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The geography of learning: Ferrari gestione sportiva 1929–2008

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Abstract

This article considers the mechanisms that permit and enhance the movement of highly tacit component (technical) knowledge and geographically sticky architectural knowledge across borders and between clusters and firms. We address a number of critical research questions that relate to intra- and inter-locational knowledge transfer. We use a theory-driven, longitudinal, single case study to develop a conceptual framework to examine and describe how shifting the geography of knowledge sourcing can facilitate architectural change by following the transformation of one business unit within a specialist global organization through a series of evolutionary steps that involved internalizing new component knowledge from other firms and locations, transforming the company's architectural knowledge through various transactions with firms and individuals from a foreign cluster, and eventually radically transforming the concept of the firm and its focus. We close by generalizing this model to address the fundamental processes of the spatial aspects of organizational learning.

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1. Introduction

The spatial development of knowledge is of enduring interest to scholars of economic geography and international business (Wood and Reynolds, 2011). In particular the process of innovation and its engagement of dispersed networks provides an important basis for the creation of competitive advantage both at the firm and the regional level (Jenkins and Tallman, 2010; Bessant et al., 2012). The globalization of the world economy has shifted the focus of knowledge development away from the local to concern for knowledge transfers over what are often long distances (Bathelt and Henn, 2014). A variety of studies have addressed the flow of technology across borders (Almeida et al., 2002; Feinberg and Gupta, 2004), often by considering changes in patenting patterns (Almeida et al., 2002; Rosenkopf and Almeida, 2003; Feinberg and Gupta, 2004). They typically consider how different relational architectures might influence the ease and impact of technology transfer. Thus, Kogut (1991) discusses how national technological patterns limit the movement of tacit knowledge internationally, Feinberg and Gupta (2004) show that technical knowledge moves more easily between multinational firms that have similar national backgrounds, and Almeida et al. (2002) show that patentable knowledge moves more easily in alliances than through markets and more easily within firms than in alliances. Bathelt and Cohendet (2014) propose that the interweaving of local and global knowledge dimensions result in channeling knowledge through cross-national feedback loops.

However, the mechanisms and processes of transferring the complex, tacit, path-dependent organization capabilities (Teece et al., 1997) or architectural knowledge (Henderson and Clark 1990) that provide long-term competitive advantage are not generally addressed or are seen as extremely difficult to pursue (Kogut, 1991; Szulanski, 1996; Tallman and Phene, 2007). Indeed, architectural or systemic knowledge is seen as both organizationally and geographically sticky (Prahalad and Hamel, 1990; Saxenian, 1994; Tallman et al., 2004). Architectural knowledge is path dependent, built up over time through idiosyncratic learning experiences not easily identified or assembled and, therefore, is highly immobile. The embedded nature of this knowledge makes changes, particularly directed and intentional changes, problematic even among geographically separated subunits of a firm, much less when it has been imported from another organization. Rather, when challenged by foreign competitors with new and superior architectural understandings of the relevant system, firms initially fail to grasp the new 'way of the world', redouble their efforts at pursuing old ideas more efficiently under old understandings, and eventually fail (Christensen, 1997). The implication for economic geography is that in the face of such competency traps among constituent firms, regional clusters too eventually will collapse (Pouder and St. John, 1996).

However, there are examples of firms that have undergone systemic change, usually under conditions of near-failure, and have emerged as changed entities that have become very successful. Changing the nature of the firm occurs mostly in crisis situations when there is little to lose by rejecting the current architecture and attempting to shift to a new conceptualization of the basis for advantage. IBM was changed by an outsider CEO from a manufacturer of computers to an IT services and consulting firm that does a bit of manufacturing on the side (Gerstner, 2003). Apple was near collapse when Steve Jobs was rehired and transformed personal computing, music and personal communication by restructuring the company to a new model that overwhelmed more entrenched and divisionalized competitors; competitors that are now struggling to adapt to the new structures imposed on their industries by Apple (Young and Simon, 2005).

This article focuses on a firm that successfully renewed its organizational architecture by importing knowledge from a foreign cluster in the same industry when the required capabilities were not available locally (Bathelt and Cohendet, 2014). It explores the mechanisms that permit and enhance the movement of highly tacit component (technical) knowledge and even of very geographically sticky architectural knowledge across borders and between clusters and firms. In doing so, it addresses a number of critical research questions that relate to intra- and inter-locational knowledge transfer. First, we consider what eventualities motivate firms to look for complex technologies or new organizational routines and capabilities both locally and inter-regionally or internationally. We see competitive pressures from other firms driving the search for knowledge, but this then leads us to our second question, which is to understand when and how a firm decides to import technical or component knowledge and when it shifts to seeking new architectural knowledge—new routines and processes for engaging in this competition. Third, we seek improved understanding of methods of transmitting such knowledge to include accessing local knowledge in foreign locations, attracting knowledgeable individuals from other locations and firms as change agents, and restructuring the core architectural characteristics of the focal firm.

We use a theory-driven, longitudinal, single case study to demonstrate that indeed the 'organizational context', the firm's architectural understanding of its core processes, can be changed by importing architectural knowledge from other firms in distant locations. We develop a conceptual framework to examine and describe how shifting the geography of knowledge sourcing can facilitate architectural change by following the transformation of one business unit within a specialist global organization, Ferrari Gestione Sportiva (FGS), through a series of evolutionary steps that involved internalizing new component knowledge from other firms and locations, transforming the company's architectural knowledge through various transactions with firms and individuals from a foreign cluster, and eventually transforming the concept of the firm and its focus radically. These combine to provide a conceptual framework for knowledge transformation that is explored through the analysis of individuals interacting with a single firm, but which offers parallels to the roles played by multinational firms tapping into and internalizing location-specific component and architectural knowledge from various locations. We close by generalizing this model to address the fundamental processes of organizational learning at various levels.

2. Knowledge and knowledge transfer among firms and clusters

Industrial clusters are 'geographically proximate groups of interconnected companies and associated institutions in a particular field, linked by commonalities and complementarities' according to Porter (2000, 16). These clusters are often sources of innovative technologies and processes for an industry. However, although Porter's (2000) framing of the cluster concept within the notion of regional competitive advantage has gained much popular support, there are concerns relating to lack of theoretical grounding to provide the basis for understanding and identifying the underpinning mechanisms that create such regional capability (Martin and Sunley, 2003).

Clusters depend on the localized conditions that stimulate economic transformation such as a confluence of private, public and quasi-public structures often framed as institutional thickness (Henry and Pinch, 2001; Amin and Thrift, 2005). In this context, place and spatial proximity are the key foundations of a socially embedded network of relationships that enhance trust and knowledge generation and are, therefore, able to stimulate greater levels of innovation and economic transformation (Granovetter, 1973). Such regional agglomerations are not unitary in their capabilities but are sustained by a related variety of competences and complementary sectors (Boschma and Iammarino, 2009). This geographical lens views the economic and social processes from a spatial perspective, and although it emphasizes the embedded, path-dependent nature of these processes, it also recognizes that agents such as organizations make choices which may create shifts and transformations from these particular paths (Bathelt and Gluckler, 2011).

Within the body of work on clusters there has been a recognition of the importance of distilling the nature of knowledge creation in agglomerations and attempting to isolate the mechanisms which lead to firm learning and innovation (Malmberg and Maskell, 2002). One perspective for considering the movement of knowledge among firms within clusters and between firms across cluster boundaries utilizes the concepts of component and architectural knowledge (Henderson and Clark, 1990). Pinch et al. (2003, 379) describe component knowledge, which '. . . refers to those specific knowledge resources, skills and technologies that relate to identifiable parts of an organizational system, rather than to the whole. Component knowledge is therefore normally tied to the technology and operating norms of particular industrial sectors'. For example, component knowledge in building racing cars may be very explicit, such as the design and use of shock absorbers, pistons, turbochargers and other parts, or much more complex and tacit, such as the use of aerodynamic design principles or exhaust layouts. However, it is often tied to scientific and engineering principles and can be measured, codified and transferred to other informed individuals and organizations.

Component knowledge must be organized into some larger framework to make a system function, whereas architectural knowledge relates to the organization of such a system and the structures and routines for organizing its component knowledge for productive use (Matusik and Hill, 1998). Architectural knowledge is, therefore, concerned with the relationship between an individual piece of component knowledge and an overall system of knowledge (Pinch et al., 2003). Architectural knowledge is tacit, complex, deeply embedded in individuals and organizations and highly path-dependent (Tallman et al., 2004). Architectural knowledge exists at multiple levels, from the work group (Henderson and Clark, 1990; Carlile and Rebentisch, 2003; Carlile, 2004) to the firm (Matusik and Hill, 1998), to the industry cluster (Pinch et al., 2003) where it develops as firms interact within a geographically defined social network milieu.

2.1. The process of managing knowledge flows

Henderson and Clark (1990) focus on three areas for managing knowledge flows: communication channels, filters and problem-solving strategies—together these create the knowledge architecture for the firm. Formal (licensing, alliances, acquisitions) and informal (spillovers, social network interactions) communication channels for component knowledge delimit the interactions essential for effective design development and the relationships that underpin architectural knowledge. Organizations are constantly bombarded with information through even these limited communication channels. Therefore, firms must develop filters that allow them to identify immediately those components that are most critical to them in the information stream (Arrow, 1974; Daft and Weick, 1984). These filters are part of the firm's architectural knowledge, as they are a key part of the knowledge describing the relationships between the components. As extant architectural frameworks tend to screen out information that contradicts their expectations, hence information intakes tend to be limited to component knowledge that fits within the existing framework of channels and filters; information that might lead to changing the architectural framework is largely filtered out. Specific communication channels and effective filters allow an organization to cope with complexity by keeping information intakes limited and structured so that it is not constantly recreating its organizational 'dominant logic' (Prahalad and Bettis, 1986) in response to random contextual variation. However, this same process tends to prevent the firm from identifying fundamental disruptive change and exposes it to the risk of building core rigidities for itself (Leonard-Barton, 1992).

Thus, architectural knowledge becomes implicit in the organization, and problem-solving strategies are framed in the context of the existing architecture. Problem-solving strategies tend to focus on improving efficiency at existing tasks/technologies, filtering out supposedly irrelevant component knowledge to focus on easing absorption of the relevant. Henderson and Clark (1990, 27) say that, 'We have assumed that architectural knowledge embedded in routines and channels becomes inert and hard to change. Future research designed to investigate information filters, problem-solving strategies and communication channels in more detail could explore the extent to which this could be avoided.' These concepts have been taken forward at the microlevel in addressing some of the specific problems of knowledge moving across boundaries of different working groups in an automotive setting (Carlile and Rebentisch, 2003; Carlile, 2004). Our focus here, however, is to consider the explicit spatial aspects in the nature of these flows.

2.2. The limits to knowledge transfer across geographic distance

Given that architectures for knowledge flow management develop in all organizations to make fundamentally chaotic environments comprehensible, certain currently accepted general rules of knowledge transfer can be described. First, highly tacit architectural knowledge is essentially very difficult to transfer, often described as 'sticky' (Henderson and Clark, 1990; Tallman et al., 2004). As it develops through practice and experiential learning, with strong path dependency, and as all organizations, firms or clusters have different experiences, none will develop identical architectural knowledge (Dierickx and Cool, 1989). Further, all human systems have some architectural concepts, and existing architectural knowledge provides filters to resist the import of alternative systemic architectures. Second, while component knowledge is transferred more easily, it moves even more quickly among organizations that have higher absorptive capacities (Cohen and Levinthal, 1990) for each other's technical know-how due to their common architectural frameworks or sets of channels, filters and problem-solving strategies. Due both to accessibility and absorptive advantage related to common architectural knowledge (Tallman et al., 2004), knowledge search and exchange tend to be local and incremental (Zucker et al., 1998).

Thus, new ideas move more quickly and clearly within firms than between firms, and more quickly and clearly among firms within a geographical knowledge cluster than across cluster boundaries, and similarly faster within a nation than across borders (Kogut, 1991; Tallman and Phene, 2007). Therefore, performance differences can persist between clusters, if one cluster-level architectural framework provides a more competitive framework than others, and within clusters, if one firm has superior private architectural knowledge to others. Over time, competitive pressures cause firms to incorporate new component knowledge, though their unique architectures may apply it differently, and also to attempt to develop new architectural knowledge. However, such efforts are difficult, lengthy and uncertain due to the tacit and embedded nature of architectural knowledge that makes copying other architectures or even directed internal development of innovative architectural knowledge uncertain at best.

Architectural knowledge is embedded in the structure and information processes of established organizations or clusters of organizations, and therefore these organizations struggle to recognize and respond to threats from innovations in architectural knowledge (Henderson and Clark, 1990). Path dependency suggests that a firm's experience with an evolving technology shapes its architectural knowledge to reflect an organizational dominant logic (Prahalad and Bettis, 1986), dominant design (Abernathy and Utterback, 1978) or technological trajectory (Jenkins and Floyd, 2001).[1] Once a particular product design architecture becomes accepted as dominant, change and development tend to be focused on component areas, whereas the architecture behind the product or technology becomes taken for granted. Similarly, when a particular organizational logic is accepted and standardized, top management use this logic to address all organizational issues (Prahalad and Bettis, 1986), management learning focusing on new component areas rather than new architectures. The consequence is that incumbent firms tend to be displaced in instances of disruptive change to which they cannot adapt (Christensen, 1997) and clusters of firms eventually become so enmeshed in internal knowledge flows and intra-cluster competition that they fail to respond to superior innovation from external sources (Pouder and St. John, 1996).

We consider that these issues are particularly difficult in international industries, where firms are separated by geographical space and also by differences in cluster-level architectural knowledge and national-level institutional differences (Tallman and Phene, 2007); what could be referred to as differences in place (Lorenzen et al., 2012). There is an extensive literature describing the international transfer of knowledge (e.g., Gupta and Govindarajan, 2000), but most of it focuses on the transfer of technology or component knowledge. Rosenkopf and Almeida (2003) propose the idea that alliances and/or the transfer of individuals may increase technological exchange by some process of increasing contextual similarity. However, their results from an empirical test of secondary data are not supportive of the idea of importing context. Szulanski (1996) and Kogut and Zander (1993) describe and demonstrate the difficulties of moving highly tacit knowledge across borders, even within firms. Kogut (1991) suggests that moving complex knowledge across borders is very slow and difficult except within a multinational firm—and even then is difficult due to cultural and institutional (what might be considered national-level architectural knowledge or dominant logic) differences. Moving tacit, embedded, contextually sticky architectural knowledge internationally from a cluster in one country to a firm (in another cluster) in another country is near impossible—or so the majority of models insist (Markusen, 1999).

However, as rare as it may be that a firm is able to undergo the process of reconstructing its organizational architecture, we propose that this process does occur, could occur more frequently and would be of great value to incumbent organizations if it were expressed in a generalized framework. The remainder of this article uses the case of FGS to examine how architectural knowledge develops in a firm based in a

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[1] Prahalad and Bettis (1986, 490) use 'dominant logic' to describe the 'way in which managers conceptualize the business and make critical resource allocation decisions... '. Abernathy and Utterback (1978) use 'dominant design' to describe standardization of product design on a set of common attributes across a product category. We will use 'dominant logic' to describe architectural knowledge at the organizational level and 'dominant design' in reference to the architecture of technical knowledge about the racing car itself.

geographical cluster, how it interacts with knowledge embedded in another cluster in a distant location and how an architectural framework can be recreated under conditions of extreme competitive pressures when faced with alternative successful architectures. We observe the process of architectural development and evolution in FGS over the period 1929–2008 and derive a conceptual model of the mechanisms underlying the import of architectural knowledge. It is important to note that FGS had only a limited sense of what it was trying to accomplish in renewing and restructuring its knowledge base—indeed, many of what will be seen as critical decisions were driven by expediency or individual preferences unrelated to, even seemingly destructive of, successful knowledge transfer. We argue that the planned and unplanned process followed by Ferrari reflects concepts from learning theory, however, and finish by presenting a conceptual model for cross-border architectural knowledge transfer.

3. The case study

3.1. The case method and industry context

The research in this article follows a longitudinal, multistage case study design (Yin 1984; Leonard-Barton, 1990). It focuses on major periods in the history of Ferrari's racing operations. Ferrari has one of the most successful global brands in the automotive industry, regularly appearing in global brand rankings (e.g., Interbrand, 2013). Key aspects of their brand strength are sporting heritage and reputation. We chart their progression in the sporting arena from a locally focused specialist car manufacturer to a globally dominant operation that is now the most successful in the history of Formula 1 (F1) motorsport. We use a theoretical sampling approach (Eisenhardt, 1989) to focus on this organization. Our approach can be described as a multilevel comparative analysis in that we consider the organization at both the architectural and component levels, making comparisons across different time periods (Burgelman, 2002). Our approach is to move beyond the descriptive and to use qualitative research to develop theory, but we do so with an explicit recognition of prior concepts and relationships (Birkinshaw et al., 2011). We apply Henderson and Clark's (1990) concept of architectural and component knowledge as a framing for our interrogation of the case material through the areas of activity they identify as supporting existing architectural knowledge: communication channels, filters and problem-solving strategies. We also specifically focus on variations in the spatial aspects of the firm, most notably the location of facilities and partnerships during these periods (Jenkins and Tallman, 2010). We use this interrogation of the case data to generate a series of propositions that delineate the changes involved in developing component and architectural knowledge and the potential importance of localization in this process.

Ferrari is chosen because it demonstrates transitions through periods of environmental change and also, as our theoretical lens focuses on shifts in architectural knowledge, is the one firm which has survived through a series of changes in the dominant design of the F1 racing car. F1 racing itself offers strong evidence of geographical clustering of architectural and component knowledge (Jenkins and Tallman, 2010) and established standards of design and performance (Jenkins, 2010). Our selection of respondents is purposeful, as we have sought to explore the technical shifts and strategic changes that were made during this period. Table 1 provides a summary of the respondents, their roles and their affiliations. As Table 1 illustrates, the

Table 1. Details of interview respondents

Respondent	FGS role and involvements	Date of interviews
John Barnard	Technical Director, Ferrari 1986–1989 Head of Ferrari Design and Development 1992–1997	5 May 1999 25 September 2000 30 March 2004 31 March 2004
Ross Brawn	Technical Director Ferrari 1997–2006	24 June 2004
Mauro Forghieri	Various technical positions through to Technical Director, Ferrari 1962–1987	18 October 1999
Paolo Martinelli	Various technical positions through to Engine Director, Ferrari 1978–2006	24 June 2004
Jean Todt	Sporting Director and then CEO Ferrari 1993–2007.	24 June 2004

interviews were undertaken between 1999 and 2004. The purpose of these interviews was to develop a deeper understanding of the shifting basis of competitive advantage for Ferrari from the 1970s through to the 2000s. Although the focus of the interviews did not specifically concern the geographic aspects of the company strategy, the broader focus on competitive performance and the reasons behind this created a rich picture from which the geographic dimensions emerged as a key construct in the ability of the organization to both develop and change its approach to innovation. Part of the discussion in the interviews necessarily focused on past events that often allowed a more open reflection on causal dynamics than would be the case with contemporary accounts (Hargadon and Yellowlees, 2001). All of the interviews were fully transcribed and the transcriptions analyzed in detail through the framework outlined in Table 1.

We also accessed a wide range of secondary data sources including autobiographies and biographies of key players, and a range of specialist motorsport magazines that had been published since the 1950s. These are outlined in Table 2. The use of a wide variety of secondary data enable such recollections to be checked against contemporaneous events to ensure that as comprehensive picture as possible is developed.

Table 3 represents two key aspects of the industry and spatial context. First, it lists the key areas of component knowledge within the design and development of F1 racing cars. These component areas are taken from an engineering forum for motorsport technologies and hence represent particular technological elements and knowledge domains that are required for the creation of these specialist vehicles. Second, it distinguishes between the architectural characteristics of two key geographically agglomerating regions—‘Motor Valley’ in Emilia Romagna (www.motorvalley.com), an area in northern Italy around Milan and Bologna, which includes the city of Modena, and the area known as ‘Motorsport Valley’ in the UK which represents a crescent area to the north, west and south of London (www.the-mia.com/The-Industry). Both of these areas have been identified as demonstrating the distinctive capabilities of global clusters, with the British cluster receiving detailed consideration in the economic geography literature (Henry et al., 1996; Henry and Pinch, 1999; Pinch and Henry, 1999).

In the case of the Italian region, *Motor Racing* developed in the 1930s led by Alfa Romeo of Milan who had recruited Enzo Ferrari to run their racing department in Modena.

Table 2. Details of secondary sources

Title and author	Publication details
Beck-Burridge, M., Walton, J. *Britain's Winning Formula: Achieving World Leadership in Motorsports.*	(2000) London: Macmillan Press.
Chapman, C. Colin Chapman explains why lightweight cars are safer.	(1958) *Motor Racing Magazine*, October 1958, 71–72.
Colombo, G. *Origins of the Ferrari Legend: Memories of the Designer of the Earliest Ferrari Cars.*	(1985) Yeovil, Somerset: Haynes Publishing.
Couldwell, C. *Formula One: Made in Britain.*	(2003) London: Virgin Books.
Crombac, G. *Colin Chapman: The Man and His Cars.*	(2001) (re-issued version) Yeovil, Somerset: Haynes Publishing.
Ferrari, E. (translated by Ivan Scott) *The Enzo Ferrari Memoirs.*	(1963) London: Hamish Hamilton.
Lawrence, M. *Grand Prix Cars 1945–1965.*	(1998) Croydon: Motor Racing Publications.
Motorsport	All editions 1950–2004.
Nye, D. *The Autocourse History of the Grand Prix Car.* 1945–1965.	(1993) Richmond: Hazleton Publishing.
Robson, G. *Cosworth: The Search for Power.*	(1999) Somerset: Haynes Publishing.
Autosport	All editions 1950–2004.
F1 Racing	March 1996–2004.
Williams, R. *Enzo Ferrari: A Life.*	(2001) London: Random House.
Yates, B. *Enzo Ferrari: The Man and the Machin.*	(1991) London: Doubleday.

Table 3. Core and peripheral subsystems Northern Italy versus Britain's Motorsport Valley[a]

	Italian Motor Valley	Britain's Motorsport Valley
Core subsystem	Engine and transmission	Chassis/Materials aerodynamics
Peripheral subsystems	Chassis/Materials Aerodynamics Braking Electronics Tyres and wheels Fuels and lubricants Safety	Engines and transmissions Braking Electronics Tyres and wheels Fuels and lubricants Safety

[a] These categories have been adapted from the key knowledge domains used to define the track for the Society of Automotive Engineers' Motorsport Engineering Symposium in 2005.

At that time *Motor Racing* was dominated by long-distance racing on public roads with events such as France's Le Mans and Italy's Mille Miglia. With Italy's aerospace sector effectively dismantled following World War 2, and a focus on high-speed public road races, the postwar focus was to privilege the engine as the source of competitive performance. This meant that the firms active in Motor Valley in the 1950s—Ferrari, Alfa Romeo, Maserati and Lancia—all focused on engine development, with their technical managers all coming from a background of engine design. This created a horizontally based agglomeration cluster with a particular view on the primacy of knowledge domains. This leads to the inference in Table 3, that the architectural knowledge of the Italian region was focused first and foremost on engine development.

In contrast, the British cluster had developed in the 1950s through small light cars designed to compete on closed circuits, often disused airfields—such as RAF Silverstone—that provided tarmac surfaces for racing. This racing culture developed in the same region as an ongoing, but diminishing, aerospace cluster that provided a source of scientists and engineers in areas such as materials and aerodynamics and also unique facilities such as wind tunnels for testing designs. In contrast to the Italians, the British designs focused on making the cars agile rather than powerful, with an emphasis on the development of the chassis (Chapman, 1958) and later on the application of aerodynamics. In the early 1950s, the Italian region dominated F1. However, after a series of accidents involving fatalities among spectators in the mid- and late-1950s, racing on public roads became restricted and the focus shifted to using compact, closed circuits, which played to the strengths of the British designers.

3.2. The case of FGS 1929–2008

3.2.1. 1929–1949: success and establishing an architectural model

Enzo Ferrari first formed Scuderia Ferrari in 1929 as one of the earliest specialist motorsport organizations (Yates, 1991). Subsequently the company developed both a racing (Gestione Sportiva) and a road car manufacturing operation (Gestione Gran Turismo). Here we focus primarily on the racing operation of Gestione Sportiva. The original FGS was located in Modena in the Emilio-Romagna area of northern Italy. Enzo was himself a former Grand Prix driver for the Alfa Romeo team, and Scuderia Ferrari ran the official Alfa Romeo racing team from 1930 to 1937 during which time they were successful at long-distance road racing events such as the Targa Florio, Mille Miglia and Le Mans. In 1938, Alfa Romeo relocated their motorsport activities to their factory premises in Portello, Milan, under the name of Alfa Corse (Nye, 1993). This resulted in Enzo Ferrari severing his ties with Alfa Romeo and signing an agreement not to race under his own name for 5 years. During the period 1940–1945, Ferrari established a new business, Auto Avio Construzioni Ferrari, manufacturing ball-bearing grinding machines (Williams, 2001). In 1943, they moved to new premises to the south in the small town of Maranello.

In 1945, progress toward the first Ferrari racing car began when former Alfa Romeo designer Gioachino Colombo traveled to Modena to discuss design of a new car, the 125, with Enzo Ferrari. Colombo had joined Alfa Romeo in 1924 and had produced some of the most iconic Grand Prix cars of the 1930s. He recounted his conversation with Ferrari: 'Colombo – I want to go back to making racing-cars; I've had enough of utilities! What do you say: how would you propose to make a fifteen hundred?' (Colombo, 1985, 16). The term 'fifteen-hundred' refers to the engine capacity in cubic centimeters of Grand Prix cars at the time—note that the discussion starts with a clear focus on the engine.

Colombo replied: 'Listen – Maserati has a first-class eight-cylinder machine; the English have the ERA six-cylinder, and Alfa have their own eight cylinder. In my view, you should be making a twelve-cylinder.' Colombo then noted that Ferrari smiled, giving him *'the confirmation he wanted of a decision he had already made some time ago'* (Colombo, 1985, 16). The Ferrari 125 (so named as the capacity of each of its 12 cylinders was 125 cc) made its race debut on 11 May 1947, at the Piacenza circuit in Emiliano-Romagnolo. The chassis of the car was made of tubular steel, the conventional approach during this time and was fabricated by chassis specialists GILCO Autotelaio in Milan (Colombo, 1985).

The emerging architectural knowledge of Ferrari is, therefore, focused on the design of the engine as the central component of the system, as Ferrari noted in his autobiography: 'In fact I have always given great importance to the engine and much less to the chassis, endeavoring to squeeze as much power as possible in the conviction that it is engine power which is – not 50 per cent but 80 per cent – responsible for success on the track' (Ferrari, 1963, 41–42).

At that time it was usual to produce both a single-seat 'monoposto' and twin-seat 'gran turismo' version, with bodies built by specialist bodybuilders such as Pininfarina, in the Milan area. Ferrari also used Pirelli tyres (produced in Milan) and worked closely with Shell Italiana: 'Stefano Somazzi, in particular, a Swiss engineer of Shell Italiana's, worked with us closely and gave us his help in tackling a number of problems concerning both fuels and lubrication' (Ferrari, 1963, 145–146).

In summary, we see a philosophy of car design that focused primarily on the design of the engine, with the other elements being very much secondary, and frequently outsourced to local, specialist contractors. As is generally presented to be the case for geographical clusters of firms, the knowledge needed to develop this process was all held within the localized area of Milan, Bologna and Modena, with Ferrari gradually absorbing and enacting the consensus architectural framework of the Italian Motor Valley cluster, the technical and social interactions—in the Italian tradition the engineers who worked together also spent many of their evenings dining and socializing together—within this small region came to define an Italian approach to F1 racing.

3.2.2. 1950–1960: architectural consolidation

From 1950 Ferrari competed in the F1 World Championship. Figure 1 provides details on their race performance during this time, along with a number of key events that are noted during the case narrative. During the years that followed, Ferrari built on their early success—they won their first World Championship in 1952, and in 1952 and 1953 won all the races in the championship. This dominance was clearly a vindication of their philosophy of prioritizing engine development in the design of an F1 car—they were embedding their particular architectural knowledge and focusing on improving areas of component knowledge, particularly those relating to the engine. Other specialized knowledge in particular component areas, was accessed from other countries, including Roots superchargers from the USA and specialist bearings sourced from the UK: '. . . we were enabled later to develop this engine fully and perfectly only by the use of

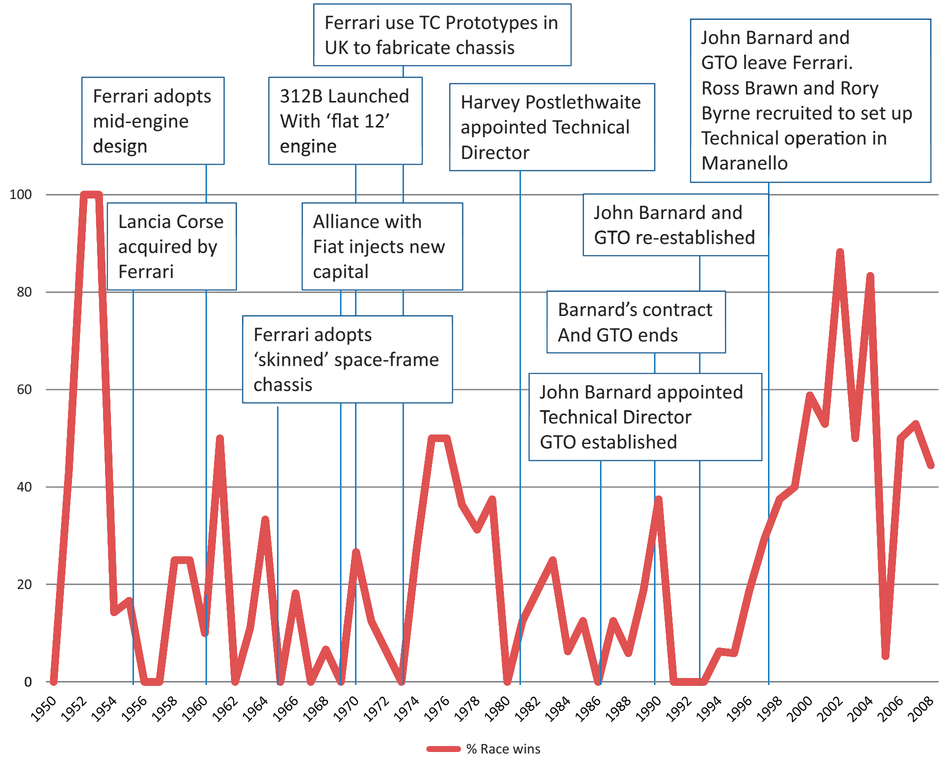

Figure 1. Ferrari performance 1950–2008 (percentage of Grand Prix wins during each year).

the special materials not then available, such as the famous thin-wall indiumised bearings of Tony Vandervell, the meteoric builder of the Vanwall' (Ferrari, 1963, 41).

From these observations, we can illustrate the way in which the knowledge architecture has evolved both at a firm and cluster level. In the context of Ferrari there appeared to be no question that the design should start with the engine, and no question that the engine would be the most important component area of the car. Further, Ferrari was embedded in a horizontal cluster of similar firms that comprised the North Italian 'Motor Valley' cluster (Alfa Romeo, Maserati, Lancia), which all employed similar, or the same, designers, who all approached their problem solving in similar ways.

Ferrari's domination during 1952 and 1953 proved hard to repeat, but in 1955 the Lancia motorsport operation (Lancia Corse) was struggling to survive. With help from Gianni Agnelli of Fiat, Ferrari negotiated the take-over of Lancia designs, which then were integrated into the Ferrari racecars (Figure 1). Maserati too succumbed to financial pressures and withdrew from racing in 1957 (Nye, 1993), effectively creating a shift in the North Italian cluster from a horizontal agglomeration of competing firms to a vertical configuration (Markusen, 1999) focused around Ferrari and their supply chain. However, toward the end of the 1950s the English constructors emerged as a competitive threat, led by father and son Charles and John Cooper (Beck-Burridge and Walton, 2000). The Cooper was a small, light racecar that had been originally developed for racing in junior formula, such as Formula 2, using chassis components taken from the Fiat Topolino car (Nye, 1993). In contrast to Ferrari's 'engine centric' architecture, the design of the Cooper focused on the chassis and maximizing the grip of the wheels. Unlike Ferrari, they did not build their own engine, but used an adapted fire pump engine built by Coventry Climax in the UK (Couldwell, 2003). A key part of the Cooper design was that the engine sat immediately behind the driver—known as a mid-engine layout—thereby giving the car better weight distribution and reducing overall weight by removing the need for a long heavy transmission, as was necessary with the front engine Ferraris (Lawrence, 1998).

Enzo Ferrari had strong views on the positioning of the engine as recounted by Giochino Colombo: 'For some time I had been thinking about this project [a rear engine design], and I'd been studying some possible solutions in my spare time. Enzo Ferrari listened very closely to my proposal. He wanted to know all the details, and asked for explanations which he followed with great attention. And then he vetoed the whole scheme! "No", he said, "it's always been the ox that pulls the cart"' (Colombo, 1985, 14). Enzo's response found its way into Ferrari and motorsport legend, as an example of the Italian philosophy on car design. This suggests the following proposition:

Proposition 1: Business, technical and social networks within limited geographical areas—often described as industrial clusters—circumscribe the early evolution of different regional architectural frameworks in an international industry. Communication channels are local, local focus filters out alternative ideas and problem solving occurs within the local architectural model.

3.2.3. 1961–1980: competitive challenges and component solutions

By 1960, the success of the English mid-engine design had an impact on Enzo and, in preparation for new regulations in 1961, and despite considerable in-house opposition, he allowed the team's ex-Alfa Romeo Chief Engineer, Carlo Chiti, to build a prototype mid-engine Ferrari. This proved highly successful in testing and led to the development of the Ferrari 156 'Sharknose' that dominated the 1961 season (as shown in Figure 1). Although the move of the engine from front to behind the driver could be seen as a shift in architectural knowledge, in many ways it was not, as the design process was still rooted in the 'engine-frame-body' logic of Ferrari. The focus of the design was a new V6 engine and the car still used the tubular chassis concept that was used in the Ferrari 125 back in 1948. Indeed, even the car's '156' nomenclature was due to the engine configuration of 1.5 l, six cylinders.

However, Ferrari's success during 1961 was soon forgotten as a new chassis design was pioneered by UK constructor Lotus. Up to this point the dominant design had been the tubular 'space-frame' chassis, with the structure formed from welded steel tubes. Founder and technical brains behind Lotus Racing, Colin Chapman, had followed Cooper's route into F1. Chapman was exploring a way to both improve the rigidity of the chassis and overcome the difficult task of fabricating aluminum fuel tanks to sit inside the space-frame structure. The problem-solving approach they followed was to redesign the chassis and replace the tubes with box sections that would provide increased rigidity with the fuel carried within them in rubber bags (Nye, 1993). This innovation—the monocoque chassis—was incorporated into the Lotus 25 of 1962 and marked a major shift in chassis technology. It was not until 1964, some two seasons after the launch of the Lotus 25, that Ferrari responded with a car that used some of the concepts of the monocoque chassis, although these were still based around the tubular structure, with stress-bearing aluminum sheets shaped and riveted over the tubes known as ‘skinned space-frames’ (Nye, 1993). Ferrari’s designs at this time were essentially stopgap while they developed a new engine to respond to the regulation change for the 1966 season when the engine size would be increased from 1.5 to 3.0 l.

Ferrari were consistently beaten by the English designers. This lack of competitiveness took a further negative turn for FGS in 1967 when a new Lotus design, the Type 49, was complemented by a new F1 engine specifically designed by Cosworth Engineering in Northamptonshire, UK (Robson, 1999). The major innovation of this design was that the engine effectively became part of the chassis. It was a fully stressed component of the car and, therefore, did not require the supporting steel frames that were necessary for nonload-bearing engines, such as the Ferrari. In 1968, a Ford Cosworth engine, capable of winning a Grand Prix in the right chassis, could be purchased for £7500 (Beck-Burridge and Walton, 2000). This led to the late 1960s and early 1970s being totally dominated by British teams. In 1969 and 1971, every Grand Prix was won by a car with one of these engines.

This created even greater pressure at Ferrari to improve performance. Technical Director Mauro Forghieri had been replaced by Sandro Colombo, who decided to try a new approach to improve the chassis of the Ferrari. He explored the possibility of fabricating the chassis in the UK, and approached chassis specialist John Thompson who ran TC Prototypes in Wellingborough, Northamptonshire. ‘Colombo turned up at our place seeking someone to build him some chassis. He showed us the drawings, we gave him a price and he accepted it straightaway I was very impressed with the detail of the drawings’ he remembers. ‘What they wanted was a fairly straightforward monocoque and we just did as they asked and built it. It was nice and light. They as much as admitted that doing a monocoque was a learning curve for them, and I never expected things to go any further. They just wanted to acquire the technology. Skinned space-frames was all they knew’ (Tremayne, 2001, 144).

However, despite these problem-solving attempts to improve the chassis, the car still remained uncompetitive, and in 1973 Mauro Forghieri was brought back to lead development. His comments reflect a view that the historical approach of Ferrari to construct their own chassis should have been maintained: ‘I came back in ’73. In this period there was a man sent by Fiat who asked people to do the chassis in England. You know, in my opinion, the chassis has to be rigid and light. It doesn’t count in which material it is done and the way in which you do it. Especially considering the possibility you have here [in Maranello] to do some kind of chassis. So in my opinion you have to use the ability of the people who are here. You cannot use people 2,500 miles away from here it becomes too difficult’ (Mauro Forghieri, interview).

Although it did not meet with Forghieri’s approval, the move to use a British contractor to produce a chassis, albeit designed by Ferrari, was a major step away from their existing component knowledge in the area of chassis fabrication. This and earlier steps illustrate an important shift in Ferrari’s focus for sources of competitive advantage. Having been clearly outperformed by the Cooper mid-engine and the Lotus chassis innovations, they made attempts to imitate successful designs, but only within their existing architecture of the space frame chassis. This accords with Henderson and Clark’s (1990) notion that successful incumbents may not grasp the full significance of innovations that are based upon a different architecture. In this case, we see Ferrari's partial response—the skinned space frame and outsourcing of the fabrication of the chassis—to the monocoque chassis developed from the distinct 'chassis-body-engine' architecture of the UK cluster, as exemplified by Cooper and Lotus.

Proposition 2: As competitive pressures become significant, firm problem solving will seek new component knowledge but will fit it into existing firm—and cluster-level architectural concepts. Component knowledge may be modeled on perceptions of foreign technology, but information filtering will tend to adapt technical advances to make them compatible with preconceived architectural and existing component knowledge, typically failing to provide the intended improvement in performance. This outcome is particularly likely for knowledge sourced from other clusters with alternative architectural knowledge biases.

Forghieri's focus had been on developing his own design of engine, the Boxer 'Flat 12', a 12-cylinder engine with the cylinders horizontal to the ground, giving it a very low-center of gravity. The fact that the engine was a 12 cylinder (and so mirroring the first Ferrari) meant that it was also capable of producing greater levels of power than the 8-cylinder Ford Cosworth. The 312T (312 representing 3.0 l, 12 cylinder)—was developed around this engine and focused on making the most of its low and wide profile, which made it both powerful and aerodynamically effective. With this car, and a succession of evolutionary versions, Ferrari was able to dominate the period from 1974 through to 1979. However, the success of the 312T resulted in more radical attempts by the competition to find a way round the Ferrari's superiority. This came, once more, from Lotus, who had pioneered a new aerodynamic design that used the air flowing under the car to create a low-pressure area to suck the car onto the track. Racing driver Mario Andretti described the Lotus 78 as being '*painted on the road*' (Crombac, 2001, 284). Ferrari again needed to look to new ways to restore their success on the racetrack.

3.2.4. 1981–1988: competitive failure and changing architecture

In the early 1980s, Ferrari endured very poor performance on the racetrack. This led to a series of new and significant technical appointments. First, in 1981, following a direct approach by Enzo Ferrari, English designer Dr Harvey Postlethwaite was appointed to the technical team, initially working alongside the long-standing Forghieri. Postlethwaite had worked with a long line of British constructors and was responsible for the success of the Hesketh team in 1974. During the early 1980s F1 cars used very powerful turbo-charged engines, which played to Ferrari's strengths, except that this required advances in chassis design to ensure that the power was translated to performance on the track. Postlethwaite's role was to help develop chassis technology at Ferrari, as recounted by Forghieri (interview): 'So Harvey [Postlethwaite] came to us. We did the first chassis in aluminum honeycomb and it was a mistake and afterwards we did it in carbon fibre. I learnt a lot at that time with Harvey.'

Postlethwaite moved to Italy and very much engaged in the Ferrari culture (Roebuck, 1999), but Ferrari's performance was still very poor. This led to a second appointment, that of John Barnard, formerly with British constructor McLaren: 'When I went to Ferrari I think it was a move by Enzo Ferrari to make the chassis side more important, to give the chassis side a boost. I suspect it wasn't just about doing the latest breed of composite chassis because they already had Harvey Postlethwaite there and Harvey knew about composites. They'd actually been making some composite chassis but it was more a case of bringing somebody in that would dominate some of the engine side and bring in much more thinking about the chassis concept and the package and all the rest of it' (John Barnard, Interview).

Barnard's description of '*giving the chassis side a boost*' was an attempt to change the architectural knowledge of Ferrari. This was not simply a case of developing a better chassis by using British contractors, this was changing the relationship between the key component areas: someone who could *'dominate'* the engine side and bring it into line with the other areas, thereby shifting the architectural knowledge base.

Perhaps the most significant aspect of the appointment of John Barnard in 1986 was that he refused to move to Italy and established a design and development center in Surrey, referred to as the Guildford Technical Office (GTO): 'When they contacted me originally I said ''No, thanks very much I don't want to move to Italy'' . . . they then turn around and say ''But what if you could set something up in England?'' and you think ''Hang on, all this money and I can set up my own place in England? I've got to give it a go really''.' This proved to be a particularly tough assignment, as Barnard himself reflected, in the challenges regarding communication channels:

> I was overall technically in charge and that was my position in charge of the engine and everything. Obviously I couldn't be in day to day charge of the engine because a) I was based in Britain and b) with a thing that big you have to work through managers so you have to be interfacing through one or two people but what I had to get into their head was that the engine had to be part of the package you couldn't just let the engine designer say ''Well I'm going to hang the water pumps out here, I don't want to hang it on the chassis like that, I want to do it . . .'' so you have to then dictate to the engine people how you want the package to work and that was quite tough initially . . . tough because you're fighting the old guard, the old brigade, the old ''We've been doing this for 30 years, don't tell us what to do'' kind of thing . . . (John Barnard, Interview).

Barnard reflected on the role of Enzo Ferrari in creating the changes that took place in his organization: '. . . at the end of the day it's what needed to happen, it was probably things like that, that Enzo saw were fundamentally wrong with the team but he didn't know how to change them. Bring this hard-arsed, bull-at-the-gate, bloody Englishman in and however it happens' (John Barnard, Interview).

This period represents the time that FGS began to diverge from the expected path of ever more internally focused component knowledge changes hung on an obsolete chassis. Rather, Enzo Ferrari himself seems to have recognized that FGS must incorporate the changes coming out of the British cluster, and that only bringing in British engineers could accomplish this. That this was a commitment to fundamental change was endorsed by the move to appoint Barnard as technical director, while allowing him to remain in England at the GTO. It appears that Postlethwaite provided the latest technical component knowledge about chassis development, but that his immersion in the Ferrari culture kept him from changing the dominant logic, the architectural knowledge, of FGS about how to build a winning racecar. Barnard, in an oversight position and isolated from the organizational culture's influence, began to restructure Ferrari's fundamental process architecture.

Proposition 3: Changing tacit component knowledge is encouraged by incorporating experienced individuals from a location with alternative architecture, but if isolated within the focal firm's system, they are unlikely to change its architectural knowledge.

Key individuals from the alternative architectural system can act as communication channels, but local filters must be by passed if architectural level problems are to be solved. The FGS experience at this stage suggests:

P3A: Top-level recognition of an existential crisis is needed to force the existing architectural framework to open up to alternative experience.

P3B: A change agent with deep knowledge of the alternative architecture must be incorporated to initiate restructuring the dominant logic of the firm.

P3C: Initiation of alternative problem-solving techniques requires protection, even isolation, of the individuals involved from organizational pressures toward inertia.

3.2.5. 1989–1993

Enzo's death in 1990 led to a very different dynamic in the leadership of FGS. Barnard left Ferrari at the end of his 3-year contract that expired on 31 October 1989. He was replaced by Argentine Enrique Scalabroni (*Motorsport*, August 1989, 773), but Barnard's absence was short lived and he returned in 1992 to continue the UK operation.

> They came back again and said 'Well we would quite like to start another English arm.' I said 'Yes I am interested, but don't make me overall Technical Director, because I can't do that from England. So they said what do you suggest? I said 'I think if you allow us to build a big enough set-up we could be an R&D centre in England that would be working on the next car. You need a complete team in Italy to race and develop that racing car while we work on the next one.' So we set this place up and at that time we had our own wind tunnel operation as well. We had an aerodynamic group here who built our own model bits and pieces and we even built the rolling road that we fitted into the British Aerospace Filton tunnel at Bristol (John Barnard, Interview).

3.2.6. 1994–1997

During this period a new leadership team at Ferrari, led by Jean Todt, was putting together a plan to bring success. Within this they recognized the need to integrate the whole operation in one location. 'Jean Todt had come along and naturally - he had been talking to me about it, so it wasn't a secret - wanted to get everything back based in Italy. They couldn't do this unless they got the right people. My contract finished in the spring of 1997' (John Barnard, Interview).

A key part of the plan was to bring in World Champion driver Michael Schumacher, who had arrived from British-based constructor Benetton. Todt sought his advice on building a new technical team. 'Once we had Michael, of course, I asked him who was good in your team, which is normal and he spoke to me about Ross [Brawn] and Rory [Byrne], so I contacted them' (Jean Todt, interview). This led to the recruitment of both Brawn (technical director) and Byrne (Chief Designer). Their first priority was to integrate the operation back to Maranello: '. . . there had been a recognition that designing a car in England and building in Italy was not the easiest of things and that really we had to move on from that. So when I had my earlier discussions with Jean about how the company would be structured that was one of the objectives. When I arrived in 1997 we had to set up a design office at Maranello' (Ross Brawn, interview).

3.2.7. 1998–2008: recombination to create a unique architecture

In the final phase of the reinvention of FGS, it was important that the new knowledge and approaches that had been developed in the UK-based operation were successfully integrated back into the Maranello site. A key part of this was the engagement of those involved in the engine design and development: 'I really felt that we could get into a situation where we could have an engine completely integrated into the car and that must be the best situation so one of the things that was very important to myself and Rory was to have someone here who understood that and luckily Paolo Martinelli [Engine Director] very quickly appreciated our ideas and was completely receptive to the idea of a fully integrated engine as part of the car package' (Ross Brawn, interview).

During this period the emphasis was placed on integrating the knowledge developed in the UK facility back into the operation at Maranello. This was needed, as although the two operations enabled new knowledge to be absorbed, their ability to innovate and compete was impeded by the distance between the operations: as summarized by Paolo Martinelli (interview): 'It was the correct decision [locating in the UK] if you want to recover through technology and find the knowledge you need . . . but coming back a year from now, even a link with the telephone or with the telephone lines is not so fast as it is now and telecommunications by fax or even email is not so prompt, it cannot give the team spirit if you have 2000 km distance. Sometimes you need to be by the car, or by the chart, working shoulder to shoulder, is very important.'

An important change to the effort to incorporate the British architectural knowledge into FGS took place during this period. It was recognized that the current operational responsibilities of the Technical Director must be pursued in Italy. The regional effect is emphasized by the fact that it was not Barnard and his operation that was transplanted into Maranello, but a new operation was built up by another group of technical specialists who had been located in the British cluster. Ross Brawn was able to bring an entire team from the British cluster, which offered a level of support for architectural change that was not available before. This final stage in the development of the evolution of FGS meant that the differing channels, filters and problem-solving approaches which had necessarily evolved in the different locations now had to be integrated through co-location. It was only this final phase that allowed the development of the new architecture that was essentially a hybrid of old and new brought together in one location through a new management team.

Proposition 4: Integration of new, spatially remote architectural knowledge into the firm's dominant logic requires that key proponents must eventually be brought into the core of the firm. Combining the new architecture with the firm's inherited architecture to establish new communication channels, redefine filter parameters and recast problem-solving approaches requires direct involvement. From the FGS experience, we derive the following rules:

P4A: When the change agent is relocated to the core of the firm, support structures must be transported as well if the agent is to be effective.

P4B: The change agent must be given top management support and the organization's dominant logic must be restructured to support the new conceptual architecture.

P4C: Future innovation from the base of the restructured architecture requires recombination of the old and new frameworks.

The key transition for FGS was the step to embed in the British cluster. It appears that most firms, and most clusters, faced with an emergent architectural logic that offers consistently superior performance become mired in seeking solutions in new component technologies grafted onto the established or dominant logic architecture of the firm (Prahalad and Bettis, 1986; Christensen, 1997). Sticking with success by reinforcing current architectural knowledge and engaging primarily in local search for new component knowledge is easy to understand, but is the mechanism that creates the inertia which drives the ultimate failure of firms and clusters (Pouder and St. John, 1996). Cycling through multiple iterations of such a process leads firms into capability traps where increasing levels of investment only raise the cost of eventual competitive failure (Leonard-Barton, 1992). Ferrari, however, discovered the key insight that the British constructors had a superior concept for building a racecar, and determined to incorporate this knowledge into their design process. In the case of Ferrari, the mythical status of Enzo Ferrari allowed him to make and enforce the decision to locate in the UK Motorsport Valley. His competitive drive overcame his preconceptions of what made for a competitive racecar, and his status within the firm enforced structural changes that were very much foreign to the old logic of FGS.

4. Discussion and conclusions

From the case, we have developed process logic for the specifics of knowledge transformation in FGS. We have acknowledged that other firms have successfully transformed their dominant logic, though it seems a comparatively rare occurrence. We propose a model that could be applied generally by firms faced with a competitive challenge from another region to their architectural understanding of their industry sector to suggest, with reference to the structural solutions derived from the FGS experience, a systematic approach to a competitive solution and to an analytical framework.

Figure 2 offers a double-loop approach to component and architectural learning, or incorporation of new knowledge, in firms faced with severe international competitive challenges (Argyris, 1976; Bathelt and Cohendet, 2014). Integrating our various propositions in Figure 2, we see that there are a number of considerations involving the spatial characteristics of knowledge flows that have implications for the growth and development of firms. The first is that as firms develop their existing localized knowledge, it will evolve into a particular dominant product design and organizational logic. This will form the basis of growth and expansion through development of the component areas that are elements of the architectural knowledge, but not involve changes in the architectural knowledge—effectively the left hand, or original dominant logic, loop in Figure 2. Firms can develop successfully without fundamentally changing their architectural knowledge and by simply improving component areas as they compete at home and initially expand into new regions. This is the realm of benchmarking local, regional and national competition, using established

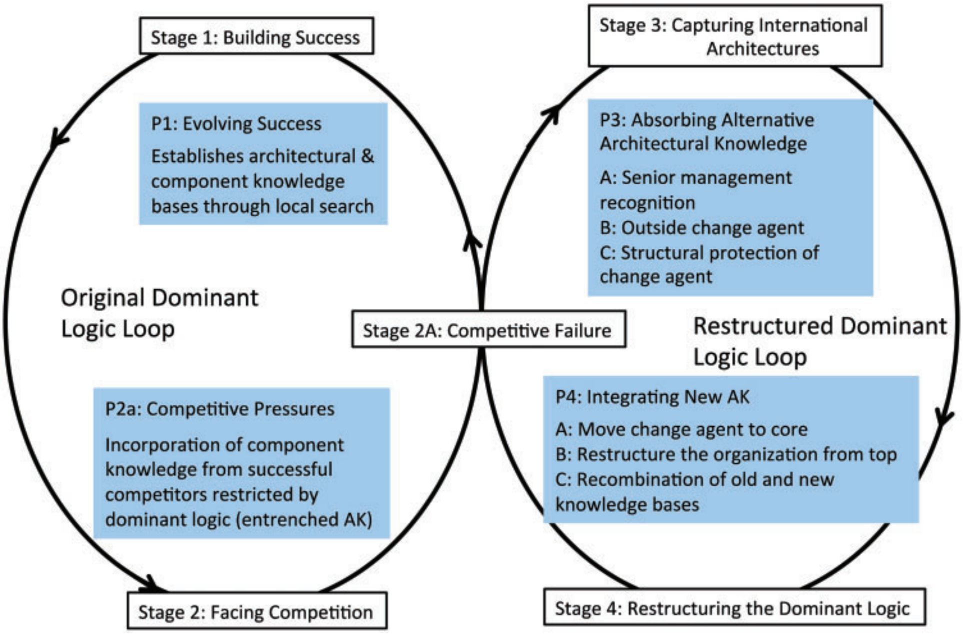

Figure 2. A double-loop model of geographic learning in a multinational enterprise.

communication channels and problem-solving approaches. New ideas from other regions are tried, but typically are drastically modified to fit the existing architectural knowledge.

At a later stage, international competition, whether attacking the home market or in foreign markets, is recognized and its component knowledge is added to the mix. As with local component knowledge, adaptation is likely, but in this case the gulf between dominant logics (architectural knowledge pools) suggests complete misunderstanding of how the new technical know-how is incorporated in the system is likely. Bingham and Davis (2012) describe various learning sequences, but find that firms often struggle unsuccessfully with changing processes to admit knowledge from low-status locations even in the face of admitted failure.

If, however, due to the continued superior performance of foreign competitors or to discontinuities in the external environment, the organization is unable to provide sufficient performance enhancement through development of component knowledge and faces competitive failure, then the double-loop effect (the right hand, or restructured dominant logic, loop in Figure 2) may occur. This is the point at which the imagination of most incumbent firms appears to fail, and additional nonproductive journeys around the left-hand loop are taken, following the old logic but to ever less benefit. For the uniquely thoughtful or lucky firm that recognizes the need for fundamental process change, our framework suggests that geography can play a critical role in the evolution of architectural knowledge within the firm. This is because the regionally embedded nature of architectural knowledge (Tallman et al., 2004) means that firms can only change their internal architectural knowledge—their dominant logics—through disassociating themselves from their 'old' regional or cluster architectural knowledge. We also demonstrate that the cluster-relatedness of architectural knowledge makes identification, if not incorporation, of the potential source of new knowledge obvious to industry insiders. However, final incorporation of an alternative architecture requires eventual reconnection back to their roots, their original logic, to create a hybrid architectural knowledge based on a dialectic recombination of the old and new (Kogut and Zander, 1992, 1993).

In this sense, we are suggesting that development of architectural knowledge is both evolutionary and highly path-dependent (Henderson and Clark, 1990), but that geography provides a mechanism by which firms can identify, access and eventually incorporate unique architectural knowledge, engendering new evolutionary paths and levels of performance. These implications go beyond the level of the firm, and suggest that clusters may transform architectural knowledge through such pathways of reconfiguration. In this sense, the vertical cluster centered on FGS in Northern Italy became transformed by the incorporation of architectural knowledge from the horizontal cluster in Britain's Motorsport Valley. However, the hybrid architectural knowledge that developed in the Northern Italian region was distinctive in that it amalgamated both the engine-centric and the chassis/aero-centric knowledge of the two regions to create a new architecture of knowledge not easily replicated by those firms in the British cluster.

Firms do initially learn from the spillovers and comparisons that they can gain from their local cluster (Maskell, 2001), but the common architectural knowledge and limited technological innovation inherent to local component knowledge will eventually lead the cluster and its firms into a downward performance spiral (Pouder and St. John, 1996). We find that an expansive view of the geography of learning is essential to fundamental change at the firm and cluster level, as difficult as this is to accomplish. Foreign locations provide much greater variation in component and architectural knowledge. The first of these suggests the potential gain, whereas the second suggests the potential difficulty of foreign learning, but at some point it seems to become essential. What foreign clusters do offer are specific target locations for learning: FGS knew that the English 'Motorsport Valley' was the source of chassis and aerodynamic technology, so that any effort to incorporate such knowledge could at least be targeted appropriately (Henry et al., 1996).

Studying alternative foreign locations and the interplay between them may also provide benefits to scholars hoping to understand the evolution of clusters and regions. Persistent, distinguishable architectural knowledge can develop at the regional level, hence the Italian focus on the engine as the key to a winning racecar, contrasted for decades with the English focus on the design and materials of the chassis for the same purpose. If initial conditions can be determined through a comparison across geographical distance, then changes in knowledge, and particularly architectural knowledge, become apparent and traceable when addressed in the international setting. We have been able to present the transformation of FGS in detail because the movement of knowledge and people from England to Italy is easily distinguished. Local innovations do move, but while informal spillovers of knowledge may be valuable to the recipient firms, their pathways tend to be obscure and often beyond the reach of researchers.

The model that we have developed focuses on firm-level learning, but there are wider implications for the development and transformations of regions. The 'evolutionary turn' in economic geography places innovation and knowledge development as central to the processes of transformation of economic landscapes

(Boschma and Martin, 2007). Maskell and Malmberg (2007) suggest a link between the micro processes of firm-level innovation, selection and retention and evolutionary processes of knowledge creation at the regional level. Maskell (2014) recognizes that local economic systems have always required some degree of outside knowledge input to stay competitive. Our framework has broader implications for the mechanisms by which regions may evolve new knowledge and, therefore, adapt to changing exogenous landscapes. Economic geography has clearly established the existence of industry clusters, but has limited tools for understanding the mechanisms by which these distinctive locales influence the activities of companies in international industries. We believe that strategic management models offer relevant tools and propose the model development herein as one approach to understanding the relevance of location to strategy and of strategic management to the exploitation of locations.

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