BuR - Business Research
Official Open Access Journal of VHB
Verband der Hochschullehrer für Betriebswirtschaft e.V.
Volume 2 | Issue 1 | May 2009 | 67-84

Path Dependence in Decision-Making Processes: Exploring the Impact of Complexity under Increasing Returns

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Abstract
The development of path-dependent processes basically refers to positive feedback in terms of increasing returns as the main driving forces of such processes. Furthermore, path dependence can be affected by context factors, such as different degrees of complexity. Up to now, it has been unclear whether and how different settings of complexity impact path-dependent processes and the probability of lock-in. In this paper we investigate the relationship between environmental complexity and path dependence by means of an experimental study. By focusing on the mode of information load and decision quality in chronological sequences, the study explores the impact of complexity on decision-making processes. The results contribute to both the development of path-dependence theory and a better understanding of decision-making behavior under conditions of positive feedback. Since previous path research has mostly applied qualitative case-study research and (to a minor part) simulations, this paper makes a further contribution by establishing an experimental approach for research on path dependence.

Keywords: Complexity; Decision-making; Path dependence; Lock-in

Manuscript received December 9, 2007, accepted by Peter Walgenbach (Management) February 3, 2009

1 Introduction

Path dependence is a dynamic theory assuming that initial events can increasingly restrain present and future choices. The theory originates in the historical studies of Paul David (1985, 1986) who explored the development of QWERTY keyboard technology. He shows how an inferior and inefficient technological standard becomes established and is maintained. Brian Arthur (1989, 1994) has highlighted the importance of self-reinforcing mechanisms of such path-dependent processes. The focus on self-reinforcing effects became the hallmark of path-dependence theory (Arthur 1983; David 1993; Arthur 1994; Bassanini and Dosi 2000; Ackermann 2001). These effects are the central triggering elements that drive path dependence (Sydow, Schreyögg, and Koch 2009). In addition, path-dependent processes are embedded in institutional fields and environments which may affect the path process as well (Pierson 2000). Yet little is known about the particular impact of context factors, such as ambiguity, power structures, institutional density or complexity on path-dependent processes (North 1990; Greif 1994; Thelen 2003; Pierson 2004).

2 The unexplored context of path-dependent process

The assumption that context matters in path-dependent processes are based on a conceptual argument. The complexity of goals, tasks, and environments in which decision makers have to operate as well as the loose and diffuse links between actions and outcomes render such settings inherently ambiguous; they are, therefore, prone to increasing returns (Pierson 2004). Context factors contribute to imper-

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fect market conditions as indicated by the existence of transaction costs. They make it difficult (if not impossible) to apply rational decision rules in terms of neoclassical theory. Pierson's argument that a context matter goes further and refers not only to the constitution of imperfect markets but to the effect that context factors impact the occurrence and intensity of self-reinforcement as well (Pierson 2004).

The literature on path dependence in economic, institutional, and political fields fails to provide clear evidence of what kind of impact relates to what kind of context factor. For instance, in the conceptualization provided by Arthur, self-reinforcing mechanisms are necessary and sufficient preconditions of path dependence, whereas context is taken for granted and, therefore, kept constant. Context is not irrelevant, but is considered a fixed premise (e.g., perfect information and the non-sponsoring rule (Arthur 1989) which frame the process). In North's conceptualization, though, context provides a necessary precondition. Without imperfect markets and transaction costs, path dependence does not occur, at least not in cases where path dependence is considered potentially inefficient: "If institutions existed in the zero-transaction-cost framework, the history would not matter; a change in relative prices or preferences would induce an immediate restructuring of institutions to adjust efficiently [...]" (North 1990: 93). Finally, Pierson places more attention on the role of contextual influences on path dependence in order to underline his central argument of political systems being more prone to path dependence than economic systems. While the discussion of differences between political and economic systems is beyond the scope of this paper, it is worthwhile emphasizing his basic assumption that also context may affect path-dependent processes. Even if this assumption may be intuitively plausible, the conceptual and empirical evidence for that issue is somewhat weak due to at least three shortcomings:

First, Pierson refers to context in a very broad and unspecified manner, mentioning a variety of factors, such as power structures, uncertainty, and unspecified preferences that describe the context of (political) decision-making. It is plausible that these factors can influence political decision-making and may lead to inertia and rigidity. Hence, context factors may provide the same explanation for outcomes such as path dependence. They could, though, provide different, alternative explanations as well. There may be a correlation between both factors that influence rigidity but not necessarily a causal link.

Second, focusing on context in a broad sense makes it difficult to discern and distinguish the existence of specific causal relations between a concrete context factor and a path-dependent process. For instance, power structures and complexity are very different but nevertheless potentially interdependent concepts (e.g., power structures could be very complex and complexity may foster the emergence of informal power structures). Referring to a broad understanding of context may entail a lot of unrecognized cross effects. That may finally lead to the not-falsifiable assumption that context always matters.

Third, given the fact that path-dependent processes are evolutionary and contingent, path analysis is often retrograde and provides an ex-post explanation only (see also Mahoney 2000). This is especially problematic for empirical studies based on a single or just a few cases. Referring to an opaque and highly interdependent context, it does not provide better insights into the assumed causal relationship due to the threat of ad-hoc theorizing; a given result (a path) is referred to an unspecified context which in turn is interpreted as the causal reason for that result. Another result of another case and another posteriori interpretation of the context are quite likely when following this research approach.

Considering these caveats, it seems more appropriate to opt for another research strategy by specifying and providing a clear-cut research design, focusing exclusively on very few variables and the direct measurement of their relationship. For that reason, we focus on only one particular context factor: the degree of complexity. We apply an experimental approach in order to isolate the context effect and to control for possible interferences on both the contextual level and the level of self-reinforcement.

The outline of the paper is as follows: First, we give a short introduction into path-dependence theory in order to specify our understanding of path-dependent processes. Then, we describe the context factor complexity by referring to complexity theory and psychological research on decision-making. Building on these insights, we deduce our hypothesis and research questions which are presented in the following section. Finally, we present and discuss the results of the study.

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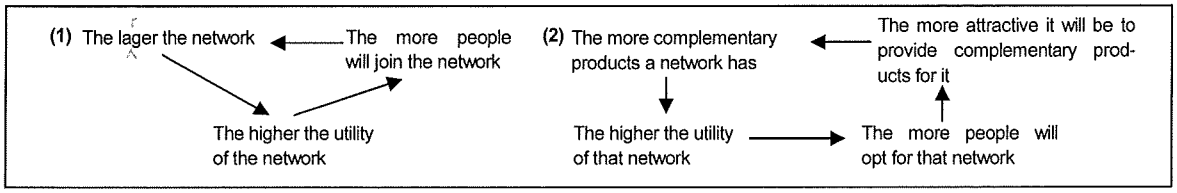
3 Path-dependence theory

Path dependence is the outcome of a dynamic process that is reigned by one or more self-reinforcing mechanisms. According to previous research, we distinguish between at least six different forms of self-reinforcing mechanisms (Sydow, Schreyögg, and Koch 2005, 2009): (1) economies of scale and scope, (2) direct and indirect network externalities, (3) learning effects, (4) adaptive expectations, (5) coordination effects, and (6) complementary effects. All mechanisms share the same inherent logic. For instance, direct network externalities imply that a user's benefits from a purchased good or service increase as more users use the same good or service; purchasing and using a telephone becomes more rewarding the more users there are already using this device. Indirect externalities refer to complementary products and services accompanying a product (e.g., video stores, video recorders, etc. in the case of VHS see Cusumano, Mylonadis, and Rosenbloom 1992). Figure 1 illustrates the self-reinforcing working of both effects.

Figure 1: Direct (1) and indirect (2) network effects



All these effects lead to positive feedback loops in which at least two variables are reciprocally linked in the following way: a higher (or lower) level of one variable leads to a higher (or lower) level of the second variable which in turn leads to a higher (or lower) level of the first variable and so on.

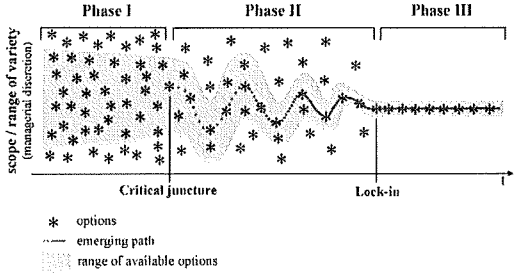
From a dynamic decision-making perspective such a process requires a situation of repeated decisions; a decision-making system is repeatedly confronted with the same decision-making problem. Self-reinforcing mechanisms provide increasing returns to a decision-making system for each new decision. When a decision-making system follows the emerging path, the situation improves in terms of increasingly higher utility or increasingly lower costs of a repeatedly chosen option.

There are two sides to the coin, though: A path also constitutes a restriction of choice. While choices are not restricted at the beginning of the process, ongoing decision-making leads to restrictions. Decision-making systems reinforce path-building effects and at the same time the variety of choices diminish and limitations increase. They "lose sight" of other data and adopt particular decision strategies which guide them more and more in a particular direction.

It is important to note that in contrast to the common understanding of dynamic decision-making (Harvey and Fischer 2005), path-dependent processes do not require a direct and causal link between the option once chosen and the options that will still be available to the decision maker at a later point in time. In a path-dependent process the vanishing of previously available options is collateral and not necessarily a direct or causal effect of the decision path.

To sum up, paths are the emergent outcome of a self-reinforcing process resulting in a pattern of action and reflection. The development of such pattern is a *non-ergodic process* that becomes more and more inflexible. The concrete pattern is *not predictable* at the beginning and can lead to an *inefficient outcome* in the end Arthur (1989, 1994); David (2001); Pierson (2004), Sydow, Schreyögg, and Koch (2009) have re-conceptualized this process in a 3-stage model (see Figure 2).

Figure 2: The constitution of a path (Sydow, Schreyögg, and Koch 2009)



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Phase I of the model is characterized by contingency. Neither is decision-making behavior undirected nor are choices fully unconstrained. History matters but in a broader sense of foregoing imprints (Boeker 1988). These imprints can lead to a narrowing of choices (indicated by the shadow), although there always remains a considerable scope of choice. Phase I ends with a critical juncture (Collier and Collier 1991), i.e., a decision and/or event leads to self-reinforcement. At that moment, a decision-making system enters (often unconsciously) a dynamic narrowing process triggered by positive feedback for a particular option. The system chooses the option by chance (in the sense of a small event) or intentionally (in the sense of a bigger event). The strategic intent of the choice is not necessarily the triggering of a self-reinforcing dynamic; it is rather considered a collateral outcome of strategic actions.
Entering into **Phase II,** a set of decisions is likely to be reproduced over time. If self-reinforcing mechanisms consolidate, a pattern of reflecting and/or acting builds up that reproduces the initial decision or set of decisions. A dominant solution emerges and the process becomes more stable. Decisions taken in Phase II are nevertheless still contingent, i.e., options for alternatives still exist, although they are more and more constrained (indicated by the shadow).

With the transition to **Phase III,** the path becomes locked-in and the dominant pattern gains a deterministic character. The decision process is fully bound and a particular choice or decision pattern from the past has become the predominant mode. Any other alternatives are ruled out – even if they become more efficient. In contrast to technological solutions, a behavioral pattern of acting and reflecting is locked-in not only when it is completely predetermined, but also when restricted to a very narrow area of its state space (indicated by the shadow in Phase III).

The lock-in situation indicates that a path-dependent process leads to a stable and, thus, rigid outcome which is potentially inefficient and cannot be overcome by the decision-making system. The potential inefficiency is caused by a *rationality shift*, i.e. a change in the environment that makes another alternative more attractive. In lock-in situations the decision-making system is unable to switch to that alternative[1]. It is very likely that a decision-making system will not get locked-in if it becomes aware of such a change in the environment during Phase II. Then, the decision-making system will switch to the more attractive solution. Yet, there is strong evidence from different bodies of literature that such a change does not occur, if a decision-making system perceives the previous and present decisions as successful (see, for instance Miller 1993). Thus, path dependence implies a potential tradeoff between the inner rationality of a decision system and a second point of view (an outer or observer perspective) applying another form of rationality (Koch 2008). A rationality shift is defined from the observer's perspective, but whether it is noticed and how it is perceived, depends on the inner rationality of the decision-making system.
Up to now, path-dependence research has emphasized some pivotal elements that drive path-emerging processes in Phase II of the model and that eventually lead to a lock-in. As described in the introductory section, we argue that beyond these mechanisms a particular context may encourage path-dependent processes as well (Pierson 2004; see also Beyer 2005). We will now focus on complexity as such a context factor.

4 Complexity theory, decision-making and path dependence

According to Anderson (1999), complexity is a structural variable that "can be equated with the number of different items or elements that must be dealt with simultaneously" (Anderson 1999). Complexity refers to the relations between elements; an interconnected collection of elements is called complex "when, because of immanent constraints in the elements' connective capacity, it is no longer possible at any moment to connect every element with every other element" (Luhmann 1995: 24). Complexity also refers to decision-making systems and their ability to cope with situations of incomplete information: "Complexity [...] means being forced to select" (Luhmann 1995: 25). A complex environment requires a decision maker to reduce complex-

[1] This argument of potential inefficiency has provoked remarkable criticism from neoclassical researchers (Liebowitz and Margolis 1990; Liebowitz and Margolis 1994; Liebowitz and Margolis 1995; see also Regibeau 1995) because in neoclassical theory an inefficient but nevertheless rigid solution cannot occur, and if it does occur, it is always remediable.

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ity in order to make decisions. "People in organizations reduce a complex description of a system to a simpler one by abstracting out what is unnecessary or minor [...] compressing a longer description into a shorter one that is easier to grasp" (Anderson 1999).

Complexity impacts decision-making behavior in various ways: The first and most important implication is that complexity leads to a situation where the application of rational decision-making models is no longer possible or does not lead to better decisions (Simon 1987, 1990; Weick and Sutcliff 2001). As we know from the bulk of research describing and analyzing how decisions are made in organizations (Allison 1971; Cohen, March, and Olsen 1972; Pettigrew 1973; Mintzberg, Raisinghani, and Théorêt 1976; Beyer 1981; Brunsson 1982; March 1994; Crozier 1995; Staw 1997; Hendry 2000), rational decision behavior rarely occurs in the mode presumed by rational choice theory: problems are ill-defined, solutions are seeking for problems, evaluations are implicit, etc. For that reason, the linear logic of rational choice theory and the assumption of rational behavior are problematic premises for both prescribing and describing decision-making in the real world.

Due to bounded rationality, a decision-making system is unable to realize and to compute any possible relation between elements in complex situations. Complexity and bounded rationality are just two sides of the same coin. The limitations of the human mind and the structure of the environment in which the mind operates are interlocked (Simon 1991; Gigerenzer and Todd 1999). Decision-making systems in real-world settings have only limited time, knowledge, and computational capacities and, therefore, complexity restrains the decision maker to draw inferences on the environment in order to reduce complexity.

In real-world settings decision makers, therefore, rely on cognitive heuristics while processing information and making decisions (Goldstein and Gigerenzer 2002). Heuristics are an appropriate strategy for reducing complexity. „The degree to which heuristics are used depends on the decision-making context" (Åstebro and Elhedhli 2006). The higher the degree of complexity the faster and the more frugal the heuristics have to be in order to work efficiently under such conditions (Rieskamp and Hoffrage 1999).

5 Hypothesis and research questions

The main assumption to be tested is whether complexity impacts the probability of becoming path-dependent. As shown above, this hypothesis derives directly from the path-dependence literature (Pierson 2000; 2004). In a path-dependent process successful decision-making requires the ability to detect relevant changes (a rationality shift) while positive feedback for a previously chosen option is still at work. Once a decision strategy is chosen and is reinforced by positive feedback, a decision maker is less likely to detect relevant changes in overly complex situations compared to less complex situations. The decision strategy may result in path dependence.

H1: High (versus low) complexity enhances the probability that a decision maker becomes path-dependent.

Previous research has hallmarked the role heuristics play in complex settings of decision-making and has explored which types of heuristics are applied to different tasks and environmental conditions (Tversky and Kahneman 1974; Goldstein and Gigerenzer 2002; Betsch and Haberstroh 2005; Harvey 2007). Research in the field of psychology concerning the process of sequential decision-making, the role of feedback, the internal and external reasons for staying with a previous chosen solution, and the way complexity and heuristics interact provides several explanations for path-dependent processes (Einhorn and Hogarth 1981; Hogarth, Gibbs, McKenzie, and Marquis 1991; Harvey and Fischer 2005; Jonas, Schulz-Hardt, Frey, and Thelen 2001; Sevdalis and Harvey 2007). Nevertheless and to the best of our knowledge, evidence is lacking on the functionality of heuristics under increasing returns and rationality shifts, as the central elements of path-dependent processes. Bearing in mind the purpose of this paper, we rely on very fundamental categories for capturing and analyzing such heuristics and decision-making processes. Besides testing the hypothesis of whether complexity indeed leads to path dependence, we further try to explore *how* complexity has an impact on path dependence. For this, we refer to basic dimensions of information which are (1) alternatives, (2) attributes, and (3) time.

Previous studies have differentiated between compensatory (attributes are outweighed by other attributes) and non-compensatory (a specific attribute