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探究動態能耐的緣起：誘發多樣化的技術創新例規

Untangling the Emergence of Dynamic Capabilities: Variety-inducing Organizational Routines for Technological Innovation

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摘 要

究竟動態能耐是如何形成與演變的呢？這一直是動態能耐文獻上的核心議題。本研究嘗試從共同演化的觀點，勾勒企業如何交互運用策略更新與組織例規，轉化為技術創新的歷程，進而解構其創新能耐的組織內機制。實證上，我們採用質性研究方法，以台灣積體電路公司 (以下簡稱 TSMC) 為研究個案，深度剖析其做為晶圓專業製造服務廠商，如何歷經開創期的成熟製程創新 (1987-1998)、延展期的先進製程創新 (1999-2001)、以及更新期的產品創新 (2002-2007) 等動態發展階段。根據此深度研究的過程，我們提出誘發多樣化與縮減多樣化兩種組合組織例規的構念，並進而歸納出不同創新策略與組織例規間，在同一時期互動的 Y 路徑，以及跨期互動的 Z 路徑，作為理解 TSMC 建構與轉化其創新能耐的機制。最後，歸結本研究對動態能耐文獻的貢獻，以及技術創新策略的管理意涵。

【關鍵字】動態能耐、 策略更新、組織例規

Abstract

How dynamic capabilities emerge and evolve in an organization has been a central inquiry in the literature on dynamic capabilities. Applying the lens of co-evolutionary dynamics, we explore how an organization undertakes strategic renewals and uses organizational routines in order to facilitate technological innovation, leading to the emergence of dynamic capabilities. We discuss our qualitative case study of the sequential strategic renewals that enabled a specialized semiconductor foundry (Taiwan Semiconductor Manufacturing Corp., TSMC) to transform from a technology-latecomer to a technology-leader. TSMC's co-evolutionary dynamics for technological innovation started in the creating phase of mature process-innovation (1987-1998), evolved to the extending phase of advanced process-innovation (1999-2001), and then to the modifying phase of product innovation (2002-2007). Each phase illustrates the role of variety-inducing and variety-reducing organizational routines and their interactive patterns co-evolving with core strategies of technological innovation. We show how the organizational mechanisms for the formation and transformation of dynamic capabilities in the TSMC case follow cross-sectional Y-paths and longitudinal Z-paths. Finally, we discuss our research contributions and the managerial implications that can be drawn from our research.

【Keywords】dynamic capabilities, strategic renewal, organizational routine

1. Introduction

Strategic management scholars have given much attention to exploring the organizational mechanisms by which dynamic capabilities are created and sustained, which has become a central inquiry of the dynamic resource-based view (Eisenhardt & Martin, 2000; Helfat, Finkelstein, Mitchell, Peteraf, Singh, Teece, & Winter, 2007; Helfat & Peteraf, 2003; Makadok, 2001; Teece, Pisano, & Shuen, 1997). According to this mainstream literature, the dynamic capability is defined as "the capacity of an organization to purposefully create, extend, or modify its resource base" (Helfat et al., 2007). By implicitly assuming that a dynamic capability is distinct from its resource base, scholars in this field highlight the need for untangling the organizational antecedents and mechanisms by which an existing critical resource base would be qualitatively altered so that a new set of capabilities can dynamically emerge. Despite this research need, the existing literature on the dynamic resource-based view emphasizes outcomes, content and purposeful changes in the resource base of dynamic capabilities. Such research attempts to uncover what idiosyncratic capabilities an organization has and how these capabilities impact organizational performance, thus leaving the origin and the emerging processes of these capabilities by and large unanswered.

In order to address this literature gap, our research explores the organizational mechanisms facilitating the emerging processes of a focal dynamic capability, such as technological innovation. Specifically, instead of asking what kinds of dynamic capabilities enable a firm to survive and to grow (Helfat et al., 2007), we investigate what kinds of organizational antecendents and processes that enable an organization to develop its dynamic capabilities more vigorously. Unlike the mainstream literature which assumes strategy to be something an organization has, we view strategy as something that people do, or indeed "an activity" (Jarzabkowski, 2003; Johanson, Langley, Melin, & Whittington, 2007; Johnson, Melin, & Whittington, 2003). From the lens of "strategy as practice", our research attempts to untangle the emergence of dynamic capabilities via the co-evolutionary patterns where strategy contents and processes are intertwined. In such cross-sectional and longitudinal patterns, the implicit strategies and routines for forming and transforming dynamic capabilities may become explicit. In short, we explore how a focal dynamic capability evolutionarily emerges from its resource base by highlighting the role that organizational routines play in organizational change (Feldman & Rafaeli, 2002; Feldman, 2000; Feldman, 2003; Feldman & Pentland, 2003; Pentland & Feldman, 2005).

Despite the critical importance of such an inquiry, it is a challenge to choose the appropriate research methodology. This challenge lies in the conceptual ambiguity between resources and capabilities, as well as in the causal ambiguity between the changes of resource base and dynamic capabilities. In addition, the formation processes and the transformation mechanisms are more difficult to observe and analyze than the content and the outcomes of a dynamic capability addressed in the literature. We have therefore adopted a qualitative approach by studying one longitudinal case of an organization from the time of its establishment, focusing on how it forms and transforms its dynamic capability for technological innovation. Our longitudinal case study examines the intra-organizational co-evolutionary dynamics between strategies and routines, where a focal dynamic capability emerges from its prior and current resource base.

In short, our research aims to contribute to untangling the emergence of dynamic capabilities, a less explored inquiry in the literature on the dynamic resource-based view, by focusing on the following three complementary aspects; research inquiry, empirical context, and inductive findings. First, for contributing to the dynamic resource-based view, our research attempts to contribute to the dynamic resource-based literature by making the implicit organizational mechanisms explicit, in order to explore the formation and transformation processes of dynamic capabilities in the three sequential strategic renewals of creating, extending and modifying phases. Second, contributing to the research on technological innovation, we empirically articulate how a dynamic capability of technological innovation in an organization emerges and evolves from its prior and current resource base consisting of strategies and routines. Third, contributing to the literature on organizational routines, we suggest both cross-sectionally and longitudinally interactive patterns of strategies and routines, attesting to the argument that organizational routines serve as a source of continuous change (Feldman, 2000).

The following sections elaborate the story of co-evolutionary dynamics between strategies and routines for technological innovation as we proceed to untangle the emergence of dynamic capabilities. The story starts with the literature review, the research methods, the research findings that illustrate the organization-specific transformation mechanisms, and then concludes with research contributions and managerial implications.

2. Literature Review

In search for the emergence of dynamic capabilities, we reviewed the existing literature regarding the transformation mechanisms from its resource base to a dynamic capability. Our study is based on the dynamic resource-based view with a co-evolutionary perspective.

We apply this theoretical lens to the empirical context of organizational routines for technological innovation.

2.1 The Dynamic Resource-based View

Dynamic capabilities are the central construct of the dynamic resource-based view (Dosi, Nelson, & Winter, 2000; Eisenhardt & Martin, 2000; Helfat et al., 2007; Helfat & Peteraf, 2003; Makadok, 2001; Teece et al., 1997), which basically combines the resource-based view (Barney, 1991, 1996; Barney, Wright, & Ketchen Jr, 2001; Mahoney, 1995, 2001; Makadok, 2001) and the evolutionary theory (Dosi & Marengo, 2007; Huygens, Baden-Fuller, Van Den Bosch, & Volberda, 2001; Lovas & Ghoshal, 2000; Nelson & Winter, 1982). In principle, this line of research defines a dynamic capability as "the capacity of an organization to purposefully create, extend, or modify its resource base." (Helfat et al., 2007).

The key argument of the resource-base view is that the economic value creation and the sustainable competitive advantage of an organization are fundamentally driven by resources, which are characterized as rare, valuable, non-substitutable and difficult to imitate (Barney, 1996; Barney et al., 2001; Mahoney, 1995, 2001; Makadok, 2001; Wernerfelt, 1984). From the resource-based perspective, dynamic capabilities are a bundle of resources, which in the broadest sense consist of anything upon which an organization can draw in an effort to accomplish its aim; while in a narrower sense are defined as tangible, intangible, or human assets (Helfat et al., 2007).

Scholars further differentiate such narrowly-defined resources from those capabilities that the organization owns, controls, or has access to on a preferential basis. Accordingly, the antecedents of a dynamic capability are named its resource base, which includes narrowly-defined resources as well as prior and other capabilities (Helfat et al., 2007). However, a conceptual distinction is made between a dynamic capability and its resource base as the former involving some kind of purposeful change of the latter. In addition, the literature offers neither theoretical explanations nor empirical evidence on purposeful changes that may be different from one organization to another. To narrow those literature gaps, our research addresses the intra-organizational dynamics of those mechanisms that form and transform a resource base, with a focus on the evolutionary paths from the past towards the next phase of a dynamic capability.

There are a few studies portraying the transformation mechanisms in the development of dynamic capabilities. Arguing that the traditional resource-based view over-emphasizes outcomes, Eisenhardt and Martin (2000) called for more process-based research. In response to such a call, the mainstream literature categorizes managerial and organizational processes as two subsets of development versus deployment of dynamic capabilities (Maritan, 2007). Examples of such developmental processes include two intra-organizational processes of learning (Zollo & Winter, 2002) and investment (Maritan, 2001), as well as two inter-organizational processes of acquiring and allying with another organizational unit (Maritan, 2007).

Why cannot those specified antecedents and developmental processes fully answer our research inquiry, the emergence of dynamic capabilities? As Penrose argued, the resources themselves are never the input in the production process (Mahoney, 2005; Penrose, 1959). We argue that the existence of those antecedents specified in the literature is a sufficient, rather than a necessary condition. The necessary condition for a dynamic capability to emerge are the organization-specific mechanisms that enable a dynamic capability to become something more than and different from the sum of its antecedents or its resource base. In addition, we argue that these specified developmental processes, still confined by a static view of resources, simply describe the sourcing channels of new elements or changes in the overall resource base of an organization, rather than the organizational mechanisms that enable a specific dynamic capability to emerge Moreover, there are only few studies that illustrate the evolutionary paths of the creating, extending, and modifying phases, as well as the interacting paths between the three phases in the life-cycle of a focal dynamic capability.

Through the lens of co-evolutionary dynamics, we attempt to identify the intra-organizational mechanisms in order to untangle the emergence of dynamic capabilities. The extensive selection-adaptation literature spans diverse theoretical perspectives, but is inconclusive on the role of managerial intentionality in organizational adaptation (Volberda & Lewin, 2003). Based on different levels of managerial intentionality, Volberda and Lewin (2003) identified four co-evolutionary mechanisms that illustrate the extensive range of evolutionary paths in a population of organizations, including naïve selection, managed selection, hierarchical renewal and holistic renewal. Among these four mechanisms, the managed selection co-evolutionary path requires continuous attention to the reflection and refreshing of routines (Lewin & Volberda, 2003; Volberda & Lewin, 2003). In short, the co-evolutionary perspective emphasizes proactive managerial intentionality and the role of routines, which fits well with our research purpose.

In view of the shifting focus from evolution to co-evolution, Volberda and Lewin (2003) specifically called for longitudinal research on how an organization and its industry co-evolve and emerge over very long periods of time where several renewal engines can be compared. Responding to such a call, we have undertaken a longitudinal case study to illustrate multi-phase intra-organizational co-evolutionary dynamics between routines and strategies of technological innovation across three sequential strategic renewals leading towards the emergence of a focal capability. Strategic renewal refers to major strategic change preceded by internal experimentation and selection (Burgelman, Christensen, & Wheelwright, 2004; Crossan & Berdrow, 2003). Therefore, strategic renewals are driven by managerial intentionality as emphasized by the dynamic resource-based view as well as the co-evolutionary perspective.

2.2 Organizational Routines of Technological Innovation

In his seminal work "The Theory of Economic Development", Schumpeter (1934) defined technological innovation as the development of new ideas into marketable products and processes, while separating the technological change process into three sequential stages; invention, innovation and then diffusion. Different types of innovation have been identified in the literature, such as incremental versus radical, and product versus process (Burgelman et al., 2004). To illustrate the co-evolutionary dynamics of technological innovation, our research applies Porter (1983) distinction between product and process innovation. The former focuses on product design to enhance quality and features to meet customer needs, while the latter emphasizes process development in order to tune the production and delivery system towards improving performance.

Our research highlights the role of organizational routines in organizational change (Feldman & Rafaeli, 2002; Feldman, 2000, 2003; Feldman & Pentland, 2003; Pentland & Feldman, 2005), by specifying the intertwining patterns between routines and strategies in the emergence and evolution of the dynamic capability of technological innovation. Although both the behavioral theory of the firm (Cyert & March, 1963) and the evolutionary theory of economic change (Nelson & Winter, 1982) identify the critical role of organizational routines in breeding innovation, they suggest different concepts of routine change. Whereas Cyert and March (1963) regarded routine change as adaptation, Nelson and Winter (1982) called it mutation, especially evident in the advent of a crisis. Neither Cyert and March (1963) nor Nelson and Winter (1982) fully addressed whether and how an organization designs its new routines or changes its existing routines in order to adapt proactively to a future environment. In addition, research has so far by and large confined innovation to the outcome of routines, which serve as motivation, support, and guidance for innovation (Nelson & Winter, 1982). Therefore, whether, or indeed how, organizational routines themselves may also be developed as outcomes of innovation has not yet been theoretically discussed and empirically examined.

2.3 Making Implicit Mechanisms Explicit

In order to explore how a dynamic capability emerges from its resource base, our first attempt is to search for potential transformation mechanisms by examining the founding history of an organization. Since the tradability of resources is one of the key attributes that distinguishes them from capabilities (Helfat et al., 2007), all the resources which a new organization purchases from the market do not compose its capacity to create. Instead, we argue that the entrepreneurial capabilities that are embedded in the individual founders and parent organizations of a specific organization are the potential sources of dynamic capabilities. Furthermore, two ideal types of creation can be involved in the founding of a new organization: a transfer of existing resources and/or capabilities owned by its entrepreneurs, or the realization of new ideas. Although the former type is commonly observed, our research focuses on the latter type, based on our assertion that dynamic capabilities are about transformation into something new, rather than combinations of existing resources. Accordingly, our research focuses on the specific path where an organization realizes a new idea, and then extends to another new idea, which is different from the founding idea. As a result, we aim to make the implicit mechanisms that enable the transformation of a resource base into a capability more explicit.

3. Research Methods

This section discusses our research methods for exploring how the dynamic capability of technological innovation emerges and evolves in an organization. Methodologically, content research relies more on the deductive method as opposed to the inductive method that is more common in strategy process research, in which case-based methods have been suggested as a more appropriate approach to enhance our in-depth of understanding of dynamic capabilities (Helfat et al., 2007). We therefore selected the inductive case-based research approach for exploring the emergence of dynamic capabilities.

Specifically, we selected Taiwan Semiconductor Manufacturing Company (TSMC, hereafter), the world's largest semiconductor manufacturing service, as our empirical case. The choice of one corporate setting (Burgelman, 1994, 2002; Yin, 2002) reflects our research attempt to unravel the organizational-specific transformation mechanisms for dynamic capabilities. As this case is an intentional sample (Eisenhardt, 1989), we shall further elaborate on this choice after providing the case background. Our data collection includes not only archival and interview data about TSMC, but also comparisons with its major competitor, United Microelectronics Corporation (UMC, hereafter), and their interactions with the semiconductor industry since TSMC's establishment in 1987.

3.1 Case Background

TSMC was founded in 1987 as an international joint venture of ITRI (Industrial Technology Research Institute), a Taiwanese government-sponsored agency, and Philips, the Dutch technology-leader. TSMC is the world's first business organization establishing a pure-play semiconductor foundry model, specializing in the manufacturing of a variety of semiconductor products based on designs provided by its up-stream customers, fabless firms. Ever since its establishment, TSMC has successfully maintained its leading position in the foundry sub-industry it initiated either in terms of technological innovation or in terms of revenues. TSMC's turnover has grown more than 100 times in twenty years-from less than 100 million in 1990 to 10 billion US dollars in 2006.

Although initially a technology-latecomer in an emerging economy, it only took TSMC fifteen years to achieve a leading position in the top-ten club of semiconductor industry that surpasses its technology source, Philips, since it successfully launched the next-generational platform to manufacture 12-inch wafers in 2002. TSMC in Taiwan and Samsung in Korea are the only two semiconductor firms rooted in emerging economies that have achieved the extraordinary transition from a latecomer to a leader (ITRI, 2001~2008; Mathews & Cho, 1999). Moreover, TSMC is the only pure-play semiconductor foundry service provider among the top-ten semiconductor firms. In contrast, the other nine semiconductor leaders, including Samsung, all adopt the mainstream business-model of IDM (Integrated Device Manufacturer), meaning that they design, manufacture, and sell their own integrated circuit (IC) products to down-stream customers.

Competing in a technology-intensive industry, TSMC has invested about 6% of its revenues in research and development. The company specializes in process innovation and is strongly committed to technology leadership, as indicated by the following statement in its annual report;

In order to stay technologically ahead of our foundry competitors and maintain our market position in the foundry industry, we need to maintain a process technology leader not only in the foundry sector but in the semiconductor industry in general (TSMC, 2000~2006).

3.2 Why TSMC?

We selected TSMC as an intentional case for our research because of the following three reasons: the semiconductor industry is technology-intensive; TSMC is a technology-leader founded in an emerging economy; and the co-evolutionary dynamics between TSMC and the semiconductor industry are driven by technological innovation.

First, the semiconductor industry is characterized as technology-intensive due to its rapid changes in technology, which frequently result in the obsolescence of recently introduced products. Scholars define technology-intensive firms as those which “require complex coordination of knowledge and activities more generally.” (Helfat & Raubitschek, 2000). Following Moor's law (Moore, 1965) as a self-fulfilling prophecy, the semiconductor industry has regularly developed next-generational technologies to manufacture larger-sized wafers with increasingly higher circuit resolutions. As a result, more transistors or IC's can be designed and manufactured at lower average costs on a single wafer. Therefore, the semiconductor players continue to develop technological capabilities in order to maintain their margins. (TSMC, 2000~2006)

Second, as a new business model of pure-play semiconductor foundry, TSMC enjoys a unique technological scope by specializing in process innovation, rather than product innovation, which other mainstream IDM players are committed to. Such unique evolutionary paths for TSMC transforming from a technology-latecomer to a technology-leader and extending from process innovation to product innovation may generate useful lessons for other technology latecomers who are striving for innovation in emerging economies (Meyer, 2006; Wright, Filatotchev, Hoskisson, & Peng, 2005). Moreover, some scholars specifically highlight that the corporate renewal of technology industries is an increasingly important part of many emerging economies (Bruton, Dess, & Janney, 2007; Bruton & Rubanik, 2002).

Third, the interactions between TSMC and the semiconductor industry provide an applicable empirical context for studying the co-evolutionary dynamics of technological innovation. In addition to serving as a growth driver, Baumol (2002) highlighted the role of routinized innovation in facilitating the emerging trends of inter-firm cooperation in innovation. From a macro co-evolutionary perspective, TSMC has initiated two critical types of routinized innovation, which have then fundamentally changed the landscape of the semiconductor industry. First, TSMC's specialization in process innovation has accelerated the disintegration trend of the semiconductor industry, including fabless firms (IC design), packaging and testing firms in the 1990s, and design-service and SIP (Silicon Intellectual

Property) firms in 2000s. Second, the aggressive capacity expansion supported by TSMC's leading position in advanced process-technologies has pushed more incumbent semiconductor leaders as Intel to outsource their manufacturing to pure-foundry as TSMC, and some even to convert their business model from IDM to fabless as AMD.

3.3 Fieldwork and Data Collection

Our research was carried out in two stages. The first stage from the fall of 2006 throughout the summer of 2007 focused on the conceptual framework and the selection of TSMC as the focal case. The second stage from the fall of 2007 to the spring of 2008 focused on archival data analysis and field interviews with the employees, competitors, and partners of TSMC.

Both archival and interview data were collected and analyzed with a focus on the historical events of technological innovation. Regarding the archival data, we extensively searched the printed and electronic data about TSMC and UMC, mostly in Chinese (ITIS, 1991~2005; Mathews, 1997; Shih, 2003; Tung, 2001). The financial data was consolidated from the database of Taiwan Economic Journal (TEJ) and TSMC's filings to the Security Exchange Commission in the U.S. (TSMC, 2000~2006). Two cases on TSMC published by Harvard Business School (Iansiti, 2003) and Stanford Graduate School of Business (Shneorson, 2005) provided the historical background for TSMC's distributed innovation with its partners and for its e-foundry program. Searches on Google also helped locate relevant press releases and press interviews about the history of TSMC and UMC, with a focus on their R&D activities.

Confined by concerns with confidentiality about research and development activities, we eventually completed 15 interviews sessions as listed in Table 1. All interviewees requested to remain anonymous. Each interview lasted from one to two hours. The profile of our interviewees included 7 TSMC employees, 3 UMC employees, and 5 TSMC partners. Due to TSMC's practice of cross-functional transfer, 7 TSMC interviewees in fact covered multi-level and multi-functional perspectives, including engineer, director, vice president, and senior vice president of R&D; the quality and reliability engineering function; manager of design service, financial and sales, as well as manager and vice president of marketing. The profile of the UMC interviewees covered executives of R&D, financial as well as IC design functions. Further, the interviewed TSMC partners included executives of an EDA (Electronic Design Automation) supplier, two fabless customers, a venture capitalist, an ex-chairman of ITRI, which is the local founder of TSMC.

Table 1 The profile of interviewees

ID	Type	Organization	Function / Title (Current)	Interview Date YY/MM/DD	Duration
A	Focal Firm	TSMC	R&D / Senior VP	07/11/20	90 min.
B	Focal Firm	Ex-TSMC	R&D; Marketing / VP (Entrepreneur)	07/11/29	90 min.
C	Focal Firm	TSMC	R&D / Director	07/12/14	90 min.
D	Focal Firm	Ex-TSMC	Marketing; Design Service / Manager (Fabless)	07/12/12	120 min.
E	Focal Firm	TSMC	Sales / Manager	07/12/12	120 min.
F	Focal Firm	TSMC	R&D; Quality / Engineer	07/12/07	90 min.
G	Focal Firm	TSMC	Finance / Manager	07/12/17	60 min.
H	Competitor	UMC	Finance / Executive	07/11/12	90 min.
I	Competitor	UMC	IC Design / Director	07/12/31	120 min.
J	Competitor	Ex-UMC	R&D / Manager (Professor)	07/12/14	90 min.
K	Partner	Ex-Government	Chairman of ITRI (Professor)	07/12/06	90 min.
L	Partner	EDA	TSMC Account Director	07/12/21	120 min.
M	Partner	Fabless	TSMC Customer M / R&D VP	07/10/20	120 min.
N	Partner	Fabless	TSMC Customer N / GM	08/03/05	60 min.
O	Partner	VC	Venture Capitalist of TSMC Funds	07/10/19	120 min.

The interview process proceeded as follows. After introducing our research framework, we asked each interviewee to briefly narrate his or her history with TSMC and/or UMC, including service periods and functions, and then to describe his or her experience regarding the critical events (what-to-do) of technological innovation. For each historical event mentioned, the interviewees were asked to clarify whether their responses were based on their own experiences versus their interpretations on organizational history, and elaborate the event both in terms of activities (how-to-do) and strategies (why-to-do). After such individual memory-recall, we probed additional information about events collected from archival data and other interviewees. Since TSMC and UMC have maintained their competitive situation for long, we also asked all interviewees to compare these two companies. Although their comparison in historical facts was not the main focus of our research inquiry, their views did help us portray the unique co-evolutionary paths by which TSMC has proactively built its leadership in technological innovation and out-performed its competitors.

In those cases where interviewees declined our request to record the interview due to their concern with confidentiality, two interviewers, including the corresponding author and a research assistant, would compare notes after the interview to ensure the consistency of interview data. For all interviews, the transcripts were sent out to the interviewees for confirmation. The corresponding author then discussed the preliminary findings with the co-author, who did not participate in the interview in person, in order to triangulate our interpretations. In addition to such triangulation between researchers, the cross-verification of archival and interview data also helped triangulate the historical events and viewpoints recorded in documents versus memories.

As suggested by Eisenhardt (1989), although there is no standard format, the process of within-case analysis "allows the unique patterns of each case to emerge before the investigators push to generalize patterns across cases." Accordingly, we analyzed the archival and interview data by the following three sub-processes. First, applying the lens of dynamic capabilities on archival data, we specified the strategic renewals of TSMC as three phases of creating, extending, and modifying its dynamic capability of technological innovation. Second, applying the co-evolutionary lens on the interview data, we listed down all the relevant organizational routines in each phase, and then matched each routine and innovation strategy as shown in Figure 1. Third, we compared the characteristics of routines across different phases and innovation strategies, and then inductively specified cross-sectional and longitudinal patterns as Figure 2, 3, and 4.

As a result of the prior data-analysis process, we portrayed the co-evolutionary dynamics between innovation strategies and organizational routines of an emerging technology-leader and highlight the active role of organizational routines in facilitating organizational changes. The case of TSMC shows that it proactively renewed its innovative strategies and routines in order to speed up its development of next-generational technologies.

4. Research Findings

To provide the empirical evidence for untangling the emergence of dynamic capabilities, the following illustrates the co-evolutionary dynamics between strategies and routines targeting for technological innovation in three sequential strategic renewals of

TSMC. Each strategic renewal illustrates how TSMC's core innovation strategies were interwoven with emerging strategies over time, and how variety-inducing and variety-reducing routines knot those core strategies firmly together, as illustrated in Figure 1 and Figure 2. From such intra-organizational co-evolutionary dynamics, we inducted the cross-sectional Y-paths and longitudinal Z-paths intertwined by strategies and routines. Following the argument that dynamic capabilities could open up new strategy alternatives or “paths” for the firm (Helfat, 1997), we used “paths” mainly driven by variety-inducing routines to denote the mechanisms we found at the micro level for transforming the resource base into the dynamic capabilities of technological innovation. From the perspective of technological innovation, the case of TSMC shows an alternative co-evolutionary path, where process innovation is not only breeding, but also leading towards product innovation.

4.1 Multi-phase Strategic Renewals

Focusing on the life cycle of dynamic capabilities for technological innovation, we portrayed TSMC's intra-organizational co-evolutionary dynamics in terms of three sequential strategic renewals, as its core strategies of technological innovation evolved from the mature process, through the advanced process and into product innovation. Consistent with the definition of a dynamic capability as “the capacity of an organization to purposefully create, extend, or modify its resource base” (Helfat et al., 2007), we named TSMC's renewals the creating phase of mature process-innovation, which led to the extending phase of advanced process-innovation, and ended in the modifying phase of product innovation.

In the creating phase from 1987 to 1998, by applying mature process-technologies transferred from its foreign founder Philips in order to manufacture 6-inch and 8-inch wafers, TSMC's innovative business model as a pure-play foundry became the world's first semiconductor fab where in-house product innovation was not required at all. Because of the absence of product innovation, all TSMC employees were pushed into actively making the customers specialized in product technologies the top priority. During the second stage of renewal, when the semiconductor industry was geared towards developing the disruptive technology of cupper-interconnect as a replacement for aluminum-interconnect, TSMC extended its innovation capability from a latecomer in mature process-technologies to a leader in advanced process-technologies.

The critical historical event separating these sequential renewals was the launch of TSMC's first self-developed fabrication plant in 2001, manufacturing 12-inch wafers with the 0.13-micron platform equipped with black-diamond technology. This occurred one year before the competing silk-technology developed by the R&D alliance of IBM and UMC emerged. Outperforming its foundry competitor (UMC) and the technology leader (IBM), TSMC further strengthened its position as a leader in the sub-industry of semiconductor foundry, and expanded its customer base from fabless firms without any manufacturing facilities even to leading Integrated Devise Manufacturers (IDM) with manufacturing facilities such as Intel, thus becoming the leading certification-site of next-generational technologies.

During the third strategic renewal (2002-2007), which involved a gradual shift from process innovation to product innovation, TSMC faced the innovator's dilemma in that its advanced process technologies were too far ahead of the design-specs of its customers. Because the SIP houses prefer to design the SIP of standard cells in a higher resolution for customers who pay the IP licensing fee, it was more difficult for TSMC to find a development partner who would provide a simulated recipe and be equipped with all the necessary SIPs for test-runs in the R&D phase and in the operational phase as well. Therefore, TSMC had to expand its design capabilities by hiring and merging up to 600 design engineers in 2007, in order to prepare the in-house simulated recipe, initially as complementary resources for SIP and design partners. Serving today as an enabler of next-generational platforms, the emerging competence of SIP design may push TSMC to drift away from its business model of dedicated foundry relying on advanced process technologies as its core competence.

4.2 Variety-inducing v.s. Variety-reducing Routines

As illustrated in Figure 1, our research identifies variety-inducing (denoted as V-I) and variety-reducing (denoted as V-R) routines in each phase of strategic renewal. These two types of organizational routines reveal contrasting attributes in facilitating the emergence and the evolution of dynamic capabilities. A variety-reducing routine is defined as a set of organizational activities that reduce the degree of variety in the organizational resources in view of strengthening the organization's prior or current core strategies. In contrast, a variety-inducing routine is defined as a set of organizational activities that commit resources beyond the scope of the core strategies, so that the organizational variety is induced to support its current strategies or emerging strategic renewal process.

The concept of variety-inducing stems from the following episodes, occurred during TSMC's extending phase of dynamic capability in 1999-2001. The first example is a pink anti-dust suit, designed to accommodate the developmental requirements of multiple technologies in the same R&D site. The shift of the leading wafer-size from 8-inch to 12-inch wafers forced the R&D team of TSMC to catch up with mature process-technologies for 8-inch wafers, such as aluminum-interconnect, and simultaneously to develop advanced process-technologies for 12-inch wafers, such as copper-interconnect. However, the new material of copper would contaminate the existing R&D and production lines of aluminum-interconnect, thus decreasing yields, increasing associated manufacturing costs and postponing the delivery time. To avoid such risky contamination, the copper-interconnect team members had to wear a unique pink suit, and the aluminum-interconnect team members wearing a white anti-dust suit were to maintain a safe distance from those wearing "threatening" pink suits. Therefore, the "pink suit" represents an artifact of variety-inducing routines for both physical and psychological contamination-problems embedded in the technological development and operational migration.

The second example comes from an interview with the R&D director in charge of copper-interconnect development. He highlighted how one of the thermo-electronic experiments showed that the low-K performance of silk material significantly decreases in higher temperatures. Because testing such a simulated design-recipe developed from its manufactured IC for projectors, which require high temperature resistance, TSMC was able to give up silk as the low-K material much earlier than the silk technology-leader, IBM. Such a thermo-electronic experiment represents an artifact of immunity toward potential problems when migrating to a new technology. The later success of TSMC to develop low-K technology using the alternative black-diamond material in 2000 became the first milestone on its journey from latecomer to technology-leader. The contrasting trends of sales-growth between TSMC and IBM Microelectronics attest to such a transformation. In 1999, TSMC's sales turnover was only about half of IBM's. In 2003, TSMC's sales reached 2.3 times those of IBM, who suffered a 3% decrease compared with the sales in 1999. (ITRI, 2001~2008)

Why do variety-inducing routines matter more than variety-reducing routines, especially when untangling the emergence of dynamic capabilities of technological innovation? First, variety-reducing routines are posited as backward-looking, driving inertia and the maintaining of prior and current strategies; while variety-inducing routines are posited as forward-looking, explicitly driving current strategy and implicitly driving future strategy or purposeful change. Accordingly, during each phase of dynamic capability, we expect to find both variety-inducing and variety-reducing routines to support the current core strategies. Based on our assertion that the core strategies and supported routines of an organization are easier observable and imitated by other organizations than those which support emerging or future strategies, our research attempts to make the implicit drivers of dynamic capabilities more explicit.

Second, one intra-organizational mechanism that facilitates TSMC's successful transformation from a technology-latecomer to a leader is its unique and intertwined pattern of variety-inducing and variety-reducing routines and the evolving core strategies for technological innovation. Despite the fact that TSMC's key competitor UMC has imitated its core strategies, such imitation not only makes UMC lag behind TSMC in terms of technology innovation, but also confines UMC to being a technological latecomer. Therefore, our research attempts to establish alternative explanations of the fact that TSMC outperforms its direct rival in transformation.

The first explanation is TSMC's capability over time to devise new routines co-evolving with its core strategies as illustrated in Figure 1. The second explanation is TSMC's capability to develop variety-inducing routines facilitating the next strategic renewals as an implicit barrier to imitation for its competitors. The competitive dynamics of TSMC and UMC attest to our assertion that the imitation of the core strategy of a technology leader is not relevant to the emergence of dynamic capabilities. The third explanation is how TSMC's innovative business model co-evolved with the semiconductor industry to transform its specialization in process innovation. The existing literature tends to underplay such a co-evolutionary role of process innovation. For example, the literature on technology cycles assumes that the basis of competition starts with product innovation, by competing for the dominant design, and then shifts to process innovation, by competing for lower costs and more features (Tushman & O'Reilly III, 1996). However, our case study shows an alternative co-evolutionary path for organizations specializing in process innovation to expand into product innovation even beyond firm boundaries.

4.3 Cross-sectional Y-paths

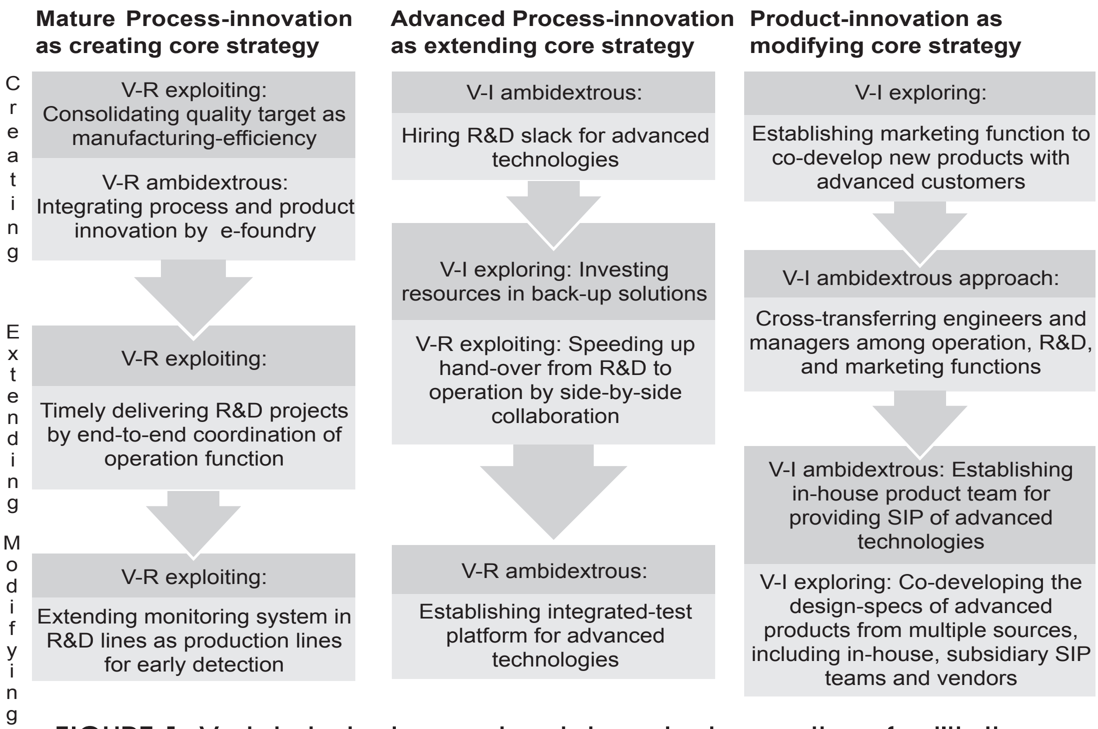


FIGURE 1 Variety-inducing and variety-reducing routines facilitating technological innovation

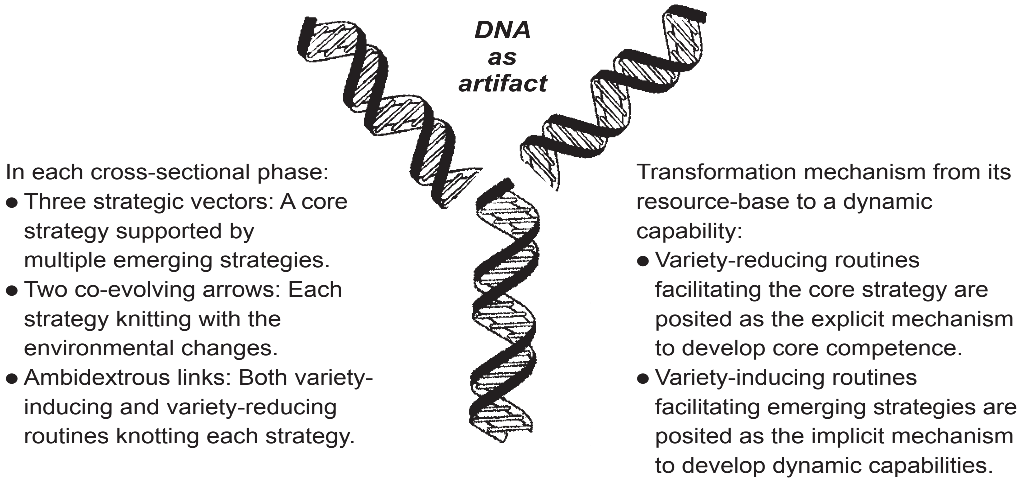
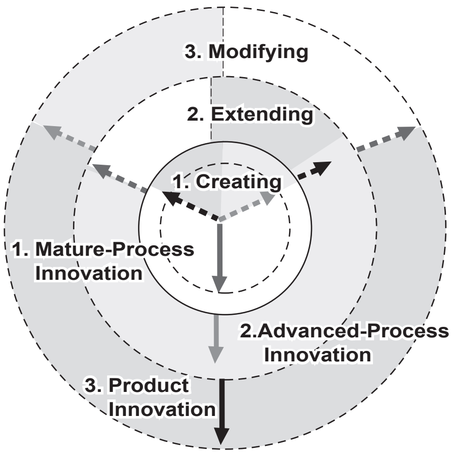


FIGURE 2 Cross-sectional Y-path consisting of strategies and routines



1. Creating Phase (1987-1998):
   Core strategy:
- Mature process-innovation emerging strategies:
- Advanced process-innovation product-innovation

2. Extending Phase (1999-2001):
   Core strategy:
- Advanced process-innovation emerging strategies:
- Product-innovation
- Mature process-innovation

3. Modifying Phase (2002-2007):
   Core strategy:
- Product-innovation emerging strategies:
- Mature process-innovation
- Advanced process-innovation

FIGURE 3 Rotational pattern of multiple core strategies of technological innovation

Based on TSMC's co-evolutionary dynamics for technological innovation, our research further specifies interlocking patterns consisting of routines and strategies as cross-sectional Y-paths and longitudinal Z-paths. Our findings of the multiple phases of TSMC's strategic renewals show how its core strategy of technological innovation has evolved from mature process-innovation in the creating phase (1987-1998), to advanced process-innovation in the extending phase (1999-2001), and then to product-innovation in the modifying phase (2002-2007). The following describes what kinds of organizational routines support the core and emerging strategies in each phase of dynamic capability formation, as illustrated in Figure 1, and then elaborates how we can use two useful conceptualizations, Y-path and Z-path, to understand the evolution processes based on variety-inducing and variety-reducing routines, as shown in Figures 2, 3, and 4.

In addition to the paired constructs of "variety-inducing" and "variety-reducing", we further categorized innovation routines according to the three characteristics of exploiting, exploring and ambidextrous, in order to reflect how innovation routines impact organizational change in various ways. As March (1991) highlighted, a central concern for studies of adaptive processes is the relationship between the exploration of new possibilities and the exploitation of old certainties (Holland, 1975; March, 1991; Schumpeter, 1934). An ambidextrous organization originally refers to an organization which is able to implement both incremental and revolutionary changes (O'Reilly III & Tushman, 2004; Tushman & O'Reilly III, 1996). Some scholars further apply the construct of ambidexterity to examining the dynamics between the twin concepts of organizational learning-exploration versus exploitation (He & Wong, 2004).

Taking this notion into our conceptualization, we found two types of variety-reducing routines supporting the core strategy of mature process innovation during the creating phase of TSMC's dynamic capability for technological innovation (1987-1998), as shown in the three top-cells of Figure 1. We labeled the routine of consolidating quality measures through manufacturing-efficiency in terms of lower cost and higher yield as the “exploiting approach”, because such industry practice was only incrementally applied to a new organization. In addition, the routine of integrating process and product innovation by “e-foundry”, a web-based customer-service platform newly developed by TSMC, was labeled an “ambidextrous approach” because such a new routine not only facilitated the incremental change of a foundry service provider but also paved the way for revolutionary change toward future product innovation renewal.

In contrast, we also identified two types of variety-inducing routines to support the next core strategies. The first routine of hiring fresh Ph.D.'s and seniors with R&D experience from other semiconductor leaders as organizational slack for developing the next core of advanced technology was categorized as an “ambidextrous approach” because such increased organizational variety in R&D talents would support both the current core strategy and the next core strategy of advanced process innovation. The second routine of establishing a marketing function to co-develop new products with advanced customers was labeled an “exploring approach” because such increased variety in functional talents brought the foundation toward the emerging strategy of product innovation.

During the extending phase (1999-2001), as shown in the three middle-cells of Figure 1, we found two types of variety-reducing routines to support the prior and current core strategies. The first new routine requiring timely delivery of R&D projects by end-to-end coordination of the operation function was extended from the practice supporting the prior core strategy of mature process innovation. The second new routine of speeding up handover from the R&D function to the operation function through side-by-side collaboration was mainly designed to support the high time pressure when developing advanced technologies. Both routines are characterized as the “exploiting approach” because they only incrementally directed more R&D resources toward the operation function. For variety-inducing routines, we also found that TSMC invested resources in alternative solutions as a back-up for their black diamond technology, including silk technology used by IBM and phase-in projects with IDM, in order to support the core strategy of advanced process-innovation. The second variety-inducing routine of cross-transferring engineers and managers among the operation, R&D, and marketing functions was designed to facilitate the emerging strategy of product innovation. We label the first back-up routine an “exploring approach” because such R&D investment helps explore new technologies, and the second routine “ambidextrous” because such increased organizational variety in human resources supports both advanced process innovation and product innovation.

During the modifying phase (2002-2007), as illustrated in the three bottom-cells of Figure 1, our research found two types of variety-reducing routines to support the prior core strategy of product innovation. The new routine of extending the monitoring systems of the production lines to the R&D lines for the early detection of potential operation problems is categorized as an “exploiting approach” because such routine change only incrementally applies the routine developed to support mature process innovation into a new functional unit. The second routine of establishing an integrated-test platform for advanced technologies is categorized as an “ambidextrous approach” for radical process innovation, because such a new routine facilitates both incremental change for advanced technologies and revolutionary change toward product innovation. In contrast, we also identified two types of variety-inducing routines for supporting the current yet emerging strategy of product innovation. The first routine of establishing an in-house product team for providing SIP of advanced technologies is attributed to the “ambidextrous approach” because such a new routine directly facilitates product innovation, while indirectly enhancing TSMC's capability to utilize advanced process technologies. The second routine of co-developing the design-specs of advanced products from multiple sources, including in-house, subsidiary SIP teams and vendors is attributed to the “exploring approach” because such a new routine implicitly pushes TSMC away from its core competence of process innovation.

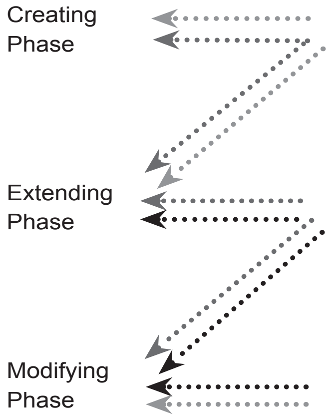
Shifting from the horizontal perspective of the three phases of creating, extending, and modifying capabilities to the vertical perspective of three evolving core strategies of technological innovation in Figure 1, our research found four types of organizational routines to support the core strategy of mature process-innovation all categorized as variety-reducing; while those supporting the core strategy of product innovation were all categorized as variety-inducing. Viewing the core strategy of advanced process-innovation from the life cycle perspective, the attributes of its four supporting routines started from ambidextrous variety-inducing in the creating phase as a source of organizational change, evolved to a mix of exploring variety-inducing and exploiting variety-reducing in the extending phase, and finally became ambidextrous variety-reducing in the modifying phase as a source of organizational inertia (Dobrev, Kim, & Carroll, 2003; Huff, Huff, & Thomas, 1992; Tripsas & Gavetti, 2000). Moreover, we also inductively found that most variety-reducing routines shared the exploiting attribute; in contrast, most variety-inducing routines shared the exploring attribute. Both the variety-inducing type and the variety-reducing type of routines can be categorized as ambidextrous depending upon whether they support multiple core strategies over time.

As illustrated in Figure 2, the concept of DNA borrowed from biology is used as an artifact to portray the cross-sectional interlocking patterns between strategies and routines. In each phase of dynamic capability, the DNA shape of a Y-path manifests three key attributes of such interlocking patterns. First, the three strategic vectors of a Y-path consist of a current core strategy (such as mature process innovation in the creating phase) and multiple emerging strategies (such as the next core strategies of advanced process innovation and product innovation). Second, the two co-evolving arrows of each vector indicate each strategy (either core or emerging) interacting with changes in the environment. Third, the ambidextrous links between the two co-evolving arrows indicate both variety-inducing and variety-reducing routines knotting each strategy vector.

Besides the DNA analogy, vector is used as an artifact where strategy is seen as the direction of the vector, and intertwined routines as the power to support each directional strategy. Accordingly, the mechanism for transforming the resource-base into a dynamic capability is portrayed as two interacting sub-mechanisms-variety-reducing routines are posited as the explicit mechanism to develop a core competence to support the prior and current strategy, and variety-inducing routines are posited as the implicit mechanism to develop dynamic capabilities to facilitate future strategic renewals.

4.4 Longitudinal Z-paths

Bridging together the cross-sectional Y-path and the longitudinal Z-path, Figure 3 further demonstrates how the rotational Y-path consists of evolving core strategies for technological innovation in the three creating, extending, and modifying phases of dynamic capability. In each phase, TSMC is found to rotate its core strategy and its multiple emerging strategies. In the TSMC case, the core strategy of mature process-innovation in the creating phase shifted to an emerging strategy in the following phases. Such formation and transformation of a mature process-innovation strategy and its supportive routines fostered the next core strategy of advanced process-innovation in the extending phase and then that of product-innovation in the modifying phase.



- Similar as Y-path, a core strategy is facilitated by multiple variety-inducing and variety-reducing routines in each phase.
- To form a Z-path, a core strategy in the next phase is facilitated by multiple variety-inducing and variety-reducing routines in both current and prior phases.
- Taking the extending phases as an example, the core strategy of advanced-process innovation was implicitly (denoted as dotted line) supported by the routines cascading from the prior phase as well as the routines to support the emerging strategies of product innovation and mature process-innovation in the current phase.

FIGURE 4 Longitudinal Z-path consisting of strategies and routines

Similar to the rotational Y-path, our research highlights the cascading effects of prior strategies and routines on the following phases of dynamic capability. The cascading effect is denoted as the longitudinal impact starting from the formation of a core strategy in the current phase to its subsequent transformation into the next core strategy or strategic renewal. As illustrated in Figure 4, in order to form a longitudinal Z-path, a core strategy in each phase is implicitly supported by multiple emerging strategies and their supportive routines in both prior and current phases. Taking the extending phases as an example (Figure 1 and Figure 3), the core strategy of advanced-process innovation was implicitly supported by the routines for the emerging strategies cascading from the prior creating phase, such as hiring R&D resource-slacks to facilitate the emerging strategy of advanced process-innovation and establishing a marketing function mainly for product innovation, as well as the routines in the current phase, such as coordinating by operation function mainly for the prior strategy of mature process-innovation and cross-transferring engineers to stimulate the third strategic renewal for product-innovation.

To sum up, our case study on TSMC's three strategic renewals between 1987 and 2007 illustrates the essence of variety-inducing and variety-reducing organizational routines and their interactive patterns with core strategies for technological innovation. Our research further specifies cross-sectional Y-paths and longitudinal Z-paths as organizational mechanisms for the formation and transformation of dynamic capabilities. As highlighted by Eisenhardt (1989) that a good case-based research shall contribute new ideas to extend and add depths in existing views of theory-building research, we posit the following proposition to conclude our research finding: Within the context of technological innovation, a firm's dynamic capabilities will emerge and evolve from interactive patterns between variety-inducing and variety-reducing routines.

5. Implications and Conclusions

How do dynamic capabilities emerge and evolve over time? More specifically, how is the dynamic capability for technological innovation formed and transformed in an organization? In order to address this question, we portrayed the renewal journey of TSMC, who successfully transformed itself from a technology-latecomer into an industry-leader through creating, extending, and modifying its dynamic capability for technological innovation. The following section further discusses the contribution of our longitudinal case study and managerial implications that can be drawn from our research.

5.1 Research Contributions

Our research contributes to explaining the emergence of technological innovation in terms of the following theoretical aspects; a dynamic resource-based view with a focus on the co-evolutionary perspective, technological innovation with a focus on dynamic ambidexterity and organizational routines, with a focus on dynamic variety.

First of all, for the literature on the dynamic resource-based view, by covering 20 years of technology development at TSMC our study provides an example of how the co-evolutionary dynamics between strategies and routines form and transform a firm's dynamic capability for technological innovation in three sequential strategic renewals. We found that TSMC's core strategy was implicitly driven by variety-inducing routines cascading from the prior phase and facilitating in the current phase. In addition, TSMC's organization-specific Y-path and Z-path explain why and when organizations with similar resource bases, like TSMC and UMC, will purposefully alter their resource base in the direction of a focal dynamic capability. In other words, the contrast between the innovation capabilities of TMSC and those of its major competitor, UMC, also provide an explanation for why a firm does something different than before, as well as different from others, and the organization-specific mechanisms that induces it to do so. As a result, our research posits the cross-sectional Y-path and longitudinal Z-path consisting of core and emerging strategies as well as variety-inducing and variety-reducing routines as the mechanisms behind the transformation of its prior resource base into a focal dynamic capability.

Second, for the literature on technological innovation, the successful transformation of

TSMC from a technology-latecomer to a leader demonstrates an alternative evolutionary path in which process innovation not only breeds but also leads product innovation. TSMC's unique evolutionary paths show that its core capability of technological innovation was built upon the foundation of mature process-innovation, extended to advanced process-innovation, and then modified to product innovation. In addition, TSMC's intra-organizational co-evolutionary dynamics between strategies and routines suggest an alternatively complementary relationship between exploration and exploitation, as a contribution to the literature of ambidextrous organization (Tushman & O'Reilly III, 1996). The literature on organizational learning regards the relations between exploration and exploitation as contradicting orientations in resource allocation, particularly those introduced by the distribution of costs and benefits across time and space, and the effects of ecological interaction (Gupta, Smith, & Shalley, 2006; March, 1991). Unlike such trade-offs between exploitation and exploration, the co-evolutionary dynamics of TSMC may demonstrate a new conceptualization of “dynamic ambidexterity” between strategies and routines for technological innovation cascading from the prior phase to transform the core strategy and to stimulate the next strategic renewal.

Third, for the literature on organizational routines, our research brings out the facilitating role of organizational routines in forming and transforming the dynamic capability of technological innovation, both in a cross-sectional and a longitudinal sense. Accordingly, our research findings empirically support the argument that organizational routines serve as stimuli to organizational changes (Feldman & Rafaeli, 2002; Feldman, 2000, 2003; Feldman & Pentland, 2003; Pentland & Feldman, 2005). Our case study of TSMC demonstrates how the “dynamic variety” of organization routines facilitates the emergence and evolution of technological innovation. We find that variety-inducing attributes play a more critical role in driving the next direction and transformation of core strategy than variety-reducing attributes. Applying the analytical lens of complexity theory (Axelrod & Cohen, 2000; Waldrop, 1992), Brown and Eisenhardt (1998) argued that the underlying insight behind competing on the edge is that strategy is the result of a firm's organizing to change constantly and letting a semi-coherent strategic direction emerge from that organization. Sharing the focus on emergence, we further argue that one of the reasons for an organization to keep its strategic direction semi-coherent or on the edge of order and chaos is because a core strategy is facilitated by multiple emerging strategies and variety-inducing routines.

5.2 Managerial Implications

From our study, we see the following implications for managers; reducing the barriers to imitating best practice for technological innovation, innovating through sequential strategic renewals, harnessing exploration and exploitation through dynamic ambidexterity, and finally reducing organizational inertia through dynamic variety.

First, when the transformation mechanisms behind dynamic capabilities become more explicit, organizations may reduce their barriers to imitating best practice especially for technological innovation by developing and improving such mechanisms. Eisenhardt and Martin (2000) argued that dynamic capabilities have significant commonalities across firms, which is popularly termed as “best practice”, although they are idiosyncratic in their details and path dependent in their emergence. Given such commonalities, it is still unclear why some best practices are easier to imitate, while others are more difficult. Our findings about TSMC's co-evolutionary dynamics help explain why it is so difficult for other latecomers, like UMC, to imitate TSMC's achievement in technological innovation. Furthermore, our research specifies not only the idiosyncratic paths of TSMC as best practice, but also their underlying mechanisms as Y-path and Z-path. In brief, the barriers to imitation are made up by the complexity of intentionally managing various organizational routines.

Second, the successful transformation of TSMC in developing its dynamic capability through sequential strategic renewals for creating, extending, and modifying technological innovation may help lower the barriers to innovate, especially for a technology latecomer in an emerging economy. Although we found variety-inducing routines serving as renewal enablers for TSMC to overcome its disadvantage as a technology-latecomer, variety-inducing routines commit resources beyond the scope of core strategies, and may therefore be too costly for technological latecomers, owing to the inherited lag in the technological innovation and the resource constraints of emerging economies. Nonetheless, TSMC's sequential strategic renewals may offer a potential solution to overcome such disadvantages and difficulties faced by industry latecomers.

Third, our specified ambidextrous routines may help lower the barriers to harness exploration and exploitation. In each phase of a dynamic capability, the TSMC case shows how the ambidextrous involves exploring next-generational technologies while maintaining the foundation of exploiting existing technologies. Accordingly, we suggest that managers proactively initiate changes as well as adapt responsively to the ever-changing environment. Specifically, the next direction of technological innovation demonstrated by the TSMC case is implicitly driven by emerging strategies and variety-inducing routines in the prior phase, especially when highlighting the cascading effects of prior routines and the rotational pattern of core strategies. After applying these interlocking paths structured by core strategies while strengthened by variety-inducing routines, managers may further develop routines matching with the core strategy in the following phases.

Last but not least, from the perspective of organizational inertia (Dobrev et al., 2003; Huff et al., 1992; Tripsas & Gavetti, 2000), the rotational patterns of TSMC imply that the emerging strategies and the variety-inducing routines in the prior phase may serve to reduce the organizational resistance to change or the unfavorable effect of inertia on technological innovation in the current phase. The existing literature on inertia provides empirical evidence that established firms often have difficulties adapting to radical technological change (Tripsas & Gavetti, 2000). Contrastingly, the successful transformation of TSMC from latecomer to leader attests to the potential contribution of multiple emerging strategies and variety-inducing routines in enhancing the organizational readiness to cope with the strategic challenges of organizational change. Because TSMC's core strategy in the current phase evolved from its emerging strategy in the prior phase, its organizational resistance to change toward such new strategy was lower than its key competitors, like UMC and IBM, who were not exposed to the same dynamic variety in terms of strategies and routines as TSMC.

5.3 Conclusion

In conclusion, our research aims to contribute to making implicit transformation mechanisms explicit by way of a qualitative approach and inductive methods. As an attempt to untangle the emergence of dynamic capabilities, our research highlights how organizational routines serve as a change agent in multiple phases of strategic renewals. Based on the co-evolutionary dynamics between strategies and routines for technological innovation, we characterize intra-organizational mechanisms as cross-sectional Y-paths and longitudinal Z-paths, displaying a rotational pattern between core and emerging strategies and cascading effects of variety-inducing and variety-reducing routines. Dynamic ambidexterity and dynamic variety are suggested in order to lower the organizational barriers to imitating best practice and to breed dynamic capabilities by innovating through sequential strategic renewals. Based on our research findings, we further propose the proposition that *within the context of technological innovation, a firm's dynamic capabilities will emerge and evolve from interactive patterns between variety-inducing and variety-reducing routines.*

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