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Analysis of internal and external influences on path creation – A simulation study

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Abstract

Path dependence is an important phenomenon in strategic management. It narrows the decision space of strategic decision making which potentially leads to inefficiency. It also causes idiosyncratic differences between firms and therefore heterogeneity in the capability and resource endowment of firms which could be beneficial in competition. Sizing the later line of argumentation, paths could be valuable for companies and path creation an important strategic task. While path dependence and creation have been conceptually explored, it is difficult to study them empirically. Using computational modeling and experimentation we further develop the conceptualization of path dependence and creation. Our model analyzes the effects of internal factors – self-reinforcing learning effects – and external factors – environmental dynamic – on the performance of path dependent and flexible decision makers.

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Keywords: path creation, path dependence, learning, environmental dynamics, simulation

1. Introduction

Path dependence denotes that strategic decision making processes of organizations are not independent of past decisions. Rather, the results of these past decisions affect current ones. The effects of path dependence on a firm's performance are discussed controversially in literature. The limitation of the decision space and influence of past decisions on future ones might potentially lead to inefficiency, for example if changes in the environment require adaption (Sydow et. al. 2009). Therefore path dependence can be perceived as problematic for firms and could be

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perceived as the direct opposite of dynamic capabilities that allow a company to reconfigure its competencies to changing environments (Eisenhardt & Martin, 2000; Teece et al. 1997, Peteraf et al., 2013).

However, a chosen path can also lead to the evolution of capabilities within firms (Vergne & Durand, 2011) and thereby to idiosyncratic differences between firms' resource and capability endowment and sustained competitive advantage (Peteraf, 1993). Following this line of argumentation creating paths could be beneficial for companies and therefore relevant strategic management (Sydow et al., 2012).

Regardless of the effect on performance, the influence of path dependence or more active path creation is not of a general 'history matters' nature – it follows a consistent pattern. Sydow et al (2009) made a great step towards a clear conceptualization of the phenomenon and process of organizational path dependence derived especially from literature on technological path dependence (e.g. Arthur, 1989). Path dependence is explained as a three stage process with increasing limitation of the decision space: (i) pre-formation phase, with a triggering event that initiates the process, (ii) a formation phase, with self-reinforcing processes like learning, synergy and coordination effects, and (iii) lock in phase with high costs to break the path due to switching or sunk costs.

While this work has enriched our understanding of path dependence, the different internal aspects that lead to path dependence – like trigger, self-reinforcing processes, path breaking costs – still require closer consideration. Moreover, relevant external factors, like the environmental complexity and dynamic or path tolerance. In this paper, we build on the seminal contribution of Sydow et al (2009) and analyze the effects of internal and external factors on path dependence and creation by means of computational modeling and experimentation. The research question of this paper therefore is: How do internal factors – i.e. learning scope and intensity – and external factors – i.e. environmental dynamic – influence performance in path creating, or in other words path dependent, companies compared to flexible, path-independent companies.

The remainder of this paper is structured as follows: Section 2 briefly outlines simulation, the method applied in this paper to study the effects of internal and external factors on the performance path dependent or creating firms and for comparisons with the performance of flexible companies. We describe the simulation model and the experimental design for the computational experiments in Section 3. Section 4 presents the results of the simulations. Section 5 finally summarizes the paper with the main conclusions drawn from our research.

2. Method

For the conceptualization and in depth analysis of path dependence we use computational modeling and experimentation, i.e. simulation. Simulation is the method of using a computer to model the operations of 'real-world' systems and processes to perform computational experiments (Law & Kelton, 1991). Though not widely applied in organizational, strategy and management research yet (Harrison et al., 2007), simulation as a methodological approach increases in importance in these fields (Davis et al., 2007). It can be seen as a middle way between the inductive and deductive approach in management studies: The implementation of the computational model requires theoretical insights and at the same time the experimentation with the model and the analysis of the resulting data has similarities to empirical research.

The formal modeling necessary to for simulation supports theory development (Davis et al., 2007) as it requires that the static elements and dynamic processes of the 'real-world' system or process need to be defined. This, in turn, leads to clarity, transparency and consistency of the conceptualization. Simulation thereby can provide insights in complex relationships among constructs especially when empirical data limitations exist (Zott, 2003, Davis et al., 2007). Since empirical path dependence research would require longitudinal studies (Sydow et al., 2009), is likely based on resource-intensive case studies (e.g. Sydow et al., 2012) or experiments (e.g. Koch et al., 2009), and the evaluation of not chosen – and therefore hard to observe – alternatives, simulation is a promising approach to deepen our understanding of path dependence and path creation.

3. Model and Experimental Design

We model the situation as a recurring choice among discrete alternatives on a strategic dimension. This strategic dimension could be for example the competitive strategy (ranging from differentiation to cost leadership) or the innovation strategy (ranging from invention leadership to late following), the organizational from (ranging from functional to divisional or process organization) or different product or production technologies, etc.

3.1. External Factors – Environmental Dynamics

A value function assigns values to these alternatives. These values are normally distributed in the alternative space. The centers of the normal distributed value functions can differ between time periods to various degrees or even stay constant. Figure 1 illustrates three value functions over a decision space ranging from 0 to 1 and with different peaks at 0.25, 0.5 and 0.75, respectively.

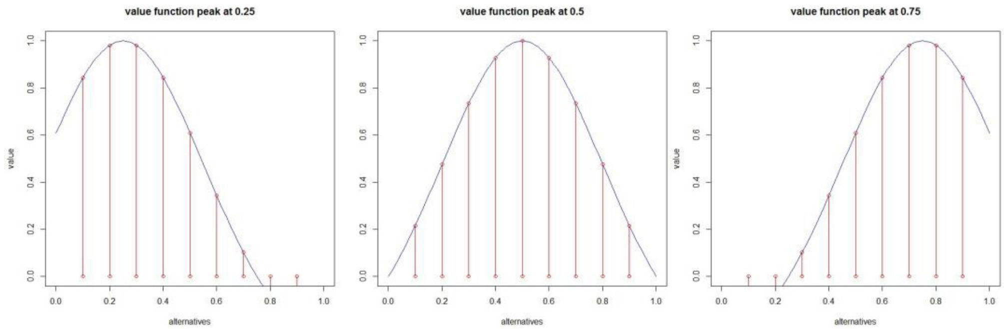

Figure 1: Value function with peaks at 0.25, 0.5 and 0.75

Changing the peak of the value function over the periods is used to model environmental dynamics. Changes in the peaks of the value functions resemble changes of the optimal alternative between periods. We generate a total of 100 decision problems each with 21 discrete alternatives in the strategic dimension ranging from 0 to 1 and repeated over 100 periods. The peaks of the value functions for each period were randomly sampled from a uniform distribution between 0 and 1 for all 100 periods of the 100 decision problems. To implement environmental dynamics exponential smoothing, according to Equation (1) was applied to determine how much the next periods value function is influenced by past.

$$peak_t^*=peak_t+(1-a)\ peak_{t-1}^* \quad (1)$$

If the next periods value function coincides with the previous one the environment is stable and the smoothing parameter a then is zero. In a totally dynamic environment the past has no influence and only the next periods value function, determined by the randomly drawn peak, is considered by a smoothing parameter a of 1. This is illustrated for the first twenty periods of decision problem one and a smoothing parameter of 0, 0.5 and 1, respectively in Figure 2.

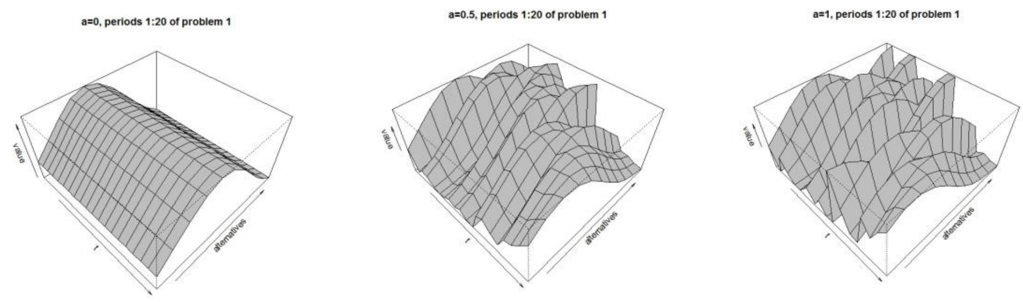

Figure 2: Environmental dynamics in periods 1:20 of problem 1 for different values of *a*

3.2. Internal Factors – Learning scope and intensity

This weight of the path dependent strategy is determined by learning and increased by factor *intensity* which models learning intensity if the alternative is the same as last period. The weight is remained the same if the alternative is within a tolerance scope *scope* of the previous periods decision and the weight is decreased by the factor *intensity* if it is outside this tolerance area, which represents the drawback of the self-reinforcing learning process. Both self-reinforcing and path breaking costs accumulate over time to model the irreversibility of the process. Furthermore, the initially chosen alternative along the strategic dimension in the first time period must lie within the tolerance area around the triggering event for a path dependent firm while a flexible firm is free to adopt any alternative in the first period.

3.3. Path creation vs. Flexibility

In these multi-period decision problems concerning the strategic dimenison, outlined in 3.1. we compare the performance of a flexible decision making strategy that chooses always the alternative a_i from the N alternatives $i=\{1, \ldots, N\}$ with the highest value function according to the value function for this period $v_t()$ according to Equation (2). On the other hand the path dependent – or path creating – decision making strategy weights all payoffs with a factor for this period and alternative w_{it} based on learning from previous decisions, as outlined in 3.2, according to Equation (3).

$$a_i \text{ s.t. } max^N_{i=1} v_t(a_i) \quad (2)$$

$$a_i \text{ s.t. } max^N_{i=1} w_{it} v_t(a_i) \quad (3)$$

Figure 3 illustrates for one problem and one parameterization of the simulation the chosen alternatives and the outcome of the path dependent relative to the flexible strategy.

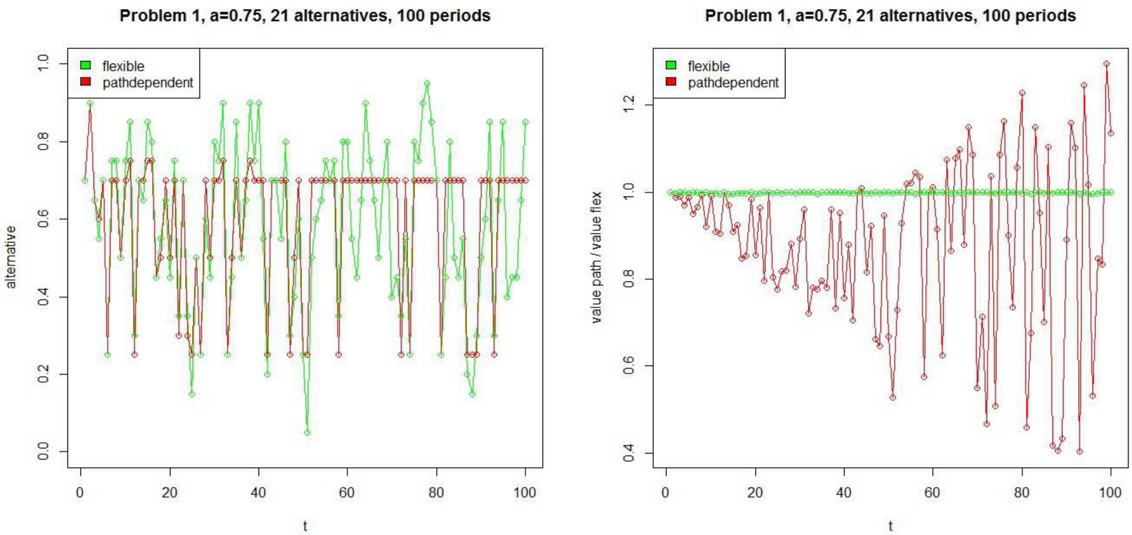

Figure 3: Choices and payoffs of the flexible and path dependent strategy

As can be seen from Figure 3 the path dependent strategy chooses alternative *0.7* very often while the flexible strategy's choice varies, on the other hand the flexible strategies payoff is always around 1 while the payoff of the path dependent strategy varies much more – in this setting it performs worse than the flexible strategy on average – depending whether the peak of the value function was close or far from the *0.7* alternative.

Table 1 summarizes the chosen parameterization for the computational experimentation which generates the data and thereby builds the basis for the analysis in Section 4. Computational experimentation with external and internal factors involves systematically varying the value of one parameter in the simulation model under ceteris paribus conditions. These parameters are the environmental dynamics and tolerance scope (external) learning intensity and tolerance scope and the number of periods considered (internal). Sensitivity analysis of the internal and external factors – i.e. rerunning the simulation with systematic variation of the parameters in the simulation model – allows to identify the relative importance of the factors and their influence on path dependence. This extend of path dependence can be calculated as the difference between the payoff of a path dependent firm decisions (according to the given parameterization) and a flexible firm that chooses the optimal payoff in each time period. This difference can also be seen as the maximum costs acceptable for a firm to keep flexible and able to implement choices without the costs and benefits of following a path in recurring decisions.

Table 1. Experimental Design.

parameter	values	range
a	11	0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1
tolerance scope	5	0.1, 0.2, 0.3, 0.4, 0.5
learning intensity	5	0.01, 0.02, 0.03, 0.04, 0.05
periods	10	10, 20, 30, 40, 50, 60, 70, 80, 90, 100
problems	100	randomly generated to account for stochastic effects

We run each parameterization in 100 decision problems, as already mentioned above, to account for stochastic influences and base our analyses on average results. In total *11*5*5*10*100=275,000* simulation runs where executed which took approximately two hours 2,9 GHz dual core computer with 8 MB RAM.

4. Results

In analyzing the performance of the path dependent strategy we set it in relation to the flexible strategy, which chooses the value maximizing alternative in each period, as outlined in the previous section. This value of one – or close to one if no discrete alternative coincides with the maximum of the value distribution for that period – serves as baseline for performance comparisons.

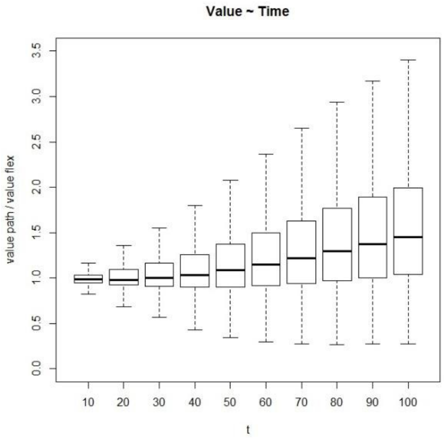

Figure 4: The performance of path dependent strategies over time

Figure 4 illustrates the performance of path depending strategies compared to flexible strategies for different number of periods of the simulation. In shorter periods the performance is almost equal, however, the more often the reoccurring decisions must be made the better do path dependent strategies perform. This could be a bias from the focus of this study on learning – with above zero learning intensity and tolerance scope in all settings – so that the results of the subsequent analyses are more conclusive. However, we observe, which was already illustrated with Figure 3, that with the emergence of paths the variance of the results increases. Path dependent strategies perform, due to learning effects, extraordinarily good in case the peak of the value function of a period 'crosses' their path and perform rather bad otherwise.

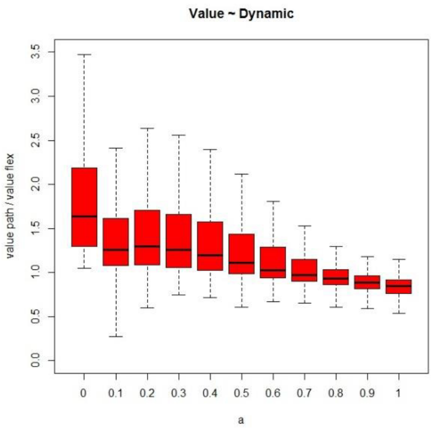

Figure 5: The influence of *environmental dynamics* on the performance of the path dependent strategy

This relation also explains the results concerning the influence of environmental dynamics to some extent. With increasing fluctuation learning does not pay off and the higher the random influence on the value function the worse the performance of the path dependent strategy becomes.

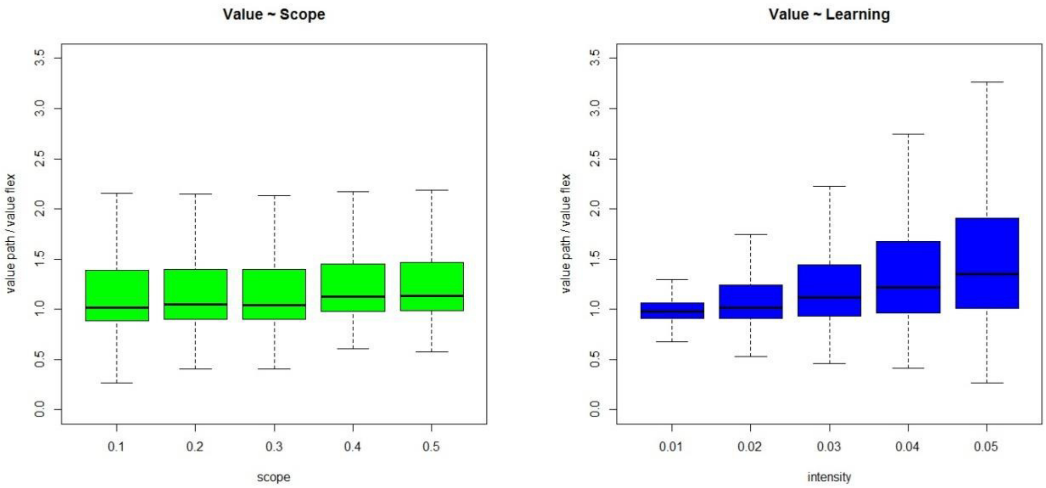

Figure 6: The influence of *tolerance scope* and *learning intensity* on the performance of the path dependent strategy

Interestingly the tolerance scope as nearly no influence on the performance of path dependent strategies, which means that it does not matter much whether the deviations from a path are large or only marginally. However, learning intensity has the expected positive influence on path dependence or in other words builds the potential for path creation.

5. Discussion and Conclusion

This study took a closer look on the internal and external influencing factors on path dependence and path creation, taking into account performance considerations. Given the inherent problems of studying this long-term phenomenon we chose simulations as an appropriate method to address our research question. The main findings are that as the range of decision alternatives considered narrows to a path the variance of the performance of path dependent decision strategies increases. Environmental dynamics negatively influences the performance of path dependent strategies, while higher learning intensity has positive effects. The argument, that path dependence could enable to adapt to changing environments and, therefore, could be perceived as dynamic capability (Vergne and Durand 2011) cannot be supported by the results of this study.

The tolerance scope, i.e. how close an alternative in the current decision has to be to the alternative chose the previous decision to allow for learning or avoid unlearning interestingly has no effect on performance. This might be due to the reactive decision making of the path dependent strategy – to maximize payoff based on past learning benefits – rather than a more pro-active decision to enter and keep a path especially to build up such learning benefits. This irrelevance of the tolerance scope also affects the generalizability of the model and its results, as the dimensionality of the decision space with bipolar extremes is, therefore, not necessary and also no restriction of the model.

Certainly there are numerous possibilities to extend and further specify the simulation model presented in this study, which opens several avenues of necessary and interesting future research. First of all, environmental dynamics, where modelled by different degrees of randomness of the payoff of alternatives, but constant over time. This does not consider path breaking changes e.g. through new product or production technologies that cause discontinuous interruptions of Schumpeterian creative destruction. This could be modelled by quite stable value functions followed by radical changes, and would yield new information about this kind of change and dynamics in the environment.

It was mentioned that the good performance – relative to the flexible strategy – to some extent might be a bias from the focus of this simulation study on learning effects as an important internal self-reinforcing process. However, even in situations where a path dependent strategy performs inferior to a flexible strategy it could be beneficial in competition. If all firms in a market adopt a flexible strategy they would compete on the basis of the same strategic terms and might engage in ruinous competition. Path dependent strategies, on the other hand, could lead to heterogeneity in the market, the focus on niches or market segments and eventually greater choice for the demand side and thereby win-win situations. Analyzing these aspects requires simulation of markets featuring populations of agents with path dependent and flexible strategies. While this study, with its comparison of the path dependent and flexible strategy, built the basis for such analyses, multi agent market simulations would enable to yield even deeper insight into the performance implications of path dependence and path creation.

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