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The Tables Have Turned: How Can the Information Systems Field Contribute to Technology and Innovation Management Research?

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Abstract

Pervasive digitalization has brought new disruptive changes in the economy. At the core of these disruptive changes is digitally enabled generativity. In this paper, I argue that scholars must offer new theoretical models and insights that guide management practices in the age of generativity that can extend, or perhaps supplant, the prevailing emphasis on modularity. To that end, I suggest that information systems scholars must attend explicitly to the generative materiality of digital artifacts by drawing on the sociomaterial perspective, which has emerged as a robust intellectual tradition of the IS community. This paper is a provocation for those IS scholars who are willing to stretch the boundaries of their intellectual imagination beyond the comfort of IS journals and conferences, and offers a promising path forward.

Keywords: *Digital Innovation, Generativity, Modularity.*

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1. Introduction

In the second half of the 20th century, modularity emerged as a powerful idea for dealing with increasingly complex systems (Schilling, 2000; Simon, 1962). Noting the transformative power of this perspective, Baldwin and Clark (1997) declared the arrival of the “age of modularity”. They argue that modularity was at the heart of the remarkable rate of innovation in recent history because modularity enables firms to design and build a complex product and process from smaller subsystems and components. Although modularity is often associated with a product architecture (Ulrich, 1995), it has broad implications on how firms should be organized in designing and producing complex products and processes (Sosa et al., 2004). Indeed, modularity has provided an intellectual bedrock of organizational scholarship that has produced a significant body of work in the domain of innovation and technology management (Garud, Kumaraswamy, & Langlois, 2003; Schilling, 2000).

The information systems (IS) community has primarily played the role of a recipient of the theory of modularity. Much IS research over the last three decades has been influenced—explicitly or implicitly—by modularity and its consequences in organizations. Modularity has provided an important context for some of the key topics that IS scholars have studied in the past. Given the pervasive digitalization that we see in society (Lyytinen & Yoo, 2002), however, the logic of modularity can no longer provide a sufficient theoretical framework to explain contemporary economic phenomena. Products and services that are enabled by programmable digital technologies and that are connected to the Internet are unleashing a new wave of generative innovations (Yoo, Henfridsson, & Lyytinen, 2010). Generativity refers to an “overall capacity to produce unprompted change driven by large, varied, and uncoordinated audiences” (Zittrain, 2006, p. 1980). Such innovations are distinctly different from previous innovations that are rooted in the precepts of modularity (Tilson Lyytinen, & Sorenson, 2010; Yoo, Bolad, Lyytinen, & Majchrzak, 2012; Yoo et al., 2010). Going forward, management scholars need to account for the changes brought by digitalization, and build new theoretical frameworks to guide efforts to organize generative innovations. In this paper, I argue that the IS community can lead such an effort by drawing on its intellectual tradition of sociomateriality. Below, after describing the shift from modularity to generativity, I propose how IS scholars might work toward a sociomaterial theory of organizing for generativity.

2. The Age of Modularity

Modularity is a general systems concept. It provides “design rules” that define how a system is divided into subsystems and how those subsystems are interconnected (Baldwin & Clark, 2000; Schilling, 2000). Modularity offers simplicity in dealing with a complex system. One can focus on an overall system—whether it is a product or process—while leaving the detail design of subsystems and components to others. Modularity allows for an effective division of labor among different actors during design and production (Sosa, Eppinger, & Rowles, 2004; Staudenmayer, Tripsas, & Tucci, 2005). Not only does modularity reduce complexity, it also increases flexibility by allowing “mixing-and-matching” (Garud & Kumaraswamy, 1995; Sanchez & Mahoney, 1996). Such a mixing-and-matching strategy is possible because one can replace one component with another as long as they both confirm to the same standardized interface. Baldwin and Clark (2000) note that modularity can provide real options to manufacturers because it allows rapid customization and multiple evolutionary trajectories.

Scholars have also noted that modularity influences the evolution of products and product life cycles (Abernathy & Utterback, 1978; Clark, 1985). For example, Garud et al. (2003) note that modularity provides the necessary stability for a system in an evolutionary environment, and enhances the speed, scope and reach of innovation through improved retention and reuse of components. Tushman and Murmann (1998) also note that the emergence of a dominant design is associated with the establishment of standardized interfaces among subsystems and components that are enabled by modularity. Dominant designs are turning points for an industry; custom-made products evolve into standardized products that can take advantage of advanced manufacturing systems (Abernathy & Utterback, 1978). As a result, dominant designs lead to a rapid expansion of market and price/performance improvements (Anderson & Tushman, 1990).

Not only does modularity affect product evolution, but it also affects the way firms are organized (Sanchez & Mahoney, 1996; Schilling, 2000). Because standardized interfaces and hidden design parameters encapsulated in modules lower transactions costs, firms can effectively pursue external network effects by leveraging specialized component producers (Langlois, 1992; Shapiro & Varian, 1999). As a result, traditional hierarchical, vertically integrated firms become disintegrated and firms increasingly rely on the external network of specialized firms (Baldwin & Clark, 2000; Langlois, 1992). Langlois and Robertson (1992) demonstrate how the modular architecture has brought vertical disintegration to the computer industry and the emergence of specialized components developers. Similar effects of modularity on organizational structure have been observed in the software (Chandler & Cortada, 2000) and telecommunication industries (Tuomi, 2002). Together with the advent of the Internet, which radically reduced communication and coordination costs (Brynjolfsson, Malone, Gurbaxani, Kambil, 1994; Malone, Yates, Benjamin, 1987), modularity has disaggregated the traditional value chain into value networks (Garud et al., 2003; Sosa, Eppinger, & Rowles, 2007). Thus, modularity has enabled economies of scale, scope, and substitution (Garud & Kumaraswamy, 1995). Firms like Cisco, Dell, and Nokia invested heavily in corporate IT infrastructures to realize “net-enabled” value networks (Sambamurthy & Zmud, 2000) whereby design and production activities could be radically distributed among networks of specialized firms (Nohria & Eccles, 1992). As a result, the key source of value creation has become the agility that flows from the ability to rapidly re-combine components in a product architecture without sacrificing cost or quality (Eisenhardt & Martin, 2000; Sambamurthy, Bharadwaj, & Grover, 2003).

A large body of IS research over the last three decades has been carried out in this precise historical context of organizational shifts from vertically integrated hierarchies to networks of distributed, specialized firms, teams, and individuals (Fulk & DeSanctis, 1995; Sambamurthy & Zmud, 2000; Zammuto, Griffith, Majchrzak, Dougherty, & Faraj, 2007). Such topics as process-centric organizational designs, virtual teams, supply chain management, and knowledge management all deal with, in part, different aspects of challenges that modularity has brought to firms. A process-centric view of organizations and IT’s role in it (Davenport, 1993; Overby, Slaughter, & Konsynski, 2010), for example, stems from the modularization of processes. Virtual teams became an important issue for IS scholars in part because firms increasingly deal with individuals and teams with specialized skills who are distributed globally (Jarvenpaa & Leidner, 1999). Similarly, supply chain management and off-shoring directly deal with the consequences of modularity that moves firms from hierarchical values chain to value networks (Leonardi & Bailey, 2008; Levina & Ross, 2003; Malhotra, Gosain, & El-Sawy, 2005). Finally, because modularity promotes reusability of the same capability through the principle of mixing and matching, knowledge sharing and reuse across different contexts become an important challenge that IS scholars have embraced (Alavi & Leidner, 1999). In this sense, the research agenda of the IS community over the last three decades has been, to a degree, shaped by the modularity discourse that began with technology and innovation management scholars.

Over time, however, IS scholars have built a unique and robust intellectual perspective as they have examined the role of IS in increasingly modular organizations. This tradition suggests that a dynamic and mutually reinforcing interplay between social and technical elements jointly determines organizational outcomes (Leonardi, 2011; Orlikowski & Scott, 2008). In research in the areas of software design, task-technology fit, group support systems, and the technology acceptance model, the socio-technical perspective has been at the core of the IS discipline. Although coming from a very different intellectual traditions, IS scholars who study economics of IS also argue that investments in organizational capabilities or structures are seen as necessary complementary resources to IS investments (Brynjolfsson, Hitt, & Yang, 1998; Brynjolfsson & Hitt, 2000; Rai, Patnayakuni, & Seth, 2006). Most recently, a broad sociomaterial perspective has emerged as an important intellectual tradition that IS scholars can take credit for (Orlikowski & Barley, 2001). This sociomaterial perspective is one that I will return to later in the paper as I make a case that the IS community must turn the tables and become an exporter of theory as the role of digital technology radically alters the way firms innovate.

3. From Modularity to Generativity

Due to the continuing development of digital technologies, such as mobile communication, embedded computing, and miniaturization of microprocessors, many everyday artifacts are increasingly becoming digital when combined with other technological developments including sensors and batteries (Yoo, 2010). Lyytinen and Yoo (2002) point out mobility, convergence, and massive scale as three key trends that define the emerging technological environment. Furthermore, as a result of the digitization of previously non-digital artifacts, a spectacular array of information is now digitally created, stored, and consumed (Kallinikos, 2006). All forms of content—books, music, photos and maps, to name a few—are now available in digital format. Furthermore, types of information that were simply impossible or impractical to capture are now routinely captured, stored, and analyzed. Such digitalization further enables and is enabled by small, yet increasingly potent, digital components that are becoming a standard part of previously non-digital artifacts such as books, cars, furniture, and buildings.

Yoo, Henfridsson, and Lyytinen (2010) articulate three unique material characteristics of digital technology: (1) homogenization of data based on the use of binary digits for all types of data (Shannon & Weaver, 1949), (2) re-programmability based on the von Neumann computing architecture, and (3) self-referentiality (i.e., one needs digital technology for digital innovations) (Kallinikos, 2006). These three characteristics of digital technology have become the basis for making digital artifacts generative and highly evolving. Nearly limitless possibilities for recombination (or “mash-ups”) of highly programmable digital artifacts through standardized interfaces enable the generativity of digital technologies (Arthur, 2009; Lassig, 2008). Furthermore, the staggering rate of improvement in the price-performance of digital devices has created a powerful positive feedback condition that accelerates the creation and diffusion of digital innovations. Unlike earlier physical resources that require extensive capital to acquire and operate, the near-universal availablity of the personal computer and the Internet has democratized innovation as users and entrepreneurs from all over the world can participate in innovative activities, which has allowed unbounded and generative innovations (von Hippel, 2005). This further makes it possible for heterogeneous actors to pursue unique ideas that may not have been conceived by the original innovator, which creates “wakes of innovations” (Boland, Lyytinen, & Yoo, 2007). As a result, companies such as Google, Facebook, and Apple deliberately create platforms that can be used to produce products and services that were not originally imagined by themselves. For example, one of Google’s most popular services is Google Maps. Google Maps can be coupled with a host of heterogeneous hardware platforms, such as mobile phone, TV, cars, navigation systems, or digital cameras. In each of these devices, the popular service can be used in a variety of ways. Many of the outcomes of such recombinations may not be what Google originally intended or thought possible when it first introduced Google Maps.

While the ideas of modularity and generativity share certain attributes (because both of them facilitate the design and production of a complex product through assemblage of subsystems and components), they do have some fundamental differences. A modular product begins with a fixed boundary. It begins with a centralized designer who creates an architecture and coordinates distributed actors to build subsystems. As such, with a modular design, modules are created through a decomposition of a complex product. That is, a product is designed first, then parts and sub-systems are designed later with standardized physical interfaces. Therefore, subsystem and components in modularity are product-specific.

To the contrary, generative digital modules are most often designed without fully knowing the "whole" design of how each module will be integrated with other modules (Gawer, 2009). When Google Maps was first introduced, for example, the designers at Google did not know that it would be combined with thousands of location-based databases to create so-called mash-ups. Nor were they aware when they developed Google MyMaps that it would be used as an emergency coordination and communication capability during a natural disaster—until hurricane Katrina. Nor did they anticipate that Nikon engineers would create a digital camera integrated with Google Maps. It is the generativity, not the modularity, of digital products that makes them highly evolving. As such, generative digital products emerge through uncoordinated interactions among distributed and heterogeneous actors. While such interactions are facilitated by standardized interfaces (in the form of APIs) and powerful platforms, they are not centrally planned or coordinated (Tuomi, 2002). Therefore, subsystems and components are product-agnostic. With generativity, then, the boundary of a product is unknowable and the product or service remains perpetually incomplete (Yoo et al., 2010). For example, smartphones remain essentially incomplete products when they are first purchased: users need to install applications to combine new affordances into an existing product; in fact, they remain incomplete throughout their lifetime as users continue to add and delete applications and change their functional capabilities.

The emergence of digitally enabled generativity is fundamentally re-shaping the industrial landscape. The firms that once dominated the industrial economy, such as Kodak, GM, Cisco, and Dell are being eclipsed by the emergence of new breed of firms such as Google, Apple, Amazon, and Facebook. Furthermore, the theories that once provided the guidelines for strategic management during the “age of modularity” (Baldwin & Clark, 1997) can no longer offer effective guidance in this age of generativity. Of course, I am not suggesting that modularity is no longer relevant. What I argue instead is that the logic of modularity—and the innovation strategies based on modularity—alone cannot offer competitive advantage to firms who follow it. Next, I conclude by suggesting how the IS community can provide a leadership role in shaping the theoretical and practical discourse around digitally-enabled generativity.

4. Toward a Sociomaterial Theory of Generativity

Over the last three decades, the IS community has developed with a unique intellectual perspective that emphasizes the mutually reenforcing and constitutive relationship between social and technological forces (Leonardi & Barley, 2008; Orlikowski & Scott, 2008). IS scholars can draw on the sociomateriality perspective to better understand the nature and the consequences of generativity in building a coherent theoretical framework of the seemingly chaotic phenomena of generativity.

An important starting point is to open up the “black box” of technology and recognize the important role of materiality of digital technology (Orlikowski & Iacono, 2001). Scholars in technology and innovation management often describe digital technology as disruptive or radical (Benner, 2010; Benner & Tripsas, 2012; Tripsas, 2009). What is lacking in this research is a more precise and nuanced understanding of the nature of digital technology that enables and constrains activities that produce generative innovations. In the management literature, technology is often treated as an exogenous variable: it is somehow created out there independent of actors and enters into the discourse as an impenetrable foreign object. Orlikowski and Scott (2008) note that “technology is missing in action” in management literature on technology (p. 434). While such a position toward technology is problematic for management scholarship in general, it is entirely unsustainable when we study generativity enabled by digital technology. Scholars who study generativity need to explicitly incorporate the unique materiality of digital technology in order to gain a deeper understanding of the phenomenon.

Over time, IS scholars have developed a nuanced understanding of technology’s digital materiality. An artifact’s digital materiality is what the artifact can do to manipulate digital representations using the software incorporated into it (Leonardi, 2010; Yoo et al., 2012). Physical materiality of an artifact, in contrast, is the artifact’s aspects that can be seen and touched, that are relatively hard to change, and that implicate a specific context of time and place. For example, clothes have physical materiality because they can be worn, are hard to convert into a screwdriver, and carry social meanings of appropriate uses and settings for wearing them. What is particularly important in understanding the current wave of digital innovations is the incorporation of digital materiality into objects that previously had a purely physical materiality. An example would include a running shoe with a microchip. This shoe has a digital materiality in that the chip can record representations of movement in a digital format, while one without the chip cannot. The uniquely powerful affordances of digital technologies (Kallinikos, Aaltonen, & Marton, 2010; Yoo et al., 2010) allow designers to expand existing physical materiality by “entangling” it with software-based digital capabilities (Yoo, 2010; Zammuto et al., 2007). For example, a microchip in your automobile can be programmed to record your acceleration, braking, and speed as you drive, communicate with your insurance company, and reduce your premiums for good driving patterns. In myriad ways, the digital materiality of artifacts enables generativity.

At the same time, IS scholars have demonstrated that the materiality of technology is deeply enmeshed with social practices in its creation and use (Orlikowski & Scott, 2008; Pentland & Feldman, 2007). Each time actors design or use a digital technology, they mobilize the traces of institutionalized social practices and taken-for-granted technology infrastructures. When developers build a location-based mobile application for Apple’s iPhone, for example, they not only use Apple’s iOS APIs (application programming interfaces) and SDK (software development kit), but also draw in layers of standards many of which were created decades ago and fiber optics cables that are literally buried under the ocean. Furthermore, these technology artifacts are simultaneously enmeshed with social norms, organizing principles, and role separations. All of these layers of social and material forces are entangled because they enable and constrain generative innovations.

Drawing on a sociomaterial perspective on generativity, IS scholars can study the nature of generativity. Generativity needs to be understood as a general sociomaterial system concept that defines how a finite number of sociomaterial building blocks can lead to the emergence of a seemingly infinite number of variations and speciations (Gaskin et al., 2010). The literature on modularity provides the vocabulary of architecture, interfaces, and components as important elements of theories of innovations and technology management. Similarly, the emerging body of literature on generativity needs to offer a new vocabulary that can explain digital innovations. Using a sociomaterial perspective, scholars can develop such a vocabulary to compare different sociomaterial generative systems and to understand the structure of generativity. Scholars have discovered highly ordered underlying structures beneath the seemingly random patterns of evolution of generative systems such as the Internet (Barabási & Albert, 1999) and biological cells (Barabási & Oltvai, 2004; Ravasz & Barabási, 2003). Using the vocabulary of sociomaterial generative systems, IS scholars might be able to discover similarly ordered patterns underneath the seemingly random patterns of continuing evolutions of digital products. Finally, we should be able to understand the dynamics of generativity. That is, we can use the vocabulary of sociomaterial generativity to characterize the evolutionary pattern of sociomaterial systems, and discover underlying generative mechanisms that give birth to the dynamic changes of the systems.

5. Conclusion

Pervasive and ubiquitous digitalization has brought new disruptive changes in the economy. In this paper, I argue that at the core of these disruptive changes is digitally enabled generativity. Management scholars must offer new theoretical models and insights that guide management practices in the age of generativity that can extend, or perhaps supplant, the prevailing emphasis on modularity. IS scholars can provide significant contributions by drawing on the sociomaterial perspective, which has emerged as a robust intellectual tradition of the IS community, and by attending explicitly to the generative materiality of digital artifacts. This paper is a provocation for those IS scholars who are willing to stretch the boundaries of their intellectual imagination beyond the comfort of IS journals and conferences, and offers a promising path forward.

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