Communications of the Association for Information Systems

Volume 41 Article 1

8-2017

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Communications of the Association for Information Systems

Research Paper ISSN: 1529-3181

Theorizing Information Systems as Evolving Technology

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Abstract:

Information systems scholars have struggled with the field's fundamental relationship to technology. In particular, they have debated whether the IT artifact is unwisely taken for granted and whether or not it lies at the field's core. Here, applying Brian Arthur's general theory of technology, I suggest that one may theorize IS itself as an evolving family of technologies. From this perspective, one may open new avenues for IS research—for, in particular, historical and other related studies where the unit of analysis is the technology itself and the focus is its evolution.

Keywords: Technology, Information Systems, IT Artifact, Evolutionary Economics, Organizing Vision, Historical Studies.

This manuscript underwent peer review. It was received 10/22/2016 and was with the authors for four months for one revision. Dirk Hovorka served as Associate Editor.

1 Introduction

Information systems (IS) scholars have struggled over the last decade with the field's fundamental relationship to technology. Most notably, they have been divided in responding to a call by Orlikowski and Iacono (2001) to focus more substantially on the "IT artifact"—the "bundles of material and cultural properties packaged in some socially-recognizable form such as hardware and/or software," (p. 121), which have been under-theorized, taken for granted, treated as "relatively stable, discrete, independent, and fixed", and "unproblematic" in IS research. This situation constitutes something of a paradox because the IT artifact is arguably, on the face of it, the field's "core subject matter". Seeking reform, Orlikowski and Iacono call for theorizing in which one understands the IT artifact as: 1) not "natural," neutral, universal, or given; 2) not independent but rather embedded in time, place, discourse, and community; 3) not discrete but typically made up of often fragile and fragmentary components that must work together; 4) not fixed but emerging from ongoing social and economic practices; 5) not static or unchanging but dynamic.

Responses to Orlikowski and Iacono's (2001) call have varied. King and Lyytinen (2006a) mention several responses in addressing the future of the IS field. A principal struggle revolves around whether the IT artifact indeed lies at the field's center. Weber (2003) thinks not: "I believe the core, if one exists, will not lie in theories that account for information technology-related phenomena. Rather it will lie in theories that account for information-systems phenomena" (p. 48) (Weber favors ontological theories of representation as the foundation for IS research). Benbasat and Zmud (2006) modify their previously presented and controversial "nomological net" (Benbasat & Zmud, 2003) to feature information systems as the central construct and state: "We conceptualize an information system…as the application of one or more IT artifacts to enable or support some task(s) embedded with structure(s) that themselves are embedded within context(s)" (p. 301). On the whole, the contributors agree that IT and IS should be differentiated, but they do not settle how they should be theoretically related.

In this paper, I do not further belabor this well worked-over debate among IS scholars about the core of the field as such (see, e.g., Alter, 2008; King & Lyytinen, 2006b). Rather, I introduce and explore a recently advanced theory, not my own, which, I conjecture, one can readily apply to respond precisely to Orlikowski and Iacono's (2001) call while also offering insights helpful to the IS field and its research. The theory is a general theory of technology that Brian Arthur (2009) presents in his provocative book *The Nature of Technology*, which deserves wider recognition among IS scholars. While Arthur informally presents the theory in the book, it is at once simple and rigorous in its basics and powerful in its implications for our understanding of technology and, in particular, its evolution. Moreover, it is the very opposite of a theory that takes the technological artifact for granted. Might then an "Arthurian approach" to theorizing the IT artifact in the IS context be fruitful?

In this paper, I explore this question while taking Arthur's (2009) perspective. In particular, I posit that one might theorize IS itself as an evolving family of technologies, which would stretch our traditional understanding of it. As I show, doing so opens up new avenues for IS research for, in particular, historical and other related studies where the unit of analysis is the technology itself and the focus is its evolution.

This paper proceeds as follows: in Section 2, I first provide additional background on the IS field's theoretical struggles with technology. In Section 3, I introduce and summarize Arthur's (2009) theory and, in Section 4, consider its application to IS. In particular, I apply the theory to the case of enterprise resource planning (ERP). While I identify a few problems and challenges in applying the theory, I find that the insights gained establish it as promising and deserving of further attention by researchers, which I discuss in Section 5. Finally, in Section 6, I conclude with a few suggestions in this regard.

2 Theoretical Struggles with Technology

Interestingly, at the time of their call, Orlikowski and Iacono (2001) noted that the IS field was then not alone in seemingly taking the technological artifact for granted. The problem also persisted in related organizational and social studies. They lamented that:

> *Processes such as innovation and change are conceptualized largely in socio-economic terms, while "things" are not considered or are treated as self-evident…. Technology, as the quintessential "thing", dissipates into the atmosphere around us, or it becomes emblematic of our "age". We throw it up as a banner of our times, but then instantly let it recede from view by stereotyping or ignoring it.* (p. 122)

This problem persists even though management scholars have long recognized the importance of technology to organizations; indeed, such studies date back at least to the 1950s (e.g., Thompson & Bates, 1957; Woodward, 1958). Researchers have also widely come to accept that one should understand that technology is “socially constructed” (Bijker, Hughes, & Pinch, 1993).

More recently, sociomateriality studies (Orlikowski & Scott, 2009) have come to prominence as a way to bring technology more thoroughly into organizational studies. They reject the traditional separateness of people and technology as such and “focus on agencies that have so thoroughly saturated each other that previously taken-for-granted boundaries are dissolved…[to] move away from focusing on how technologies influence humans, to examining how materiality is intrinsic to everyday activities and relationships” (p. 455) Leonardi, Nardi, and Kallinikos (2012) provide a recent collection addressing materiality and organizing. The contributors understand materiality itself somewhat differently. Regardless, in the case of software, one of the most prominent artifacts of our time, they recognize that it is more important for its form and function than for the physical materials in which it may be represented (Kallinikos, 2012).

Organizational sociologists are not alone in struggling with the role of technology in their theories and studies. Evolutionary economists have long claimed that technology deserves a more prominent place in economic theories. Metcalfe (2010, p. 155) provides a recent review and finds that, in modern economic theory:

> *[T]he primitive notion of technology runs in terms of a specification of the quantities of various inputs required to produce a given quantum of a particular kind of output over some definite time interval, and given the understanding of the state of the art in the minds of those operating the process. This perspective of technology as a menu (for it is less than a blueprint) appears most obviously in the theory of production and consequently in the theory of the firm, which is taken to be the controlling and managing unit of any production activity.*

While the primitive notion works well enough in many static and stationary analyses:

> *It is when we turn to problems of growth and development, and thus to questions of innovation and technological change, that the menu approach to technology becomes problematic, precisely because growth and development are so closely connected to changes in technology…. One has to move beyond the idea of technology as the menu of inputs and outputs to a more finely detailed understanding of the multiple dimensions that characterize different ways of doing things. This is the basis for the idea that a blueprint or recipe lies behind a particular menu, specifying what it means to get things done. But just as there is more to the blueprint than a menu so there is more to the actual doing than is specified in a recipe. What has to be added is knowledge of who is using the recipe because their personal knowledge and skills make a difference to what the recipe leads to.* (p. 157)

But useful knowledge and skills are unevenly distributed in the economy, and, moreover, the profit motive stimulates this through continuous search for better goods and services and means of production. Useful knowledge and technology are “restless”, and “there are always good reasons to know differently” (Metcalfe, 2010, p. 160) As a consequence, where technology is concerned, one cannot consider the economy a system in equilibrium as it is in neoclassical theory. Rather, one must see it as dynamic, in flux, and as an ongoing problem-generating and problem-solving structure.

This basic argument underpins much of the research in evolutionary economics, which Dosi and Nelson (1994) review. Evolutionary theories aim to (Dosi & Nelson, 1994, pp. 154-155):

> *Explain the movement of something over time, or to explain why that something is what it is at a moment in time in terms of how it got there; that is, the analysis is expressly dynamic. The explanation involves both random elements which generate or renew some variation in the variables in question, and mechanisms that systematically winnow on extant variation. Evolutionary models in the social domain involve some processes of imperfect (mistake-ridden) learning and discovery, on the one hand, and some selection mechanism, on the other.*

In short, such theory seeks to understand how a society or economy learns and advances (or not). Notably, it meshes with organization theory suggesting that relatively invariant *routines* (Nelson & Winter, 1982; Pentland & Feldman, 2008) guide behaviors. Dosi and Nelson (1994, p. 159) state:

> *Precisely because there is nothing which guarantees, in general, the optimality of these routines, notional opportunities for the discovery of "better" ones are always present. Hence, also the permanent scope for search and novelty. Putting it another way, the behavioral foundations of evolutionary theories rest on learning processes involving* imperfect adaptation *and* mistake-ridden discoveries*. This applies equally to the domains of technologies, behaviors and organizational setups.*

Brian Arthur's (2009) research is very much in the evolutionary economics tradition. His interest in technology stems partly from his early work exploring increasing returns to the adoption of certain new products, which might win out over competitors if they are able to dominate the market early enough (Arthur, 1989).

Arthur (2009) came to write his recent book after finding that, despite much good work on technology, something was missing (p. 13):

> *We have analyses of the design process; excellent work on how economic factors influence the design of technologies, how the adoption process works, and how technologies diffuse in the economy. We have analyses of how society shapes technology, and of how technology shapes society. And we have meditations on the meaning of technology, and on technology as determining—or not determining—human history. But we have no agreement on what the word 'technology' means, no overall theory of how technologies come into being, no deep understanding of what 'innovation' consists of, and no theory of evolution for technology. Missing is a set of overall principles that would give the subject a logical structure, the sort of structure that would help fill these gaps.*

Arthur's book takes up this challenge.

In this paper, I do not broadly assess Arthur's (2009) theory. Rather, I take it more or less as it is offered and seek to apply it to the case of information systems to see what insights we might gain. For those interested in a much broader attempt to apply Darwinian evolutionary ideas to social systems, see, in particular, Hodgson and Knudsen (2010). Arthur's theory is a singular one. Barham (2013) applies it to the development of handheld tools in the Pleistocene epoch. Most recently, Arthur (2012) speculates on the emergence of what he terms "the second economy"—a digital economy that provides the unseen "roots" that support the familiar product and service economy.

3 Arthur's (2009) Theory of Technology

Brian Arthur's (2009) theory of technology, as presented in his book, was inspired by his quest to understand technology and its relationship to the economy and, more subtly, the ways in which economic development is intertwined with technology development. He states as much in the book's preface (p. 1):

> *I became fascinated with how the economy develops and builds out. It was clear to me that the economy was in no small part generated from its technologies. After all, in a sense an economy was nothing more than the clever organization of technologies to provide what we need.*

Arthur (2009) develops and presents his theory over eleven chapters. He begins by addressing basic questions and previewing where he will ultimately arrive, which is to explain technological development as a process of combinatorial evolution:

> *Early technologies form using primitive technologies as components. These new technologies in time become possible components—building blocks—for the construction of further new technologies. Some of these in turn go on to become possible building blocks for the creation of further new technologies. In this way, slowly over time, many technologies form from an initial few, and more complex ones form using simpler ones as components. The overall collection of technologies bootstraps itself upward from the few to the many and from the simple to the complex. We can say the technology creates itself out of itself.* (p. 21)

Arthur (2009) offers a broad definition of technology as "a means to fulfill a human purpose" (p. 28), "a device, or method, or process" (p. 29), which he subsequently refines to evoke more familiar notions of technology as that achieved by applying scientific understandings of physical phenomena. The theory he develops does not ultimately depend on how broadly or narrowly the definition is applied, which, as I show below, makes it easily applicable to information systems as technology, my present interest.

Arthur then asserts a set of “three fundamental principles” from which he will develop his theory (p. 23):

> *The first will be…that technologies, all technologies, are combinations. This simply means that individual technologies are constructed or put together—combined—from components or assemblies or subsystems at hand. The second will be that each component of technology is itself in miniature a technology…. And the third…will be that all technologies harness and exploit some effect or phenomenon, usually several.*

The first two principles, which assert the combinatorial and recursive aspects of technology, are straightforward yet profound. The third principle, that all technologies harness and exploit some effect or phenomenon, is easily understood for traditionally understood technologies tied closely to nature and the physical world. Thus, for instance, “That certain objects—pendulums or quartz crystals—oscillate at a steady frequency is a phenomenon. Using this phenomenon for time keeping constitutes a principle, and yields from this a clock.” (p. 49). However, because the definition is very broad, one can stretch it to include very different engineered means, such as legal systems, monetary systems, and contracts as technologies, where the notion of what effect or phenomenon is being harnessed is less conventional and more subtle and is anchored in human behavior. Recognizing and wishing to allow one to do so, Arthur introduces the notion of a *purposed system*, which he defines as “the class of all means to purposes, whether physically or non-physically based” (p. 56) to represent this more expansive view of technology. Whether this notion is to the taste of those committed to traditional technological studies or not, it provides the opening (indeed, an invitation) to explore the application of Arthur’s theory to information systems.

Arthur (2009) goes on in subsequent chapters to address and build on these basic ideas. Drawing from the third principle, he introduces the concept of technological domains:

> *As families of phenomena—the chemical ones, electrical ones, quantum ones—are mined into and harnessed, they give rise to groupings of technologies that work naturally together. The devices and methods that work with electrons and their effects—capacitors, inductors, transistors, operational amplifiers—group naturally into electronics; they work with the medium of electrons, and therefore ‘talk’ to each other easily.* (p. 69)
>
> *I will call such clusters—such bodies of technology—domains. A domain will be any cluster of components drawn from in order to form devices or methods, along with its collection of practices and knowledge, its rules of combination, and its associated way of thinking.* (p. 70)

In contrast to a technology, a domain does no job but serves rather as a toolbox from which to draw components and practices. More broadly: “A domain is a realm in the imagination where designers can envisage what can be done—a realm or world of possibilities” (Arthur, 2009, p. 80). Additionally, “design in engineering begins by choosing a domain, that is, by choosing a suitable group of components to construct a device from” (p. 71). And while an individual technology (e.g., a particular computer) may be invented, its associated domain(s) (e.g. digital electronics) accrues gradually and may even come to form one or more industries.

Arthur (2009) continues in subsequent chapters to build out his theory and its ramifications. In Table A1, I briefly summarize the theory tailored to my present purposes by drawing on Arthur’s own words. The table elaborates on the basics: 1) the definition of technology, 2) the three fundamental principles, 3) purposed systems, and 4) technological domains as already introduced. It then further addresses: 5) engineering practice, where each new project always poses a new problem to be solved, 6) novel technologies and how they arise as solutions to standard engineering problems or through deliberate or non-deliberate invention, 7) a technology’s development such that it becomes more complex as it matures and is stretched to its limits, 8) redomaining of technologies where new domains displace old ones, 9) technology evolution through arising opportunity niches that call for novel solutions, and 10) the economy as an expression of the technologies employed such that it “exists perpetually in a process of self-creation” (p. 200). Rather than repeat here all of what this later portion of the table contains, I leave it to the reader to peruse the summary (see Appendix A). The ambitious character and scope of Arthur’s theory of technology should be apparent.

4 Application to Information Systems

Might we fruitfully theorize information systems (IS) as technology in the Arthurian sense? In this section, I take a brief exploratory stab at answering this question. I do it in two parts. First, I simply venture comments on how one might interpret Arthur’s (2009) theory in the IS context by elaborating in Table A1.

To facilitate matters, I focus primarily on enterprise systems, such as enterprise resource planning (ERP) and customer relationship management (CRM) (see, for background, Davenport, 2000; Klaus, Rosemann, & Gable, 2000; Shanks, Seddon, & Willcocks, 2002; Rigby & Ledingham, 2004). Both ERP and CRM are examples of IS types of which there are many that characterize the field and its history (see Ein-Dor & Segev, 1993; Hirschheim & Klein, 2012). Second, because Arthur's theory is an evolutionary one, I consider more closely the evolution of ERP by drawing from a substantial literature.

How might Arthur's (2009) theory apply to IS? From Table A1, with regard to the basic definition, it should be clear enough that basic information technology (IT) and its devices provide an easy fit. But I posit that information systems (IS), though they are more organizational than physical or even digital devices, also represent a class of technology.

With regard to the three fundamental principles, I find that applying the first two—that all technologies are combinations and that they have recursive structure—seems relatively straightforward in the case of enterprise systems. Both principles align with basic system design and building concepts and methods, such as modularization and component reuse. At a relatively high level, ERP represents a family of systems as does CRM as instantiated by product and service offerings in these categories. Recombination is reflected at multiple levels in each vendor's application software and its modular *functionality*. What is arguably combined in ERP and CRM then is the functionality of each member of the family.

Beyond this conjecture, however, ERP is also at the highest level a unifying concept, an organizing vision (Swanson & Ramiller, 1997) that articulates the IS type and itself undergoes change, not necessarily in the same way. How might this interpretation be related? I speak further to this issue below.

With regard to the third fundamental principle—that all technologies harness and exploit some effect or phenomenon—I find it not at all straightforward. What is potentially problematic is clearly identifying the phenomena or "exploitable effect" being "harnessed" in developing an IS at, for instance, the unifying level of an ERP or CRM. While one may identify physical effects in the underpinnings of enterprise systems where basic IT is employed, the harnessed effects at the unifying level are presumably more human and organizational. Here, one may suggest different interpretations by drawing, for instance, from organization theory. For instance, one can argue that, at a broad level, enterprise systems harness the phenomenon of organizational routines; that is, patterns of action by people and machines as Feldman and Pentland (2003) and Pentland and Feldman (2008) theorize. In doing so, they both draw on the coordinative capabilities of routines and seek to shape their performances with business logic and data brought to bear on them. Of course, such an interpretation does not foreclose others. One can also argue enterprise systems to harness organizational structure through, for instance, the discipline they impose on cross-functional business processes. On the whole, organizational effects, especially as they engage human agency, are likely to be more contentious in their interpretation compared to physical effects. Further, it is unclear whether systems are engineered with such effects foremost in mind in practice. I return to the issue of the third principle below.

Elsewhere, the notion of technological domains seems readily applicable. Both ERP and CRM have their respective toolkits—software components and methods—from which one may engineer individual instances. Each implementation also poses a new problem and, where eventually successful, contributes to the solution repertoire by, for example, providing a new template to the toolkit. Both ERP and CRM have also been redomained over the course of their histories: ERP achieved breakthrough prominence when its platform moved to client-server and relational database technologies, while CRM, already popular as an in-house application package, gained new impetus when reconceived as a software-as-a-service.

One interesting challenge in applying the theory arises in the case of novel technologies, which can come about through invention and through solutions to standard engineering problems. The notion of invention may be problematic in its application to IS. ERP and CRM were not invented but rather arguably arose through new organizing visions that were used to promulgate them (see Swanson & Ramiller, 1997). For instance, the ERP vision articulated the integration of financial, operational, and human resource systems that had not previously been tied together. The CRM vision promised a unifying view of the customer (Peppard, 2000). In general, novel IS as broad types do not appear to be invented as such. Rather, they emerge on the playing field of practice and come to be recognized in the community amid contentious claims made as to their novelty, practicality, and worth (Ramiller & Swanson, 2003). I discuss this point further below.

From Table A1, one can see that the balance of the initial application exercise, concerning technology development, technology evolution, and the economy is relatively straightforward. The theory appears to apply readily to IS types and, in particular, enterprise systems. Of course, my comments here are only suggestive of what one might find from a more systematic and deeper exploration.

Thus, as a second exercise, I examine the case of ERP evolution, which has an interesting and well-documented history that Jacobs and Weston (2007) summarize well (see also Rashid, Hossain, & Patrick, 2002). ERP's origins date to the late 1960s and early material requirements planning (MRP) in manufacturing. Manufacturing resource planning II ((MRP II) followed in the 1980s, and ERP emerged in a vision promulgated by Gartner in the 1990s (Wylie, 1990). In 2000, Gartner proclaimed the "death" of ERP and advent of ERP II (Bond et al., 2000; see also Beatty & Williams, 2006). Figure 1 summarizes the four-stage progression that spans almost five decades. This particular evolutionary perspective places ERP in a long-term developmental chain that incorporates predecessor types.

From an Arthurian perspective, how should we understand the evolutionary path of ERP? To gain insights, across the four stages, I consider: 1) the component technologies combined, 2) the organizational effects exploited, and 3) the domain technologies employed. I do not create a full portrait that does justice to what is a rich history. Rather, I identify only the main story line in Arthur's terms by drawing selectively from a considerable literature. Figure 1 summarizes the results of the exercise. One can see that ERP's evolution is characterized by 1) increased component combinatorial complexity in that each successive stage elaborates on the preceding one, 2) increased exploitation of opportunities to coordinate the enterprise that begins with manufacturing and then expands to other business sectors, and 3) ongoing redomaining to take advantage of new IT. The main story line nicely illustrates these important aspects of Arthur's (2009) theory.

Notably, the organizational effects that ERP has exploited over the course of its evolution present a more detailed picture than that captured by a broader theoretical explanation such as that of exploiting organizational routines and structures that I suggest above. These details pertain to dependencies in material demands (MRP), dependencies among manufacturing processes and resources (MRP II), relationships among enterprise functions (ERP), and relationships with suppliers and customers (ERP II). That all of these have offered opportunities for better coordination of the enterprise across its many facets should not be surprising because scholars have long identified coordination as central to the hierarchy (see, in particular, Williamson, 1975; Malone, 2004). From an evolutionary perspective, this need to better coordinate is seen to fundamentally drive ERP's multi-decade and still ongoing development.

In sum, the two-part application exercise suggests that enterprise systems in particular may be broadly conceived in Arthurian terms as an evolving family of technologies. If there is a remaining concern, it may be that the illustrative application of Arthur's theory comes maybe too easily and lacks depth. The present observations are obviously fragmentary and the exploration has been brief. We still need to attempt a more thorough application, such as a case study, that would be more convincing of the insights that might be derived from a deeper analysis. Such a study might pay particular attention to the agency involved in the developmental story. In the case of ERP, Jacobs and Weston (2006) offer a glimpse of this agency in speaking to various players such as gurus (e.g., Joseph Orlicky, who authored the key book on MRP (Orlicky, 1975), and Oliver Wright, who led the move to MRP II), research firms (e.g., Gartner, which announced the emergence of ERP and ERP II), and the many vendors of the enabling IT platforms and the application software itself. The full ERP story featuring a full cast of characters remains to be told in illuminating depth. Only then are we likely to understand how, in the case of ERP, "the whole bootstraps its way upward" to use Arthur's (2009) expression (which masks such agency but hardly denies it). Here, I merely provide the basic outline for such a study.

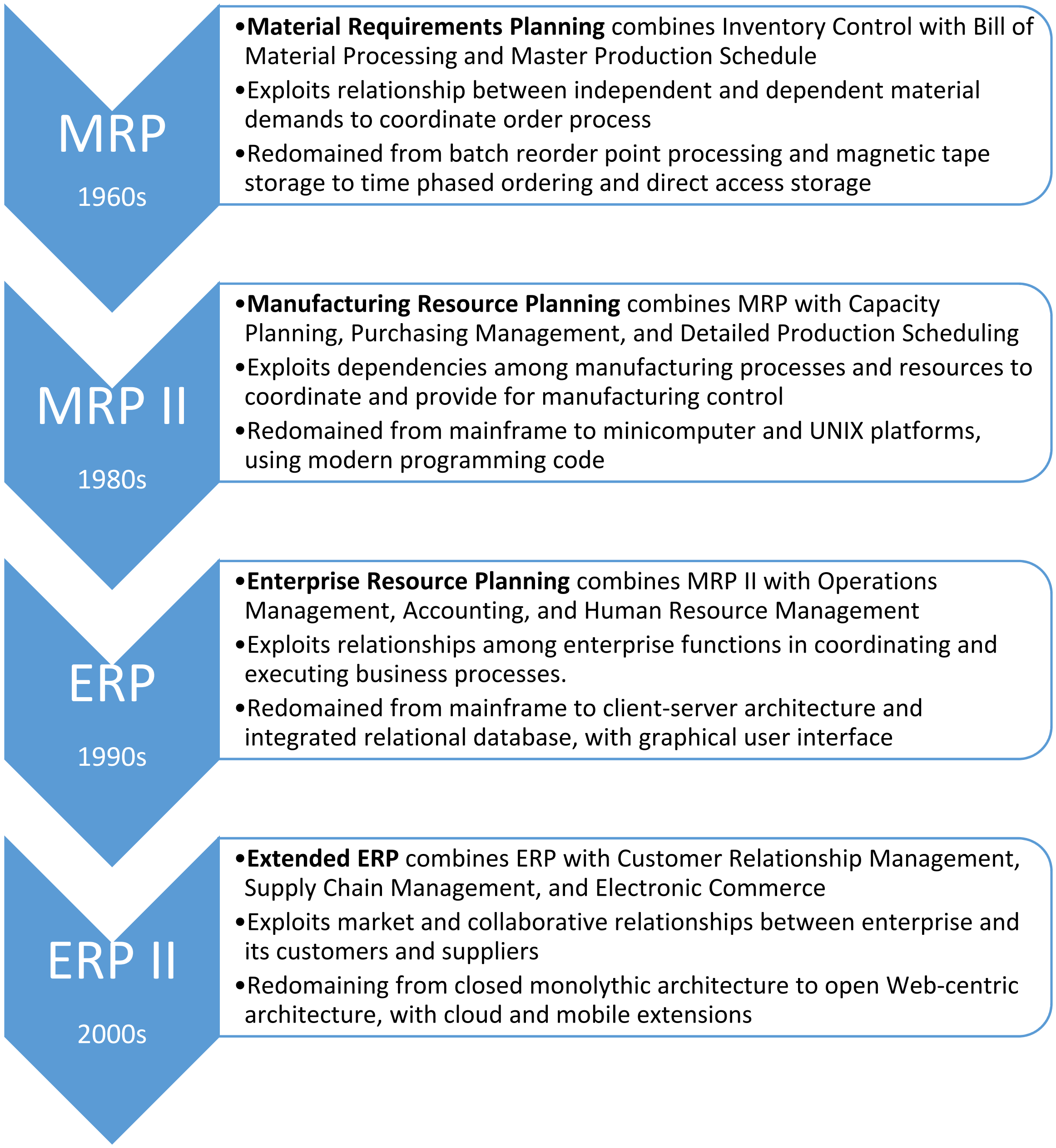

Figure 1. Evolution of ERP

5 Discussion

We still need to explore the broader implications of theorizing IS as an evolving technology. As a reminder, my two-part application exercise focuses only on enterprise systems and on ERP in particular as an information system type. It merely suggests how one might apply Arthur's (2009) theory to other IS types or to IS or digital innovation seen more broadly. Other scholars who explore Arthur's work might of course propose alternative interpretations with different implications for future research. As such, what then are the ramifications for further theorizing information systems as technology in the Arthurian sense?

First and most important, taking an Arthurian approach allows IS theory to be developed as part of technology theory more broadly. It provides a basic framework for addressing the question of how IS technologies are at once the same and yet different from other technologies, such as traditional manufacturing technologies. It invites the development of a theory of combinatorial evolution specific to IS such that IS change is better explained. But it also requires that such theory be consistent with the larger story of technology's evolution. Ultimately, it requires that the stories of the information and industrial revolutions be united (see, e.g., Gordon's (2016) recent study of technological advances since the U.S. Civil War).

For IS scholars, taking an Arthurian approach brings a fresh perspective to the field and provides new research avenues beyond the ones already exploited. In particular, because IS are characterized as technology rather than as the application of technology as if this was somehow a fundamental distinction, an Arthurian perspective also allows one to reconcile the definitional debate regarding IS and IT with which I began this paper. It is noteworthy that, in Arthur's concept, all technologies are in essence applications of what we know and what we can do with this knowledge. What arguably distinguishes IS as technology is that it is developed at a higher level of the combinatorial hierarchy and at a higher level of abstraction than the underlying IT. Further, IS exploits organizational phenomena and effects beyond the physical ones associated with their basic IT. Might Arthur's (2009) theory help IS researchers provide an overarching interpretation of the field's subject matter by assessing recombinant functionality in IS and IT across multiple levels? While much remains to be worked out, this question seems worth exploring. Bringing things convincingly together under one theoretical roof remains one of the most important challenges of the IS field.

Other challenges for IS researchers include reconciling or joining Arthur's (2009) theory with other change theories, such as that associated with organizing visions. Organizing vision studies can both be informed by Arthur's theory and serve to explore it. Importantly, information systems such as ERP are often conceived and promulgated through visions that explicate them at the highest level (Swanson & Ramiller, 1997; Wang & Ramiller, 2009). These visions speak to what the IS are about, the purposes they serve, and how to be successful with them. They try to tell the story of the technology and why it should be widely embraced. They arguably serve to propel the technology forward along its evolutionary path. In Arthur's framework, the functionality of the IS as a technology (i.e., the task it carries out) is likely to be directly addressed by the organizing vision. Less obvious in the vision is the effect that the IS as a technology purportedly harnesses. However, scholars may study organizing visions to probe this aspect of the technology.

When it is asked of a vision, such as ERP, "what is really new here?", it may be one way to ask what is really being newly combined and what is being harnessed such that the technology is recognizably distinct from that which preceded it. Thus, identifying ERP's evolving and increasingly complex component technologies provides one answer as to how the enterprise will be better coordinated. Redomained IT also enters the equation. In the case of ERP, at the peak of its popularity, redomaining involved joining client-server and relational database technologies with modularized generic packaged software (e.g., SAP's R/3 product, which enabled customers to implement "best practice" solutions while replacing mainframe-based legacy systems) (see, e.g., Klaus et al., 2000). As to harnessing an effect, ERP arguably exploited coordinative relationships among an enterprise's functional units. These characteristics and more were reflected in the organizing vision for ERP, which suggests that the study of such visions and their careers might be useful in shedding light on the combinatorial evolution of other IS types.

As a further ramification, Arthur's (2009) perspective would shift the focus of IS research to dynamic, longitudinal analyses more than comparative statics so as to better understand change. For instance, understanding ERP as a technology demands that we grasp how it initially emerged from MRP and MRP II and diffused through its own organizing vision but also how it has since evolved to become ERP II and serve as a platform for newer technologies. Researchers have yet to adequately explore this aspect of ERP to my knowledge. While the IS field has benefitted from numerous ERP studies, many have been situated in the field at moments in time where implementations have taken place and where lessons have been individually drawn and compared to those of prior studies but largely in the absence of a broader notion of an evolving technology where individual lessons learned may or may not be stable or enduring. Such short-sightedness has long characterized IS research because the field has repeatedly turned its attention from the old to what is new and current with little or no attempt to link the emergence of one from the other.

To better grasp the evolutionary dynamics, one suggestion is to conduct studies that probe how human and technical needs give rise to opportunity niches that call for new IS types. Some of these studies might be historical and address the origins of established IS retrospectively, but some might be contemporary and identify problems and current forces motivating IS change. Linkages to entrepreneurship's placing its bets on prospective solutions to presumed problems might also be forged in this research as in Wang and Swanson's (2007) study of the institutional entrepreneurship that promulgated professional services automation (PSA) as a new IS type, where the opportunity niche was evidently smaller than seen at the time.

Thus, as another ramification, the Arthurian perspective lengthens the time frame for IS studies both backward and potentially forward. It calls for both more historical studies so that we can better understand IS developmental paths but arguably also for more grounded futures research to enable us to grasp where current paths are taking us and whether we want to continue on them or, in some cases, redirect them to better ends. It is here that IS research might also better capture the interests of practitioners who track the assessments and prognostications of Gartner and other groups, who are always prepared to speak to the ebbs and flows and even the "hype cycles" (Fenn & Raskino, 2008) associated with new technologies. Solidifying the research base behind such work would make a valuable contribution.

With regard to historical studies, which have been previously called for but so far little delivered by IS scholars (see Mason, McKenney, & Copeland, 1997; Bannister, 2002; Porra, Hirschheim, & Parks, 2014), the idea of telling the larger IS story as an evolution of IS types and threading together the individual technologies that have marked the development of information systems over decades is an exciting one to my mind. As I already suggest above, case studies of organizing visions may be particularly useful as one approach (Swanson, 2013). Researchers have also suggested biographical studies of a certain kind (Williams & Pollock, 2012). Economic histories that focus on the structural conditions affecting the time pace of IS change would also be helpful (see Arthur, 2009, pp. 156-159). Such histories might yield insights into findings that IS productivity gains require years to achieve subsequent to investment (Brynjolfsson & Hitt, 1996). But these examples only illustrate the various approaches that might be taken where the center of attention and the unit of analysis would be the IS technology itself.

6 Conclusion

Finally, to return to where this essay began, one can observe that Arthur's (2009) theory of technology responds well to Orlikowski and Iacono's (2001) call for an understanding of the IT artifact as not "natural" or given, not independent but embedded, not discrete but made up of components, not fixed but emerging, and certainly not static but dynamic. What is interesting is that, while much recent research has taken a rather sophisticated social science turn toward reconciling technology and organization through the introduction of weighty concepts such as sociomateriality, Arthur offers up an alternative, parallel avenue that should be especially appealing to those with more of an interest in technology and its developmental path and economics by employing a rather straightforward theoretical approach. Of course, the insights gained from each approach may be rather different and reflect the different orientations, though I believe they should ultimately complement our understandings. There is some evidence that they might. Yoo, Boland, Lyytinen, and Majchrzak (2012) draw from Arthur's work and the sociomateriality literature in commenting on the nature of innovation in the "digitized world". Yoo (2012) also takes an evolutionary perspective. Brynjolfsson and McAfee (2014) in looking to the future of robotics draw from Arthur to provocatively suggest that "digital innovation is recombinant innovation in its purest form" (p. 81). However, we still need to explore the opportunities offered by Arthur's technology theory more fully. Here, I set such exploration in motion. Following the suggestion by King and Lyytinnen (2004), I have reached a bit to advance our theory even though what it might offer the IS field lies beyond our current grasp.

Acknowledgments

I presented earlier versions of this paper at INFORMS 2014 and the Academy of Management Annual Meeting 2015. The present version has benefitted significantly from comments received both from the presentations and from the review process.

References

Alter, S. (2008). Defining IS as work systems: Implications for the IS field. *European Journal of Information Systems*, *17*(5), 448-469.

Arthur, B. (1989). Competing technologies, increasing returns, and lock-in by historical events. *Economic Journal*, *99*, 116-131.

Arthur, B. (2009). *The nature of technology*. New York: Free Press.

Arthur, B. (2012). The second economy. *McKinsey Quarterly*. Retrieved from http://www.mckinsey.com/business-functions/strategy-and-corporate-finance/our-insights/the-second-economy

Bannister, F. (2002). The dimension of time: Historiography in information systems research. *Electronic Journal of Business Research Methods, 1*(1), 1-10.

Barham, L. (2013). *From hand to handle: The first industrial revolution*. Oxford: Oxford University Press.

Beatty, R. C., & Williams, C. D. (2006). ERP II: Best practices for successfully implementing an ERP upgrade. *Communications of the ACM*, *49*(3), 105-109.

Benbasat, I., & Zmud, R. W. (2003). The identity crisis within the IS discipline: Defining and communicating the discipline's core properties. *MIS Quarterly, 27*(2), 183-194.

Benbasat, I., & Zmud, R. W. (2006). Further reflections on the identity crisis. In J. L King & K. Lyytinen (Eds.), *Information systems: The state of the field* (pp. 300-306). Chichester, England: John Wiley & Songs.

Bijker, W. E., Hughes, T. P., & Pinch, T. J. (Eds.) (1993). *The social construction of technological systems*. Cambridge, MA: MIT Press.

Bond, B., Genovese, Y., Miklovic, D., Wood, N., Zrimsek, B., & Rayner, N. (2000). *ERP is dead—long live ERP II.* Gartner.

Brynjolfsson, E., & Hitt, L. (1996). Paradox lost? Firm-level evidence on the returns to information spending. *Management Science, 42*(4), 541-558.

Brynjolfsson, E., & McAfee, A. (2014). *The second machine age*. New York: W. W. Norton.

Davenport, T. H. (2000). *Mission critical: Realizing the promise of enterprise systems*. Boston, MA: Harvard Business School Press.

Dosi, G., & Nelson, R. R. (1994). An introduction to evolutionary theories in economics. *Journal of Evolutionary Economics, 4,* 153-172.

Ein-Dor, P., & Segev, A. (1993). A classification of information systems: Analysis and interpretation, *Information Systems Research, 4*(2), 166-204.

Feldman, M., & Pentland, B. (2003). Reconceptualizing organizational routines as a source of flexibility and change. *Administrative Science Quarterly*, *48*, 94-118.

Fenn, J., & Raskino, M. (2008). *Mastering the hype cycle*. Boston: Harvard Business Press.

Gordon, R. J. (2016). *The rise and fall of American growth*. Princeton, NJ: Princeton University Press.

Hirschheim, R., & Klein, H. (2012). A glorious and not-so-short history of the information systems field. *Journal of the Association for Information Systems*, *13*(4), 1-48.

Hodgson, G. M., & Knudsen, T. (2010). *Darwin's conjecture*. Chicago: University of Chicago Press.

Jacobs, F. R., & Weston, F. C., Jr. (2007). Enterprise resource planning (ERP)—a brief history. *Journal of Operations Management*, *25*, 357-363.

Kallinikos, J. (2012). Form, function, and matter: Crossing the border of materiality. In P. Leonardi, B. Nardi, & J. Kallinikos (Eds.), *Materiality and organizing: Social interaction in a technological world* (pp. 67-87). Oxford: Oxford University Press.

King, J. L., & Lyytinen, K. (2004). Reach and grasp, *MIS Quarterly* 28(4): 539-551.

King, J. L., & Lyytinen, K., Eds. (2006a). *Information systems: The state of the field*. Chichester, UK: Wiley.

King, J. L., & Lyytinen, K. (2006b). The market of ideas as the center of the field. *Communications of the AIS,* 17, 2-19.

Klaus, H., Rosemann, M., & Gable, G. (2000). What is ERP? *Information Systems Frontiers, 2*(2), 141-162.

Leonardi, P. M., Nardi, B. A., & Kallinikos, J. (Eds.). (2012). *Materiality and organizing*. Oxford: Oxford University Press.

Malone, T. W. (2004). *The future of work*. Boston, MA: Harvard Business School Press.

Mason, R. O., McKenney, J. L., & Copeland, D. G. (1997). Developing a historical tradition in MIS research. *MIS Quarterly, 21*(3), 257-278.

Metcalfe, J. S. (2010). Technology and economic theory. *Cambridge Journal of Economics*, *34*, 153-171.

Nelson, R., & Winter, S. (1982). *An evolutionary theory of economic change*. Cambridge, MA: Belknap Press.

Orlicky, J. (1975). *Material requirements planning*. New York: McGraw-Hill.

Orlikowski, W. J., & Iacono, C. S. (2001). Desperately seeking the "IT" in IT research: A call to theorize the IT artifact. *Information Systems Research, 12*(2), 121-134.

Orlikowski, W. J., & Scott, S. V. (2009). Sociomateriality: Challenging the separation of technology, work and organization. *Academy of Management Annals, 2*(1), 433-474.

Pentland, B. T., & Feldman, M. S. (2008). Designing routines: On the folly of designing artifacts, while hoping for patterns of action. *Information and Organization, 18,* 235-250.

Peppard, J. (2000). Customer relationship management (CRM) in financial services. *European Management Journal, 18*(3), 312-327.

Porra, J., Hirschheim, R., & Parks, M. S. (2014). The historical research method and information systems research. *Journal of the Association for Information Systems, 15*(9), 536-576.

Ramiller, N. C., & Swanson, E. B. (2003). Organizing visions for information technology and the information systems executive response. *Journal of MIS, 20*(1), 13-50.

Rashid, M. A., Hossain, L., & Patrick, J. D. (2002). The evolution of ERP systems: A historical perspective. In F. F.-H. Nah (Ed.), *Enterprise resource planning: Solution and management* (pp. 306-332). Hershey, PA: IRM Press.

Rigby, D. K., & Ledingham, D. (2004). CRM done right. *Harvard Business Review, 82*(11), 118-130.

Shanks, G., Seddon, P. B., & Willcocks, L. P. (Eds.). (2003). *Second-wave enterprise resource planning systems*. Cambridge, UK: Cambridge University Press.

Swanson, E. B. (2013). Illuminating organizing vision careers through case studies. In *Proceedings of AMCIS*.

Swanson, E. B., & Ramiller, N. C. (1997). Organizing visions in information systems innovation. *Organization Science, 8*(5), 458-474.

Thompson, J. D., & Bates, F. L. (1957). Technology, organization, and administration. *Administrative Science Quarterly, 2*(3), 325-343.

Wang, P., & Ramiller, N. C. (2009). Community learning in information technology innovation. *MIS Quarterly, 33*(4), 709-734.

Wang, P., & Swanson, E. B. (2007). Launching professional services automation: Institutional entrepreneurship for information technology innovations. *Information and Organization, 17,* 59-88.

Weber, R. (2003). Still desperately seeking the IT artifact. *MIS Quarterly, 27*(2), iii-xi.

Williams, R., & Pollock, N. (2012). Moving beyond the single site implementation study: How (and why) we should study the biography of packaged enterprise solutions. *Information Systems Research, 23*(4), 1-22.

Williamson, O. (1975). *Markets and hierarchies: Analysis and antitrust implications*. New York: Free Press.

Woodward, J. (1958). *Management and technology*. London: HMSO.

Wylie, L. (1990). ERP: A vision of the next-generation MRP II. *Gartner.*

Yoo, Y. (2012). Digital materiality and the emergence of an evolutionary science of the artificial. In P. Leonardi, B. Nardi, & J. Kallinikos (Eds.), *Materiality and organizing: Social interaction in a technological world* (pp. 134-154). Oxford: Oxford University Press.

Yoo, Y., Boland, R. J., Lyyttinen, K., & Majchrzak, A. (2012). Organizing for innovation in the digitized world. *Organization Science, 23*(5), 1398-1408.

Appendix

Table A1. Arthur's (2009) Theory of Technology and its Application to IS Context

Theory of technology	Application to IS context
Basic definition "A technology is a means to fulfill a human purpose. …[It] may be a method or process or device." (p. 28) "[It] does something. It executes a purpose. …[It may be spoken of as] an executable." (p. 29) "(It) supplies a functionality. This is simply the generic task it carries out." (pp. 29-30) Further: "A technology embodies a sequence of operations; we can call this its 'software'. And these operations require physical equipment to execute them; we can call this the technology's 'hardware'. If we emphasize the 'software' we see a process or method. If we emphasize the 'hardware', we see a physical device." (p. 31)	The basic definition is easily applied. Information technology (IT) represents a special class of technology as does digital technology, which, in the modern context, serves as the foundation for the former. Information systems (IS), which applies IT to human enterprise, represents a class of technology in its own right. While it employs physical devices, IS itself is more an organizational device. Like all technologies, IS necessarily has a performative aspect in its execution, which in its case rests on organizational learning. A subclass of IS technology is enterprise systems, including ERP and CRM.
1st fundamental principle "All technologies are combinations. …Individual technologies are constructed or put together…from components or assemblies or subsystems at hand." (p. 23) Too: "The primary structure of a technology consists of a main assembly that carries out its base function plus a set of subassemblies that support this." (pp. 33-34)	The application of this principle to the IS context would seem straightforward because it incorporates basic system design and building concepts and methods. ERP represents a family of systems as does, for instance, CRM as instantiated by product and service offerings in these categories. What is arguably combined in ERP and CRM is the functionality of each member of the family.
2nd fundamental principle "Each component of technology is itself in miniature a technology." (p. 23). "Technologies…have a recursive structure. They consist of technologies within technologies all the way down to the elemental parts." (p. 38)	The application of this principle to the IS context also seems straightforward, though it may stretch the thinking of some with regard to the use of the term. Computer programmers may appreciate this insight, however. In the case of ERP and CRM, even a low-level software subroutine can be understood as a technology providing functionality.
3rd fundamental principle "All technologies harness and exploit some effect or phenomenon, usually several." (p. 23) "A technology is always based on some phenomenon or truism of nature that can be exploited and used to a purpose." (p. 46). "[Physically based] phenomena … exist independently of humans and of technology." (p. 49) "In practice, before phenomena can be used for a technology, they must be harnessed and set up to work properly." (p. 49) A technology in essence is "a collection of phenomena captured and put to use." (pp. 50-51)	The application of this principle to the IT context is relatively straightforward but, to the IS context, it is not. It is easy to identify the phenomena harnessed to enable digital storage and transmission. But the functionalities provided by IS are typically organizational in nature and rely on human and social phenomena, not just physical phenomena. In the case of enterprise systems, for instance, they arguably harness organizational routines and structure.
Purposed systems "Conventional technologies, such as radar and electricity generation, feel like 'technologies' because they are based upon physical phenomena. Nonconventional ones, such as contracts and legal systems, do not…because they are based upon nonphysical 'effects'—organizational or behavioral effects, or even logical or mathematical ones in the case of algorithms." (p. 55) "[We] have really been talking about a class of systems: a class I will call purposed systems. This is the class of all means to purposes, whether physically on non-physically based." (p. 56)	IS are purposed systems based more immediately on nonphysical effects, such as organizational, behavioral, and computational effects than they are on physically based effects. Foundational IT is based substantially on physically based effects, such as silicon chip technology or wireless digital transmission technology.

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Domains "As families of phenomena…are mined into and harnessed, they give rise to grouping of technologies that work naturally together." (p. 69) "A domain [is] any cluster of components drawn from in order to form devices or methods, along with its collection of practices and knowledge, its rules of combination, and its associated way of thinking." (p. 70) "A domain…does no job; it merely exists as a toolbox of useful components to be drawn from, a set of practices to be used." (p. 71) "Design in engineering begins by choosing a domain, that is, by choosing a suitable group of components to construct a device from." (p. 71) "A change in domain is the main way in which technology progresses." (p. 74)	Domains are important to IS progress. ERP emerged from relative obscurity when it was redomained from a mainframe computing application to client-server computing and relational databases as instantiated by the SAP R/3 product. CRM received a boost when it was redomained from an in-house computing application package to software-as-a-service as instantiated by Salesforce.com's offering.
Engineering "In general, [engineers] design and construct artifacts. They also develop methods, build test facilities, and conduct studies to find out how…solutions will work in practice." (p. 90) "Standard engineering is the carrying out of a new project, the putting together of methods and principles that are known and accepted. ...[producing] a new instance of a known technology." (p. 91) But: "… a new project always poses a new problem." (p. 95) Hence: "a finished design is a set of solutions to a (new) set of problems." (p. 96) Further: "[If] used often enough, a solution…becomes a module…encapsulated in a device or method…available for standard use. It becomes a technology itself." (p. 102)	These notions of engineering problems and solutions are well known in the IS context. In the context of ERP, standard engineering is represented by one firm's adoption and implementation of a selected package. Each firm typically articulates unique requirements (the new problem), and configuring the package to meet these requirements may provide a new template that other, later adopters can potentially use. ERP diffusion is greatly facilitated by the use of such templates, which become part of ERP technology.
Novel technologies "A radically new (novel) technology…uses a principle new or different to the purpose at hand." (p. 108) An invention arises by "linking, conceptually and in physical form, the needs of some purpose with an exploitable effect (or set of effects)." (p. 109) Thus: "Novel building blocks arise in three possible ways: as solutions to standard engineering problems…, as non-deliberate inventions…, or as inventions proper, radically novel solutions that use new principles" (p. 130)	The notion of novel technology can be problematic in the IS context. ERP and CRM as novel technologies were not invented as such. Rather, they arose through new organizing visions. In the case of ERP, the vision articulated the integration of systems (financial, logistic, and HR) that had not previously been tied together through a common database and interface. The promise was better coordination of decisions at the firm level.
Technology development "As a technology becomes a commercial… proposition, its performance is 'pushed'." (p. 132). "Developers can overcome limitations often simply by replacing the impeded component… by one that works better." (p. 133) "But they can also work around (an obstacle) by adding an assembly… that takes care of it." (p. 134) Thus, "technologies elaborate as they evolve. They add 'depth' or design sophistication to their structures. They become more complex." (p. 135) In maturity: "The old design, the old principle, tends to be locked in." (p. 138) "When a new circumstance comes along …, it is easier to reach for the old technology—the old base principle—and adapt it by 'stretching' it to cover the new circumstances." (p. 140) "Eventually the old principle, now highly elaborated, is strained beyond its limits and gives way to a new one." (p. 141)	These development insights apply readily to the IS context. Prior to the emergence of ERP, firms commonly developed and maintained systems in house to provide much of the same functionality. Performance was constantly pushed through the adding of new features to meet new needs and to overcome problems such as poor ease of use. These "legacy systems" became over-elaborated and all the harder to maintain. They also rested on expensive mainframe platforms. Finally, as the new millennium approached, firms' exposure to the Y2K bug substantially undermined the old base principle of in-house custom mainframe development. Firms made the move to new packaged (often "plain vanilla") solutions that promised to be more sustainable and require less costly maintenance.

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Redomainings "But domains are more than the sum of their individual technologies. They are coherent wholes…whose coming into being and development has a character that differs from that of individual technologies. They are not invented; they emerge, crystallizing around a set of phenomena or a novel enabling technology, and building organically from these." (p. 145) "And as the new domain arrives, the economy encounters it and alters itself as a result." (p. 163)	Redomaining is easily recognized in the IS context. Web technology represents an important example because it has changed the way content is accessed and presented, affecting both ERP and CRM. For instance, content management systems arose as a novel technology to provide webpages with enterprise data. More recently, smart phone apps have emerged to compete with browser-based Web access.
Technology evolution "The presence of opportunity niches calls novel technologies into existence." (p. 174) "Existing technologies used in combination provide the possibilities of novel technology: the potential supply of them. And human and technical needs create opportunity niches: the demand for them. As new technologies are brought in, new opportunities appear for further harnessing and further combinings. The whole bootstraps its way upward." (p. 176)	One can historically understand the evolution of IS as a series of responses to opportunity niches created over time. The original management information systems (MIS) were created to provide managers with operational data summarized and tailored to their needs. ERP promised to integrate operational systems across firms so they could better coordinate efforts across traditional functions. CRM aimed to unify the views of the customer across the business. Big data now seeks to exploit the explosion of data gathered by today's systems, and new analytics provide insights and understandings not previously obtainable.
The economy May be defined as: "the set of arrangements and activities by which a society satisfies its needs." (p. 192) "The economy is an expression of its technologies…[which] form its skeletal structure." (p. 193) "The economy …emerges from its technologies. It constantly creates itself out of its technologies and decides which new technologies will enter it. …Technology creates the structure of the economy, and the economy mediates the creation of novel technology (and therefore its own creation)." (p. 194) "It follows that the economy is never quite at stasis." (p. 199) "It exists perpetually in a process of self-creation. It is always unsatisfied." (p. 200)	Information systems are a vital component of the economy's skeletal structure. At the most basic level, IS enable firms to transact with consumers and each other. They also supports the business technologies that embody the production functions of firms and industries more broadly. The rise of online shopping rests heavily on firms' IS and on new IT in the hands of consumers and illustrates how the economy is, thereby, currently being recreated around this new structure and its functionality.

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