087	0.029	284
2001	−0.064	0.069	0.027	288
2002	−0.629	N/A	0.027	226
2003	−2.516	0.030	0.023	241
2004	3.846	0.074	0.021	194
2005	3.128	0.080	0.019	170

Notes: Compustat for financial data; USPTO and DVN database for patent data; [a]number of patents by application year

Table II. Goodyear financial and innovation performance (1980-2005)

despite Goodyear's bumpy financial performance. In particular, while the company's return on equity decreased over the years 1998-2003, the number of new patent applications shows an overall positive trend, reaching a peak of 288 patent applications in 2001. Interestingly, the excellent innovative performance reported by the company in the early 2000s is followed by a substantial improvement in the company's financial performance (Table II).

The comparison of the patent production of Goodyear, Bridgestone and Michelin (the three major players in the international tire industry) over the period 1975-2010[5] is useful to put Goodyear's performance in perspective. The analysis reveals that, in terms of patent production, Goodyear was ahead from the very beginning until the late 1980s, producing 40 per cent more than the number of patents granted by the other two major companies. Thus, Goodyear was the innovation leader from the late 1990s until 2010, overcoming Bridgestone, which was the most innovative company in the previous 15 years largely due to the acquisition of Firestone's patent portfolio. Hence, with the exception of the decade following the radial revolution, Goodyear has been the leading innovator in the global industry.

Overall, these findings stress the importance of a consistent commitment to innovation and the role that this plays in MNE knowledge creation, performance and even survival. Over time, Goodyear has been able to develop a global leadership in patent production. This status seems to have afforded the company the ability to successfully face even the most dangerous external threats that have occurred in the global tire industry over a 30-year period. While Akron-based companies dominated the world tire industry in the 1970s, over the years only Goodyear has survived as an independent organization. Like many other companies in the industry, Goodyear was slow in reacting to the radial technological breakthrough. However, contrary to its local competitors, its strong focus on innovation allowed the firm to survive and eventually to push forward the technological frontier of the industry:

RQ2. How has the geography of Goodyear's innovative activity changed over time?

Although R&D tends to be more centralized in the firm's home country compared to other functions, MNEs increasingly organize their innovation network to exploit geographically dispersed knowledge-based resources. Recent research shows that this may happen in combination with the maintenance of strong linkages with the home location (Kumar *et al.*, 2009; Mukherjee *et al.*, 2013). Inventor location has been widely employed by IB scholars to analyze the geography of MNE innovative activity (Lahiri, 2010). To investigate how Goodyear has managed R&D locations over time, we map the geographic locations of its inventors between 1975 and 2005. The analysis shows a concentration of US-based inventors in Akron and nearby cities, demonstrating a local strong cluster effect and the importance of the corporate R&D center.

The company has clearly played a prominent role in the innovativeness of the Akron area. From 1975 to 2005 Goodyear's share of innovation as a percentage of the total innovative output of the Akron region[6] has been consistently higher than 20 per cent, reaching its peak of 35 per cent in the early 1980s. In spite of the decreasing trend that characterizes Goodyear's share of innovation in the late 1980s, starting from 1997, the company steadily accounts for more than 25 per cent of the total patent production of the Akron area.

Although the Akron corporate R&D center has consistently played a critical role in the company's innovation trajectory, Goodyear's knowledge creation is not locally bounded. Accordingly, we notice an increase in the percentage of Goodyear patents that are internationally connected. While at the end of 1979, only 8 per cent of patents were internationally connected, in 2004 almost half (48 per cent) of the patents listed at least one international collaborator and the trend is continually growing.

Analyzing the inventors' locations, it appears that the main foreign inventor location is Europe and, in particular, Luxembourg, which steadily accounts for at least 55 per cent of the total number of foreign inventors starting from the late 1980s. The rest of Goodyear foreign inventors come mainly from Belgium, Japan, France and Germany.

Mapping the other European inventors, we discovered that the majority of them (i.e. Belgian, German and French) are mainly located on the border with Luxembourg, so we can reasonably link them to the Luxembourg innovation center. This innovative activity seems to relate to exploratory product innovations. In addition, we were able to link most other dispersed inventor locations to Goodyear production plants (e.g. Danville, VA; Fayetteville NC; and Birmingham, UK). These innovations are likely to be exploitative process innovations.

Extant literature shows that knowledge created in foreign subsidiaries and R&D centers is a key source of competitive advantage and often helps MNEs to better understand their local markets (Pearce and Papanastassiou, 1999). In this regard, it is interesting to note that the company's innovation and development center in Luxembourg has been consistently productive in terms of patent output, generating on average almost 20 per cent of Goodyear patents. This may well have played a crucial role in supporting Goodyear's competitive position in the European market.

The comparison of patent production between Akron and Luxembourg reveals some interesting distinctions. Goodyear's dependence on HQ-based innovation is diminishing over time; in fact, from 1975 to 2005 the percentage of HQ-based patents decreased from 90 to 50 per cent of the firm's total patents. On the contrary, the share of innovation emanating from the Luxembourg center is steadily growing, representing from 1997 almost 30 per cent of the total Goodyear patent production. The analysis also shows that innovative collaborations between the corporate R&D center and the Luxembourg center (patents with at least one inventor located in Ohio and one in the Luxembourg area) slightly increase over time, accounting for 10 per cent of the Goodyear patent production in 2005. This finding is in line with the stream of IB literature that underscores the importance of competence creating subsidiaries (Cantwell and Mudambi, 2005) and the effect of such entities on the MNE's total innovation output. Overall, our data show that the configuration of the geographic sources of Goodyear's innovation has evolved over time, spanning from a home-centered archetypal model to a more internationally oriented model. This suggests that – along with a consistent innovation capability – the firm has progressively developed the ability to recognize the opportunities for knowledge creation arising from geographically dispersed locations and to set up a proper organization for the exploitation of such opportunities.

Next, we proceed to examine the technological categories of the patents filed from the firm's two main R&D locations. We highlight that patents with inventors based solely in Akron are roughly evenly distributed across the mechanical, chemical and design categories, while the other categories only represent 10 per cent of the total Akron production. The large share of mechanical patents – almost 40 per cent of Goodyear Akron-based patents – can be attributed to the growth of "transportation" industries in the Akron region over the period. Examining the patents with at least one inventor in each of the firm's two R&D centers of Akron and Luxembourg reveals a larger share of design patents. In the patents with inventors based solely in Luxembourg, design patents are by far the most prominent category, representing half of the Goodyear Luxembourg-based patent production. The fact that this subsidiary appears to lead the firm as a whole in this category of innovation suggests that it has achieved competence-creating status.

In spite of the gradual international dispersal of R&D activities, it is important to emphasize the local partnerships of Goodyear and their role in enhancing the talent-base of the company. Akron, proudly known as the "rubber capital of the world" for nearly the entire 20th century, no longer produces tires, but is part of a budding Midwest revival (Weissmann, 2012). It has become a leading global innovator in liquid crystals, polymer science and transportation. As tire manufacturing was phased out, the focus turned to polymers (Carlsson, 2002). The University of Akron (UA) established the first College of Polymer Science and Polymer Engineering and hosts the Goodyear Polymer Center and the National Polymer Innovation Center. Industry-university collaboration in Akron has been directed toward developing a global reputation in polymer science. More than 400 polymer-related firms are now located in Akron. Akron has also built on its role as a transportation hub and the home of the Goodyear Blimp. Firms including Goodyear, Roadway and Lockheed-Martin are creating innovation in several areas of transportation, including motor vehicle production, freight movement and lighter than air technology (City-Data.com, 2014). At the same time, Akron has attracted other global tire makers. The Chinese giant, Triangle group, has established a new research company A3T LLC to undertake rubber research, technology development and licensing by partnering with the UA and the University of Akron Research Foundation (UARF):

RQ3. How do the upstream and downstream ends of the innovation value chain evolve over time?

A firm's innovative activities concentrate at the two ends of the value chain: upstream innovation includes basic and applied research and design, that are responsible for new conceptual development, while downstream innovation encompasses marketing and brand management capabilities (Mudambi, 2008). To investigate the evolution of upstream and downstream innovation at Goodyear, we employ both patent and trademark data. More specifically, while trademarks are used to capture downstream innovation (i.e. the output of companies' marketing knowledge) utility and design patents are used to explore different aspects of upstream innovation.

Figure 2 demonstrates the major technological categories[7] of the Goodyear patents. Patents related to chemical compounds and mechanical processes dominate the innovation scenario. Traditionally, Goodyear had been focused on basic and applied R&D, and the high number of utility patents in mechanical and chemical classes supports this specialization. Nevertheless, from the early 1990s, basic R&D has been increasingly complemented by design innovation. In 1992, the number of design patents takes off, to become a significant component of Goodyear's patent portfolio. Of Goodyear's design patents, 97 per cent are classified in the USPTO category D12 (Transportation), which includes patents claiming ornamental designs for tires (USPTO, 2005). Specifically, the majority of Goodyear's design patents are related to tread design and pattern, which are not only ornamental features but also key technical characteristics determining the performance and life of the product. As a consequence,

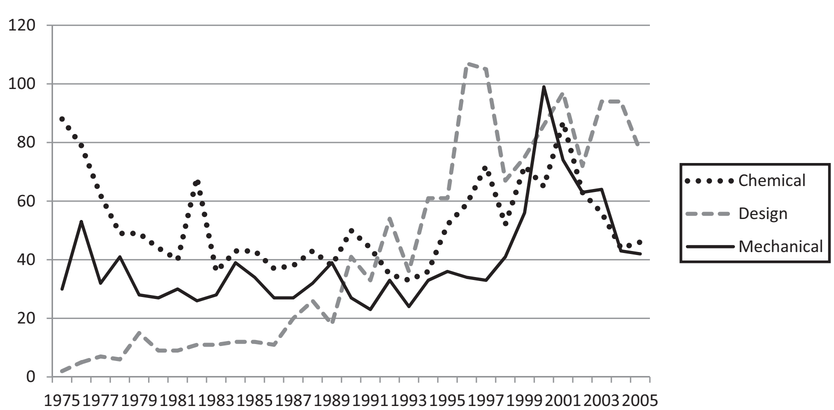


Figure 2.
Main technological classes of Goodyear patents (by application year, 1975-2005)

it appears that Goodyear's design patents are closely linked to its utility patents and represent a transition to a different type of upstream innovation.

However, research and design competences do not represent the only driving forces of competitive advantage in the global tire industry. Brands and marketing capabilities have always played a central role in this context. As highlighted by Figure 3, Goodyear filed for more than 950 trademarks between 1975 and 2005, with a peak of more than 90 trademark applications filed in 2000.

By analyzing the primary classification (i.e. the IC class) of trademarks[8], it appears that most of Goodyear trademarks are associated with the "vehicles" class (012), which accounts for 47 per cent of Goodyear's trademark registrations over the entire period of analysis, followed by the "rubber goods" class (017), which represents 18 per cent of the company's trademarks, suggesting that Goodyear protects its marketing IP mainly in these two product categories. This reflects the distribution of both utility and design patents by technological class.

Because trademarks can be abandoned, cancelled or can expire over time, we also look at the evolution of Goodyear's trademark portfolio by considering only the company's live trademarks. The analysis highlights that the stock of Goodyear's live trademarks is growing considerably between 1976 and 1982, reaching a peak of 200 live trademarks in 1982. After the initial growing trend, the portfolio of Goodyear live trademarks tends to decrease over time. In fact, from 1992 to 2005, the stock of Goodyear's live trademarks is on average less than 85 per year.

Hence, although Goodyear is still actively using trademarks to protect its marketing knowledge (Figure 3), the firm's trademark portfolio is undergoing a process of reconfiguration. Some trademarks have been abandoned or simply not renewed before expiration, and a smaller amount of new trademarks have entered the scene. This may suggest that the company is either trying to consolidate the property rights arising from trademarks, or shifting to a slightly different IP protection strategy. Because obtaining IP protection is costly and companies have a limited amount of resources to allocate to safeguarding their intangible assets, it is arguable that they constantly strive to adjust the composition of their IPRs to changing environmental conditions.

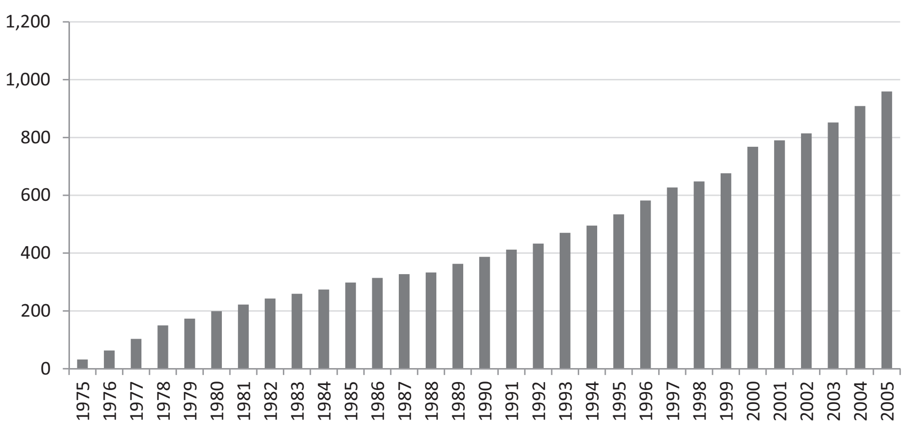


Figure 3.
Cumulative number of Goodyear trademark filings (1975-2005)

Discussion

Research and managerial implications

This research contributes to the burgeoning literature on "local contexts in global business" (Meyer *et al.*, 2011) by tracing the evolution of the innovation processes of a major US-based manufacturing company. More importantly, the settings of this study also allow us to enrich our understanding of a major US "industry cluster". This is especially crucial when we consider the intellectual movement that promotes such industrial clusters as keys to the overall competitiveness of the US economy.

The main findings of this study are consistent with the scholarly perspective that argues that continuous investment in innovation helps firms survive and capture value in the long run. We contribute to the extant literature in several ways. We explore a relatively underdeveloped, implicit but important question pertaining to MNE innovation - how does an MNE's innovation trajectory evolve over time and space? Answering this question is important as it is directly related to firm performance and indirectly sheds light on the viability of "innovation efforts" as a strategic imperative.

We also recognize that such innovation trajectories of MNEs cannot be analyzed in isolation and must be understood within a broader set of environmental variables that are intertwined with the strategic choices made by the focal MNE. We argue that such trajectories grow in parallel with factors such as globalization, technological advancements, increased competition in the domestic and global market and changes in local context. Thus, our findings are consistent with the view that the relocation of high value-added activities should be examined in the context of larger co-evolutionary forces encompassing both the industry and the firm's location profile (Bathelt *et al.*, 2004; Mukherjee *et al.*, 2013).

Interestingly, our analysis of the evolution of Goodyear's innovation network in the context of changing environmental conditions has highlighted the company's strategic choice to increase the geographic dispersion of its innovative activities, but to a limited extent. As we have documented, the organization of Goodyear's high value-added activities has moved from a corporate-centered model, with innovation being concentrated in the home region, to a more geographically distributed network in which European innovation facilities play a critical role. In spite of this transition toward a more international configuration, the company's innovation network has maintained a bi-regional focus, rather than attaining a global reach. This is consistent with the predictions of Rugman and Verbeke (2004), who suggest that MNEs are rarely able to penetrate all regions in the so-called "triad" (i.e. North America, Europe and Asia). Although a higher degree of globalization seems to be possible where the upstream end of the value chain is concerned, the authors call for a re-consideration of the "non-location-bound nature of the MNEs' knowledge base" (Rugman and Verbeke, 2004, p. 6). Goodyear's concentration of innovative activities in two (North America and Europe) of the triad regions is thus consistent with the idea of a "semi-globalized" world (Ghemawat, 2003), in which MNEs need to strive for a balance between complete global integration and national markets fragmentation (Rugman and Verbeke, 2004).

Our analysis of the different dimensions of Goodyear's innovation suggests that, in traditional industries where competition has normally been based on basic and applied R&D, new strategic levers such as design and marketing competencies are becoming increasingly relevant. Because the nature of technical innovation in mature industries is mainly incremental, companies need to find alternative ways of competing and differentiating their offerings on the marketplace. Design and marketing knowledge may provide appropriate complementary resources to develop and sustain long-term competitive advantage through differentiation. Companies may use design to communicate the quality of their offering through the product's physical appearance (Beebe, 2010). On the other hand, marketing competences and trademark protection enhance such distinctiveness by signaling specific product attributes and performance, and by generating association and awareness in the mind of customers (Krasnikov *et al.*, 2009).

Moreover, the rise of design patents and trademarks highlights the shift of design and marketing knowledge from a more tacit to a more codified nature. While in the past, such competencies were less exposed to imitation and much more appropriable, the increasingly global distribution of innovative activities, and the upsurge of new imitative competitors (e.g. rivals from emerging markets) have induced incumbents to improve protection on these assets. Design, in particular, creates a link between innovation and user perception. All the different aspects of a design patent are connected to the same nexus of delivering a better user experience. In the case of Goodyear, design innovation not only improves the look of the tire, but also conveys a better driving experience. Hence, design may enhance drivers' experience both in terms of external appearance and in terms of performance. For example, the Goodyear design patent no. D457130 protecting a new ornamental design for a tire sidewall pattern improves the aesthetics of the tire, while the external pattern and the lettering provide a visible signal of the innovativeness of the product. On the other hand, the Goodyear design patent no. D482319, introducing a new design for the tire tread, enhances the performance of the vehicle under adverse weather conditions, delivering a better experience to the driver. Overall, these insights suggest that the nature of innovation strategy is evolving toward an increasing reliance on design. In particular, it could be argued that a change is occurring in the way that innovation is managed and leveraged, at least in major MNE firms. This opens an entirely new avenue for theory development. More specifically, our study raises interesting questions for technology management theory:

- Does the increasing role of design signal a move by advanced country MNEs to more sophisticated forms of innovation?
- If so, how might such a transition be understood and modeled?

Important implications for managers also emerge from this study. First, we emphasize that successful R&D offshoring often entails making appropriate location choices. Top companies considering R&D offshoring should make their location choices based on potential talent base, presence of an appropriate ecosystem consisting of partner firms, and market growth opportunities in foreign markets. Secondly, managers should also treat global R&D laboratories as potential innovation and strategic growth hubs. These laboratories can serve as conduits of organizational learning and can transfer location-specific knowledge to other centers.

Limitations and future research directions

This study paves avenues for further research in this area. Given the limited generalizability of a single company case study, further research may benefit from large-scale longitudinal studies involving similar industrial companies based in other industrial districts. Future studies may also concentrate on the further development of constructs and measures that capture the sub-processes associated with the contribution of innovation to the resilience of a company. This requires an in-depth understanding of different models of innovation, which may be achieved through qualitative and quantitative enquiries. For instance, future research may concentrate on the unbundling of innovation activities from the headquarters and investigating the impact of increased modularity and flexibility (strategic and operational) on firm value creation and performance.

Our study has the advantage of using a variegated set of data to investigate innovation, among which are trademarks that constitute a relatively underexplored indicator in this field. However, it is worth noting that basic trademark counts can be exposed to biases arising from data consolidation issues (Mendonça *et al.*, 2004). Future studies should refine this measure, for instance by disaggregating trademark data to the level of the brand. A final issue that deserves further attention refers to the creation of consumer value through innovation practices. The potential of innovation to deliver benefits to the focal firm and the local economy is being increasingly explored by the researchers. However, the impact on the customer value has been less explored. Further studies may investigate links between company innovation and the amount of value captured by consumers.

Notes

1. Applicants must, in fact, pay filing and renewal fees, as well as provide proofs that the mark is being actually used in commerce.
2. In fact, trademarks can be obtained regardless of the existence of an underlying innovation.
3. When filing a trademark, applicants are required to indicate the goods and services on which they are willing to use the mark. This indication is the basis for classification of trademarks into specific goods and services categories. The USPTO utilizes two types of classifications, namely, the International Classification of Goods and Services under the NICE agreement, in use since 1973 and serving as the primary classification set, and the US classification, that was employed prior to 1973 and is still maintained as a secondary system (Graham *et al.*, 2013).
4. New patent applications refer to those patents that were applied for and successfully granted in our observation period.
5. Michelin acquired BFGoodrich, one of the Akron tire "majors" in 1988, after which that firm's patent output rapidly declined to zero. BFGoodrich's patent output had been relatively weak, suggesting a relatively low level of innovative output. This underlines the importance of innovation in MNE survival and also suggests that BFGoodrich was acquired for its downstream distribution and brand assets, i.e. to become a competence-exploiting subsidiary (Cantwell and Mudambi, 2005).
6. We measure the innovative output of Akron region extracting USPTO patents whose inventors were located in the Core-Based Statistical Area (CBSA) of Akron. This involved building a new database by matching locations in the DVN patent database with Akron CBSA boundaries, as defined by the US Office of Management and Budget (OMB). We used zip codes to identify inventors located in the CBSA of interest to our study. The result is a dataset of USPTO patents with at least one inventor located in the Akron CBSA.

7. We reclassified the original USPTO primary patent classes using the taxonomy of Hall *et al.* (2001). The original taxonomy includes the following six technology categories: chemical, computers and communications, drugs and medical, electrical and electronic, mechanical and others. Mechanical includes, among other subcategories, "motors, engines and parts" and "transportation". Chemical includes, among other subcategories, "Coating" and "Resins". We complemented the existing classification with an additional category including design patents.
8. It should be noted that more than one primary class can be associated with a single trademark registration.

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Corresponding author
Ram Mudambi can be contacted at: ram.mudambi@temple.edu