A Conceptual Framework for Understanding Path Dependency and Technology Option Evaluation when Valuing IT Opportunities

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Abstract

Organizations are struggling with evaluating technology options, many related to complex technologies like Enterprise Resource Planning (ERP) systems. Real options theory is one way for organizations to evaluate technology options. However, real options theory for complex technologies currently lacks organization contextualization. Path dependency theory addresses why sub-optimal technologies dominate the market. This paper addresses technology lock-in and behavioral lock-in due to path dependency occurring in complex technology implementations. This paper brings path dependency theory and real options theory together build a conceptual model of how behavioral and technological lock-in affect technology options using ERP systems as an example.

Keywords: path dependency theory, real options, ERP

1. Introduction

Complex technology investments decisions continue to be an important part of an organization's operations. One form of complex technology is the Enterprise Resource Planning (ERP) system. Most large companies already own and operate an ERP system as part of their systems investment (Kanakamedala et al. 2006). SAP, one of the largest providers of ERP software, claims "263,000 customers" on its website (http://www.sap.com/corporate-en/about/our-company/index.html). Practitioners are starting to recognize the importance of understanding past implementation decisions and the paths that companies traverse and choose with these decisions (Worthen 2003). Other aspects of the organization that depend on history, like culture (Nigel et al. 2005) are also penetrating the decision making process when deciding future technology expenditures, especially in the case of ERP systems. As companies make these decisions about acquisition of new software and further investments in information systems, critical questions come into play. How does post implementation behavior influence the value of a technology option? What is their current level of technology/software lock-in? What is their current post-implementation behavior toward complex technologies?

Switching costs that are too high for organizations to switch technologies result in technology lock-in (Chen et al. 2002). Technology lock-in also occurs as a result of path-dependence (Arthur 1989; David 1985). For example, once a company has implemented an ERP system, the likelihood of switching to different ERP system is very low. The switching costs of training, hardware, implementation costs, etc. can outweigh the potential benefits that the new software may offer. However, in addition to the notion of switching costs the notion of path dependence, where decisions made in the past about implementing ERP systems help define the options that are presently available for organizations in exploiting ERP capabilities is also important.

Behavioral lock-in occurs when organizations operate sub-optimally or inefficiently because habits, learning or culture inhibits the organization (Barnes et al. 2004; David 1985). This paper will focus on technological and behavioral lock-in implications for technology options evaluation.

Decisions about technology can be made using real options thinking (Benaroch 2000; Benaroch 2002; Fichman 2004; Taudes 2000). Real options thinking rests on the belief that limited commitment can create future decision rights. However, the question is how might lock-in affect the value of the option?

By building on the real options thinking (Fichman 2004; McGrath 1997; McGrath et al. 2000), this paper proposes a conceptual model that explores the impact of path-dependence (Arthur, 1989; David, 1985; Mahoney, 2000) on option value by taking two firm-specific contextual factors into account: technology lock-in and behavioral lock-in.

The purpose of this paper is to bring the economic theory of path dependence into the evaluation of technology options and into the MIS literature. In a review of the organizational change literature there was a note, "It seems remiss of organizational change scholars to have given limited attention to such important questions as, Does the order of things influence the way they turn out (Pettigrew et al. 2001)?" This paper addresses the call for taking path dependence into account in organizational research. First, this paper will use post-implementation ERP as the example for building our framework, though this framework could be applied to any complex technology. Second, the paper will briefly review real options literature to explain using option evaluation in technology decisions. Third, the paper will define the concepts of technological and behavioral lock-in. Finally, these diverse literature streams will be brought together to form a conceptual framework for organizations to answer the question: How should organizations evaluate complex technology options?

2. ERP Context

ERP systems are large complex technologies that span an entire organization. The extent to which an ERP system spans the entire organization is arguably a result of past systems and social constructs at play in the organization. In many cases the organization uses the ERP system in a manner that does not really take advantage of the functionality of the ERP system because of the number of instances, configuration choices, and customization of the system made years ago. These choices will affect technology options in the future for this company. Attention has been paid in the literature to the system or organizational characteristics of the organizations prior to ERP implementation through exploration of critical success factors (Akkermans et al. 2002; Al-Mashari et al. 2003; Brown 2003; Nah et al. 2003; Nandhakumar et al. 2005) and fit with the organization (Light 2005; Luo et al. 2004; Soh et al. 2004; Soh et al. 2003; Soh et al. 2000). However, less research addresses how implementation choices affect organizations post-implementation (Botta-Genoulaz et al. 2005; Jacobs et al. 2003). Post-implementation research to date has covered issues of effectiveness and usability (Scott 2005; Yu 2005)

Notable post-implementation research that begins to address issues similar to those that we raise includes Gattiker and Goodhue's (Gattiker et al. 2005) piece that looks at interdependence and differentiation between plants and the impact that these characteristics of the plant have on the benefits derived from the ERP system. Although the argument is clearly that the characteristics of the plant determine whether integration of the system reaps benefits, we hope to take that include in our framework other variables. Rather than look only at the ERP system, and the common benefits associated with the technology, we would look at the constraining and enabling aspects of the system which would be determined by looking at the historical decisions surrounding the system. For example, although an ERP system is implemented, was it implemented with a single instance? Since practitioner reports state this is probably not the case (Worthen 2003), for each organization it is important to understand why this decision was made and what decisions were made once that path was chosen. This would account for why some organizations insist that ERP systems enable acquisitions and divestitures while others say that ERP systems inhibit this capability. Historically, the company that says that ERP systems enable acquisitions and divestitures probably implemented the system knowing that this was part of what they did in the past and would do going forward and configured the system accordingly. The company that says that acquisitions and divestitures are inhibited by the system, probably implemented the system without planning for future acquisitions and divestitures. Path dependence would explain seemingly contradictory statements about the impact of ERP systems on organizations, like the acquisitions and divestitures example mentioned above.

Another related post-implementation piece concerns post-implementation reviews (Nicolaou 2004). Post-implementation reviews (PIRs) are intended to improve design effectiveness and provide feedback to modify inappropriate development and project management practices.

PIRs get close to determining path dependence, but do not close the gap as far as lock-in. As well, PIRs focus on the implementation of a particular system and what can be learned and improved in terms of that system, it consequently does not look at the system terms of evaluation of future technology options. More recently, owing to the vast implementation of complex software, research and practitioners have started to address maintenance of this software eg. McKeen and Smith 2012.

The aforementioned post-implementation research does not address path dependence or the sequences (self reinforcing or reflexive to be discussed in the "Path Dependency and Lock-in" section) that contribute to lock-in.

3. Real Options

Real options theory rests on the belief that limited commitment can create future decision rights. Real options theory has a rich history borne from the finance (Miller et al. 1961; Myers et al. 1977)[1] literature and has been applied to technology in a variety of ways. Real Options theory, in terms of technology positioning projects, proposes that technologies are desirable if they provide opportunities for future rent creation. These investments require less commitment than if a full plan was created that did not allow for quitting midstream. Beyond the specific real options literature (to be discussed in the next paragraph) that supports the logic of committing to software with the intent of exercising some future option, the project management literature in MIS also supports this notion. In the case of ERP systemsand large systems in general, organizations implementing technology have decided that a "staged" or incremental approach is preferable in many instances to "big bang" implementations. The staged approach allows for less radical change introduction in the organization. A logical extension of this trend in project implementation approaches to valuing technologies in the selection decision seems clear. If companies can commit to a technology, and yet have the option to proceed, as well as options for future rents, the technology is more valuable to the organization. ERP systems tend to allow for future options.

For the purposes of this paper, option valuation would be performed multiple times throughout the life of a project. For example, a company may look at the option value of implementing specific modules of an ERP system. Future options may be to continue to implement other modules of this system, to implement an integrated best-of-breed addition, to use these modules as a stand-alone part of their system, to integrate this module back to existing legacy systems, etc. This approach would be in congruence with current project management practices, where the project is analyzed at different steps to ensure the project is proceeding satisfactorily. Likewise, the option value of investment should be analyzed periodically to determine how to proceed with the option.[2] The emphasis being here that option value does change with time, and thus should be examined over time. We do not suggest that path dependency should be the only consideration in option value, we suggest this in addition to current thinking about IT platform decisions.

Most of the studies of real options in a technology context have used a rigorous finance influenced quantitative methods for evaluating the value of real options (Benaroch 2000; Benaroch 2002; Benaroch et al. 1999; Clemons et al. 2003; Santos 1991; Taudes 1998; Taudes 2000). Table 1 provides a synopsis of these studies. As can be seen, all the work is conceptual or case study based. I propose a conceptualization more in line with the thinking behind those of McGrath (1997), McGrath and MacMillian (2000), Chen and Chen (2005), and Fichman (2004). These studies apply real options thinking to a qualitative options valuation method. For example, McGrath (1997) provides factors that influence the option value of a technology positioning option. This framework was expanded with explicit items to characterize each factor in later work (McGrath et al. 2000). Each of the 15 factors in this theory, is represented by a series of questions scored 1 (strongly disagree) to 7 (strongly agree), the answers to which will characterize the respondent's position on the concept. Each concept has different implications to the value of the option. This theory of real options for technology positioning is built around the factors that are necessary for new product development and R&D type research. Although there are many similarities in R&D investments and IT platform investments, there are also many differences (Fichman 2004).

An excellent theoretical piece on IT platform options (Fichman 2004) explains these differences by drawing from four complementary perspectives: technology strategy, organizational learning, innovation bandwagons, and technology adaptation to develop 12 factors identified as antecedents of option value in IT platform investments. Then, he makes propositions about each factor's impact to option value that he posits will explain adoption. Previous studies have chosen to leave out contextual factors (Fichman 2004). We choose to build on the work of Fichman and add in the contextual factors of technological and behavioral lock-in. I will propose that lock-in associated with ERP systems will influence how organizations should value future technology options.

[1] For a more detailed account of the history of real options please see McGrath, R.G., Ferrier, W.J., and Mendelow, A.L. "Real options as engines of choice and heterogeneity.," *Academy of Management Review* (29:1), 2004/01// 2004, pp 86-101.

[2] For a review of potential option outcomes please see: Fichman, R.G., Keil, M., and Tiwana, A. "Beyond valuation: "Options thinking" in IT project management," *California Management Review* (47:2), Win 2005, pp 74-96.

4. Path Dependency Theory and Lock-in

A classic definition of path dependence is that: "Path-dependent sequence of economic change is one in which important influences upon the eventual outcome can be exerted by temporally remote events, including happenings dominated by chance elements rather than systematic forces. Stochastic processes like that do not converge automatically to a fixed-point distribution of outcomes and are called non-ergodic."(Araujo et al. 2002; David 1985) Path-dependence theory defines the impact that "historical 'small events' (Arthur 1989) p117" might have on the survival of technologies. The essence of this theory is that historical small events are never forgotten, and these small events may eventually decide outcomes. Path-dependence theory has at its heart an economic bearing, in that originally, path dependence theory was used to define why sub-optimal or inefficient technologies attain strong market positions. The argument is that a sub-optimal technology can become locked-in as a result of historical events. Examples in reference to path-dependence theory and technological lock-in include the QWERTY keyboard (David 1985), VCR formats (Arthur 1990; David 1985), chemical control of pests (Cowan et al. 1996), and nuclear power reactors(Cowan 1990). These examples show how technologies that are arguably less efficient and/or effective than their rivals were able to survive, as a result of historical events that reinforced their position as the market leader. We take this market theory and apply it at an organizational level to technologies (software) choices within organizations. The central tenant being, sub-optimal software solutions *can* become locked-in as a result of historical events. It is important to note that we agree with other scholars in that path dependence, though limiting options, does not imply fatalism or determinism (Araujo et al. 2002).

Since research along path dependence theory tends to focus on why different technologies are chosen by the market, very little research has applied path-dependence theory to the question of why suboptimal solutions exist for each organization. In terms of complex technologies, switching costs in the economic (Chen 1997; Gehrig et al. 2004; Taylor 2003) and marketing (Jones et al. 2000; Yang et al. 2004) literature streams have been the closest literature to address this question. Even here, path dependence theory is not a contributing perspective. In the MIS literature, for example, Chen and Hitt (Chen et al. 2002) look at customer characteristics, firm attributes, and system characteristics that lead to switching. This does not look at the history of the organization, nor is the variable of interest option value or better decision making for the locked in organization. The emphasis in that study is on predicting whether a person will switch or quit using the product. Outcomes of switching costs (Bell et al. 2005; Jones et al. 2000; Yang et al. 2004) and network externalities have been addressed (Grover et al. 1999; Parker et al. 2005; Viswanathan 2005). However, none of these works focus on what the consumer or organization can do upon recognition of switching costs or whether path dependency should be considered in switching decisions. We suggest that not only switching costs, but also path dependency should be factored into complex technology decisions. This is especially important in a complex technology such as ERP because of the reach of ERP software throughout an organization. For the purposes of this paper, technology lock-in will be defined as occurring when organizations are entangled in self-reinforcing sequences. Self-reinforcing sequences are characterized by processes of reproduction that reinforce early events (Mahoney 2000). Lock-in is more the result of self-reinforcing sequences than reactive sequences[3]. However, as was exemplified by Araujo 2002, even decisions made when they are known to have path shaping consequences (reactive sequences) result sometimes in less than optimal paths.

An example of a self-reinforcing sequence of events in terms of technology lock-in and ERP would be if an organization has a particular ERP system that lacks needed functionality, but the organization cannot realistically implement the changes needed to gain the needed functionality because of the constraints of the existing ERP system (perhaps lack of a "user-exit). Based on this lock-in, the organization may choose some other sub-optimal product (perhaps the existing ERP systems product offering) because it is compatible with the existing ERP system. This pattern of events reinforces the position of the original ERP system, and the organization is pressured to continue down a particular path with their existing ERP system.

Expanding on the understanding of path dependence theory, beyond the technology lock-in perspective, there is a behavioral lock-in perspective that is equally as important (Barnes et al. 2004). Behavioral lock-in extends the idea of lock-in to include recognition that consumer and producer behaviors can become locked in.

[3] Reactive sequences are another dimension of path dependence. Reactive sequences result when each event in the sequence is both a reaction to antecedent events and a cause of subsequent events. For a more detailed review of reactive sequences see Mahoney, J. "Path Dependence in Historical Sociology," *Theory and Society* (29:4) 2000, pp 507-548.

As stated earlier, behavioral lock-in occurs when organizations operate sub-optimally or inefficiently because habits, learning, or culture, inhibits the organization (Barnes et al. 2004; David 1985). Interestingly, practitioners are starting to recognize the importance of culture in future technology investment decisions. For example, in talking about assuming a single-instance strategy for ERP systems the Gartner Group noted, "If there is a culture of local decision making, then business-unit executives may not be willing to accept a decision that is mandated from the corporate head office p3 (Nigel et al. 2005)". Academics have also related culture changes to ERP implementation (Botta-Genoulaz et al. 2005; Jones et al. 2006; Nicolaou 2004). In vivid case examples, Barnes et al (Barnes et al. 2004) explain the factors at play in behavioral lock-in. In one example, behavioral lock-in concerns the "view of information technology" that the participants hold. A second dimension has to do with behaviors associated with adopting innovations that affect the core of a person's job - for physicians, innovations that affect how they communicate with their patients and how they record and process proprietary patient data. Behavioral lock-in has to do with behaviors associated with a technology that are propagated through self-reinforcing sequences.

5. Model Development

Given this understanding of technological lock-in, behavioral lock-in and real options logic, our conceptual model relays the relationship between option value and both types of lock-in as is shown in Figure 1.

P1: Post-implementation technological lock-in will decrease the value of technology platform options.

The value of an option is derived by uncertainty in the future options available by purchasing a specific technology today. If an organization is locked-in by previous software choices, there is less likelihood that the organization will be able to exploit newer technology options. The historical path that an organization traverses will likely be indicative of future path because of path-dependence. A similar argument is made in a longitudinal case study relating to the replacement of chlorofluorocarbons (CFCs). "In our view, path dependence whilst limiting options, does not imply fatalism or the elision of agency. p8 (Araujo et al. 2002)". As organizations grapple with technology option decisions, the understanding of what this decision will make in the future must be one of their main concerns. As organization want the best return available on their investment, they must build flexibility in to the chosen option to ensure future (unknown) investments are possible.

P2: Post-implementation behavioral lock-in will decrease the value of technology platform options.

Likewise, if an organization bears behavioral lock-in, they will derive less value from future technology options. Back to the example of doctors and electronic medical record (Barnes et al. 2004), the behavior of the doctors towards new technologies that get at the core of their jobs (interacting with patients) is to create self-reinforcing patterns that allow the physicians to avoid interaction with the electronic medical records. In the case of behavioral lock-in post implementation, the new routines, protocols, security measures will drive a certain behavior that will become embedded in the organization. The organization will be headed down a particular path, enforced by the system, that defines their future directions. This directedness, and self-reinforcing patterns, will lessen the value of future platform options.

P3. Post-implementation technological lock-in will increase behavioral lock-in.

Perhaps the most overlooked outcome of technological outcome and path dependency is its effect on behavioral lock-in. In many instances, as mentioned in the previous example, behaviors are developed in response to a technology that become embedded in the procedures followed everyday when utilizing the technology. Since employees must learn to use a new technology, new procedures will be developed. Resistance to change and inertia will build after utilizing the software for some amount of time. Thus, those behaviors will become embedded in the organization and become one more hurdle to jump over when evaluating new technology options.

6. Contributions

This paper contributes to academia in a number of ways. We bring the notion of path-dependence to light in the understanding of technology investment option value. To do this, we combined the economic theory of path dependence with the real options perspective of IT platform decisions.

Another contribution is adding a new perspective to how we think about ERP and complex technology implementation impacts. While we focus heavily on the enabling aspects and benefits of ERP systems to the organization, we focus less on the impacts that the ERP system has to other technologies and technology options within the organization. The impact to these other technologies will impact the organization. While not comprehensive in its treatment of this topic, this paper has tried to start a dialogue about these issues.

From a practitioner perspective this paper sheds light on the importance of understanding the current technology situation and understanding the decisions that organizations have made in the past in relation to technologies. Whether it seems that the decision was a path-determining decision or not, the decision may indeed help form the path the organization traverses. Organizations need to evaluate their past decisions under a framework that defines whether the decision is part of a self-reinforcing sequence or a reactive sequence. Knowledge that we are being pushed down a particular path by a particular ERP system will enable the organization to have more control over their course of action. As well, if the organization recognizes that they are being pushed, they should value future technology options less.

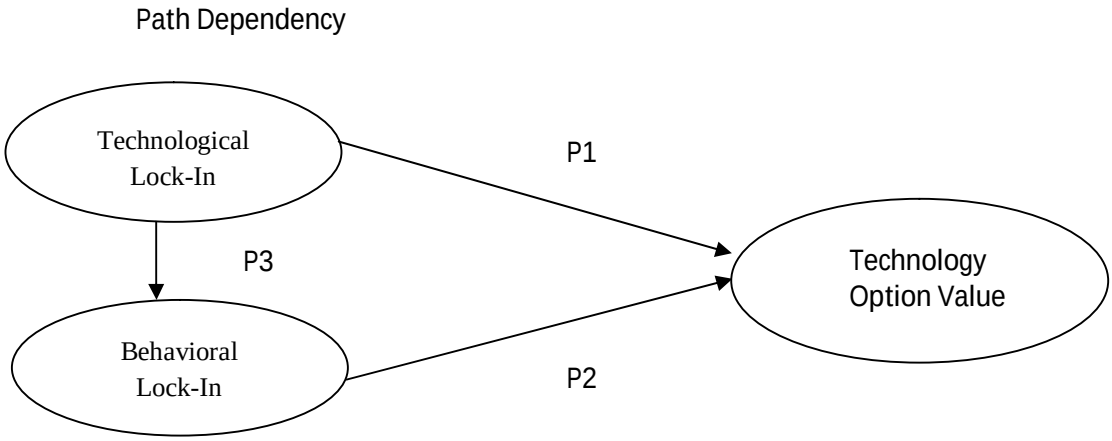
7. Future Research

Future research should address issues of social capital and culture in terms of behavioral lock-in. Social capital is a good proxy for defining behavioral lock-in because it has a micro-macro conceptualization (Kostova et al. 2003), which would allow for analysis at the organization level. Also, there are specific dimensions (Nahapiet et al. 1998) of social capital that might more often lead to behavioral lock-in. For example, the network ties that develop as part of the system implementation are a potential source of lock-in. There is a long history of culture (Schein 1990) research in the organization behavior literature that be drawn upon to determine what aspects of a culture are more likely to be associated with lock-in. Another way to view behavioral lock-in might be through theory of planned behavior (Fishbein 1975). As well, future studies should try to operationalize and perhaps demonstrate this conceptualization of lock-in.

Table 1: Finance Based Studies of IT Platform Decisions as Real Options

Authors	**Major Theme**	**Context**	**Case or Conceptual**
Clemons and Gu 2003	Strategic options in IT infrastructure	Credit Card Rates for Capital one (industry level)	Case
Benaroch 2002	Manage IT investment risk that that helps to choose which options to deliberately embed in an investment	Internet Sales Channel	Case
Benaroch and Kauffman 2000	Investment timing	POS debit market	Case
Taudes 2000	Evaluates ERP platform change	SAP R/2 to SAP R/3	Case
Benaroch and Kauffman 1999	Investment timing	POS debit market	Case
Taudes 1998	Evaluates software growth options	EDI growth option	Case
Dos Santos 1991	Applies real options theory to IT investments using two stages, where the first stage creates the option for the second stage	None	Conceptual

Figure 1: Conceptual Model



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