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ABSTRACT

At the industry level, Information Technology (IT) driven transformation can be characterized by the rapid diffusion of IT innovation across firms. This paper suggests that IT innovation has occurred over the past fifty years in four major waves, but that not all industries have been equally affected by each wave's passage. It is proposed that the depth and rate of diffusion of an IT innovation wave within an industry is contingent on the congruence between the characteristics of the wave and those of the industry. The theoretical basis for this proposition is found in the integration of Punctuated Equilibrium Theory and Venkatraman's conceptualization of perspectives on fit, providing a macro view of diffusion of IT innovation at the industry level of analysis.

Keywords

Transformation, Diffusion, Innovation, Punctuated Equilibrium, Fit, Industry

INTRODUCTION

Information Technology (IT) has been touted in top business journals as having the potential to transform industries (Porter and Millar, 1985; Venkatraman, 1994; Dedric and Kraemer, 2005). However, little research has examined the macro impact of IT and the transformational power of technology (Agarwal and Lucas, 2005) and researchers have infrequently used the industry level of analysis as a contextual space to develop IS theory (Chaisson and Davidson 2005). The intent of this paper is to present propositions regarding a conceptualization of industry level diffusion of transformational technology innovation.

The industry level of analysis is of importance to the IT diffusion literature for two key reasons. First, while the organizational level of analysis is the most commonly studied in IT business value literature (Chan 2000) and adoption decisions are characterized at the individual level (Geroski, 2000), diffusion of innovation is a cumulative effect. Consequently, industry is an appropriate level of analysis to identify diffusion effects. Second, as industries differ in their rates of change, degree of similarities of processes and configurations of their value chains, IT can have a variety of different impacts depending on the industry in which it is implemented (Broadbent et al 1999).

Several authors have called attention to the infrequent consideration industry and given the popular conception of IT's transformational capability, the industry unit of analysis appear to be under-represented in the IS research domain (Chaisson and Davidson, 2005; Crowston and Myers, 2004; Melville et al, 2004; Chan, 2000). This potential gap led the author to conduct a literature review of twenty-one IS, management and economics journals and conference proceedings examining studies conducted at the industry level, compiling approximately 200 articles that have addressed the impact of IT on entire industries. The current paper is focused on one key trend: the existence of a series of four waves of IT innovation that appear to have significant impact on certain industries whereas others appear to be unaffected.

IT INNOVATION WAVES

Articles were classified into seven Standard Industry Classification (SIC) industry groups and each paper was coded for key concepts. Those coded within an 'adoption and diffusion' category were examined in more detail, with four waves emerging as a common theme among industry groups.

A first wave of major innovation occurred in the back-office, with the automation of routine procedures enabled by the growth of computing power. Two early cases included check processing and airline scheduling (McKenney et al, 1995).

Each of these innovations occurred in the face of an increasing complexity of the manual or mechanized procedures and forecasts of inability to cope with expected growth.

This was followed by a second wave of innovation in the front-office, with the delivery of services to customers and other businesses enabled by the proliferation of corporate networks. The banking and airline industries leveraged their first wave innovations into ATMs and travel reservation networks, respectively (McKenney et al, 1995). At the business-to-business level, EDI became a major factor across the value chain from manufacturer (Gupta and Capen, 1996) through wholesalers to retailer with this wave (Clemons and Row, 1992).

A third wave of innovation moved into the customer's home and small businesses, with the delivery of products and services enabled by consumer and business adoption of Internet computing. Banks, airlines and retailers innovated with PC banking (Byers and Lederer, 2001), direct booking systems (McCubbrey, 1999), and virtual storefronts (Beck et al, 2003) respectively. Businesses have used the Internet to move away from proprietary EDI systems (Rahim et al, 2005) or extend penetration of interorganizational systems to achieve supply-chain wide distribution reforms (Johnston and Gregor, 2000).

A fourth wave is that towards mobility computing (March et al, 2000), bringing IT to the point of work, with the distribution of information enabled by an increased density of high capacity wireless networks (Smith et al, 2002). The combination of mobile services and rugged handheld computing devices has the potential to be put to innovative use in a range of industries that have previously been cut-off from IT support due to high mobility and adverse environments, such as agriculture or construction (Jain, 2003).

Innovation	Description	Enabler	Industry Groups Impacted
Back Office Automation	Automation of clerical functions for efficiency.	Increase in computer power.	Manufacturing, Wholesale/Retail, Financial
Front Office Automation	Extension of back-office functionality to other businesses and consumers.	Proliferation of business networks.	Agriculture, Construction, Manufacturing, Transportation, Wholesale/Retail, Financial, Services
Internet Computing	Extension of back and front office functionality directly to consumer.	Proliferation of the Internet.	Manufacturing, Transportation, Retail, Financial, Services
Mobility Computing	Extension of functionality beyond physical infrastructure.	Implementation of wireless networks.	Agriculture, Construction, Transportation, Services

Table 1. IT Innovation Waves

Looking over the full body of literature, parallels can be seen across the waves. The adoption of ATM technology in banking closely parallels observations of the early adoption of e-commerce, in that the industries assumed widespread adoption, but early benefits were not seen due to consumer concerns over security and benefits (Dos Santos and Peffers, 1998). Additionally, one wave, if important to the industry, may or may not be a necessary precursor to the next. While both front-end functionality and back-end integration contribute to value creation of e-business, back-end integration has been found to have a much stronger impact on firm performance than front-end functionality (Zhu and Kraemer 2005). More than the parallels across waves, it is the absence of impact on industries that attracts attention and begs explanation.

THEORETICAL FOUNDATIONS

It is suggested that the difference observed between industries appears to be the degree of congruence between the wave's characteristics and that of the industry. To apply a nautical metaphor, a ship can ride-out a wave if it is bow-on to it, but can be swamped if it the wave comes abeam. In addition to the conceptualization of the impact of a wave, it must also have a point of origin and a method of transmission. Origin, transmission and impact are linked together conceptually in framework integrating theories of punctuated equilibrium, diffusion of innovation and fit. As described next, punctuated equilibrium can be integrated with diffusion and fit at the industry level to describe the observed occurrence of IT innovation waves. A technology innovation can be considered a punctuation that initiates a wave of innovation which diffuses across industries, having have different impacts upon those industries based on the fit of the wave's profile with the industry's profile.

Punctuated Equilibrium

The central proposition of punctuated equilibrium embodies three concepts: stasis, punctuation and dominant relative frequency (Eldridge and Gould, 1972). Stasis refers to a long period of relatively unchanged form; punctuation is radical change over a short duration; and dominant relative frequency is the rate these events occur in a particular situation. Punctuated equilibrium was developed as an alternative to phyletic gradualism, which stresses consistent, cumulative changes to species.

Within the context of organizational behavior research, the punctuated equilibrium model consists of deep structures, equilibrium periods and revolutionary periods. Deep structure is "the set of fundamental 'choices' a system has made of (1) the basic parts into which its units will be organized and (2) the basic activity patterns that will maintain its existence" (Gersick, 1991, p 14). Equilibrium periods are characterized by the maintenance of organizational structures and activity patterns, where small incremental adjustments are made to adjust for environmental changes without affecting the deep structure. Revolutionary periods occur due to significant changes in the environment that lead to wholesale upheaval where a system's deep structure comes apart, leaving it in disarray until the period ends and choices are made around which a new structure forms (Gersick, 1991). In their work on organizational change, Van de Ven and Poole (1995) identified four 'motors' of change theories: life-cycle, teleological, dialectical and evolutionary. Within this framework, punctuated equilibrium is considered a dual motor theory, integrating the teleological and evolutionary motors, the former due to brief periods of purposeful reorientations of strategy and structure and the latter due to longer periods of convergence to an equilibrium based on environmental coalignment.

One of the key punctuations noted research is major environmental change caused by technological innovation (Romanelli and Tushman, 1994) where a technological discontinuity triggers a period of instability, which is closed by the emergence of a dominant design or business paradigm (Anderson and Tushman, 1990). The introduction of a disruptive, or competence destroying, IT innovation (Tushman and Anderson, 1986; Lyytinnen and Rose, 2003) can be considered an exogenous event that interrupts the existing stasis, destroying the existing deep structure. It can therefore be argued that waves of IT innovation emanate from the point of origin of these disruptive punctuations.

Diffusion of Innovation

Diffusion research generally falls into adopter and macro-diffusion studies, where the former looks at the individual factors associated with adoption of an innovation and the latter examines the spread of new technologies across groups of organizations (Attewell, 1992). One of the macro-diffusion lenses is based upon the spread of an innovation through intercommunication, where diffusion is defined as "the process by which an innovation is communicated through certain channels over time among the members of a social system" (Rogers, 2003). Particular characteristics of innovation in this tradition include trialability, relative advantage, compatibility, observability, and complexity. Additionally, rates of diffusion can be pictured as a normal curve for frequency of adoption and an S-shaped curve for cumulative adoption, with categories of adopters including innovators, early adopters, early majority, late majority and laggards. The Bass model (Bass, 1969) was an early example of the forecasting power of the S-shaped curve. Mahajan et al (1990) differentiate between the external motivations for adoption and the internal motivations, where the cumulative effects lead to a skewed normal distribution of adoptions. This 'contagion' or 'epidemic' view is the dominant paradigm within the macro IT innovation literature, but is constrained by assumptions of voluntarity (Fichman, 1992).

An alternative view is an economic one based on individual firm cost-benefit analysis of technologies, where the higher the cost and lower the potential profit, the slower the diffusion (Attewell, 1992). This view adds a dimension of choice or decision-making that the epidemic models lack. Probit models are used to differentiate potential adopters along some characteristic that changes the cost-benefit relationship in an individual firm's decision to adopt a technology innovation (Geroski, 2000). This line of reasoning is further extended to include various feedback mechanisms that develop into a need-pull/technology-push interactive model, which incorporates the concept of shocks and setbacks in the emergence of innovations (Baskerville and Pries-Heje, 2003). Finally, transformational innovations can take the form of disruptive or competency destroying innovations (Abernathy and Clark, 1985) that can face opposition from existing stakeholders. The concept of diffusion of IT innovation waves is seen as a complex interaction of many market and non-market factors influencing the economic decision whether or not to adopt a particular innovation.

Conceptualization of Fit

The lack of uniformity of diffusion and impact is possibly based on the heterogeneity of industry groups, hinting that an alignment or fit mechanism may be at work. The concept of fit is derived from contingency theory, in which models share the premise that "context and structure must somehow fit together if the organization is to perform well" (Drazin and Van de Ven, 1985, p 514). Drazin and Van de Ven (1985) interpret fit in accordance with the selection, interaction and systems approaches to structural contingency theory. Within this structure, the system is most appropriate for conceptualizing fit between wave and industry as it supports study through deviation from profiles, but with the acceptance of equifinality, that is, the generation of a feasible set of equally effective combinations of characteristics.

Venkatraman (1989) categorized the concept of fit in a classificatory framework with axes of specificity and anchoring, resulting in six interpretations of the concept. These are fit as moderation, mediation, matching, covariation, profile deviation and gestalts[1]. Selection of an appropriate conceptualization is important, as it can have an impact on results (Bergeron et al, 2001). On the specificity axis it is low, as the comparison is conceptualized as being between the industry and the technology innovation along a range of factors; on the anchoring axis it is criterion-specific, with the particular criterion being impact. This leads to a decision that the most applicable view of IT innovation impact for this study is the profile deviation classification, which is defined as "the degree of adherence to an externally specified profile" (Venkatraman, 1989). Profile deviation is criterion specific, allowing direct comparison between industry and wave, but low in specificity, not requiring a precise functional form of the fit relationship[2].

INTEGRATION OF THEORETICAL PERSPECTIVES

Innovation represents the adoption of a new idea, process, product or service, developed internally or acquired from the external environment, and can be seen as a "qualitative recombination of know-how residing in… human and capital assets" (Pennings and Harianto, 1992). Adoption is driven by innovation characteristics, including compatibility, relative advantage and complexity (Rogers, 2003). To be an asset to a firm in an industry, implementation of new technologies should consider not only the technology itself, but also how the innovation creates value (Virili and Carignani, 2001). Key technologies can be seen as changing the underlying value proposition of an industry. The wave effect is seen when the technology is sufficiently broad in scope to effect multiple industries. This handful of technologies which enable opportunities for a range of technical solutions are called 'general purpose technologies' (Bresnahan and Trajtenberg, 1995). The observed waves of IT innovation can be viewed as a sequence of competency destroying general purpose technologies.

The banking industry provides a good example of the impacts of these waves. Consoli (2005) views the banking industry as moving though three stages: mechanization, back-office automation, and front-office automation enabled by integrated networking. The first transition was as the clerk and typist of the mechanization era gave way to the computer for routine tasks in the back-office automation phase. Early banking industry adoption of IT was led by the Bank of America in the 1950s and early 1960s, where revolutionary back-office procedures for ledger posting, cheque processing and loan management were automated through the development of magnetic ink character recognition (MICR) and first innovation with computers (Weaver-Fisher and McKenney 1993). This provided an early competitive advantage which was quickly followed by the industry (McKenney et al 1997). Another back-office innovation was implementation of decision support for loan applications (Scott and Walsham 1998, Weaver-Fisher and McKenney 1993). The increased interdependencies within the sector could be seen in systems that rely on national or international databases can decrease local autonomy of branch managers in that local decisions can influence lending behaviors in other branches and inform bank or industry lending policy (Scott and Walsham 1998). This back-office revolution set the stage for changes that were to take place due to deregulation of financial markets on a global scale, the emergence of global trading systems, and the creation of cheap and effective telecommunications networks which combined to significantly change the environment for banks in the late 1970s, 1980s and early 1990s (Holland et al 1998, Kuljis et al 1998, Consoli 2005). Based on these examples, the following proposition is made:

Proposition 1. The progression of technologies in industries occurs in waves initiated by disruptive IT innovations.

Waves are initiated by technological discontinuities that act as punctuations in an otherwise stable field. As each technology innovation wave has a specific profile, the further the industry is away from the wave's profile, the less impact the innovation will have. The calculation of the impact of a technology innovation on an industry can be based upon either the distance between them or joint set membership. In the former case, the lesser the distance, the closer the fit and hence the greater the impact of the wave of innovation on the industry. In the latter case, the closer the set membership, the greater the impact. Hence, in order to predict the impact of a technology innovation on an industry, there is a need to define characteristics of industries and identify technologies types that fit the profile. There may also be a rate of diffusion effect based on the proximity, where the lesser the distance, the closer the fit and hence the faster the diffusion of the innovation. The

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[1] For a detailed treatment of the six interpretations within the context of IS research, interested readers should review Bergeron et al (2001).

[2] Two examples of the use of fit as profile deviation in recent IS research are in the areas of strategic alignment (Sabherwal and Chan, 2000) and interorganizational relationships (Premkumar et al, 2005).

heterogeneity can be attributed to different firms and industries having significantly different information needs and information processing capabilities, driving them to adopt different technologies at different rates based upon the fit of the technology to their situation (Premkumar et al, 2005). Essentially, those industries with the tightest fit would be likely earliest adopters of a technology and would show the most compressed S-shaped diffusion curve.

In spite of the popular concept of this industry group as technophobic, agriculture has long been a sector where technology innovation has been welcome, as seen in the increased yield per acre of crops over the last hundred years and the steady gains in efficiency of farm machinery. The limitations of IT in the sector have been long based on the physical immobility of IT assets. Raw computer power means very little to this industry, however in the early 1990s, technology allowed the implementation of distributed networks that provided value to producers and consumers in creating e-marketplaces that increased competition, financially rewarding those with higher quality livestock (Neo 1992). While Internet computing has enabled the refinement of e-marketplaces, the effects were not transformational. However, over the last fifteen years, focus in the industry has moved from static sites, where the product is brought to the technology, to mobile applications, where the technology is brought to the product. In the early 2000s, the ubiquity and affordability of Global Positioning Systems (GPS), ruggedized portable or handheld computers and ancillary devices, and extensive wireless networks allowed the IT-supported work to go to the workplace – the fields, forests and barns (Treiblemaier et al 2002). The convergence of these technologies was a key factor in moving from static to mobile applications in a very mobile industry. Given these observations, the following propositions are made:

Proposition 2a. The degree of adoption of each wave in an industry is proportional to the fit between the wave's characteristics and that of the industry.

Proposition 2b. The speed of diffusion of each wave in an industry is proportional to the fit between the wave's characteristics and that of the industry.

DISCUSSION AND CONCLUSIONS

The propositions introduced heed Fichman's (2004) call to move beyond the dominant paradigm in IT innovation research. In doing so, there are certain areas of diffusion of innovation research from which this paper purposefully steers clear. While transformation can stem from creative destruction (Schumpeter, 1942), it is immaterial to the propositions whether the innovator is an entrepreneur (Schumpeter, 1934) or a firm in an oligarchy (Schumpeter, 1942). Additionally, the existence of these waves and that they have diffusion effects and rates are posited, not any particular linkage of innovation to phases of an economic cycle (Schumpeter, 1939) or the particular distance between the waves (Kondratieff, 1935). The observed waves of IT innovation have been identified and isolated because they are of interest themselves; situating these individual waves within the broader Schumpeterian context may be an issue for future study.

Future research should categorize the characteristics of both IT innovation waves and industries, examine rates of technology change in industries, look for the next nascent innovation wave and identify how each particular wave is situated within the economic cycle. As technologies progress, their range of application also changes and an incremental change within a wave of innovation can make a technology newly viable for an industry as the fit improves. The next wave of innovative technologies are likely to appear in the labs or technical journals and may not have immediately apparent business value; knowing the characteristics of the new innovation and industries could allow researchers to 'stake-out' likely territory for innovation.

The main contribution of this paper is the theoretical integration of punctuated equilibrium with diffusion and fit at the industry level to describe IT innovation propagation and non-propagation. While this work adopts the S-shaped curve of cumulative adoption popularized by Rogers (2003), it differs by focusing on wave-industry congruence in place of communications channels. Acknowledging the transformational impetus of creative destruction (Schumpeter, 1942), this research takes the individual innovation as the unit of analysis instead of the economic cycle. The conceptualization of diffusion of innovation in this work is of an IT innovation as a punctuation that initiates a wave of innovation that diffuses across industries but has different impacts based on the fit of the wave's profile with the industry's profile. By knowing the salient characteristics of the wave and the industry, it is suggested that it may be possible to identify industries most likely to be influenced by a particular wave.

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