

**STRIKING NEW PATHS:  
THEORY AND METHOD IN PATH DEPENDENCE RESEARCH\***

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**Abstract:**

In this paper we argue that the main reason for the prevailing methodological dissent in path dependence research is the futile attempt of capturing “path dependence as a whole” within either a single-method research design or a single all-encompassing theoretical mechanism. By delineating two conceptual building blocks resting on different epistemological foundations – path creation/emergence and positive feedback/lock-in – we advocate for the application of complementary methodologies. We further refine this argument by proposing a general axiomatic structure for path dependence as a theoretical concept, which allows us to derive more specific methodological suggestions.

**Keywords:** path dependence, methodology, contingency, positive feedback, testability

## **1 Introduction**

While path dependence as a theoretical conception has originally been developed and discussed within different streams of economic thought (David (1985); Arthur (1989); North (1990); Witt (1997)), it recently attracts a growing interest in the field of organization and management studies (Garud and Karnoe (2001); Schreyögg and Kliesch-Eberl (2007); Sydow, Schreyögg, and Koch (2009); Vergne and Durand (2010)). However, in spite of several conceptual adaptations for its application within the organizational realm (see, for example, Koch (2008, 2011)), some of the most fundamental and still unresolved controversies have been merely imported from economics into organizational research. Among these aspects the question how to empirically validate central claims of path dependence research is particularly prominent (Kay 2006).

To us it seems that a lack of conceptual clarity in path dependence research leads to confusion on methodological issues in general and the issue of testability in particular. This is especially obvious in a recent dispute on methodology and testability in path dependence research (Vergne and Durand (2010), Garud, Kumaraswamy and Karnøe (2010)): in discussing the “missing link between theory and empirics of path dependence”, Vergne and Durand (2010) heavily refer to the mainstream economic critique by Liebowitz and Margolis (1990, 1994, 1995) when bemoaning a lack of both conceptual clarity and testability. Their “narrow definition” of path dependence (Vergne and Durand (2010)) – which is in this respect similar to the three-phases model put forward by Sydow et al. (2009) – distinguishes contingency, self-reinforcement and lock-in as the major components of path dependence and leads them to suggest – in contrast to Sydow et al. (2009) – simulations, experiments and counterfactual models as the appropriate methodological tools for investigating it. Replying to these methodological claims, Garud et al. (2010) argue for a slightly different theoretical conception but defend just another methodological view by advocating for a case study methodology in general and their narrative approach in particular when researching path dependence. This is again in conflict with the methodological suggestions provided by Sydow et al. (2009, 705), who emphasize the role of patterns of behavioral practices as an empirical anchor for analyzing path dependence and explicitly differentiate this perspective from historic process studies with a strong narrative component. In the end we have three recent articles all published in leading academic journals, which advocate

very different methodological prescriptions, but refer to a common theoretical framework.

A review of this debate shows that the current discussion (a) lacks a clear expatiation of the relevant theoretical mechanisms or propositions and (b) is driven by a debate on concrete methods, whereas the more fundamental questions regarding the epistemological nature and the axiomatic structure of path dependence remain diffuse. Hence, such an approach does not advance a rigorous discussion on “testability” since both, the clear expatiation of the alleged mechanisms as well as a pedantic analysis of these mechanisms, are necessary preconditions for evaluating the empirical content of a certain theoretical conception. Moreover, the axiomatic structure of a given theory is also the most promising starting point for developing concise methodological suggestions.

Taking the current debate as an exemplification for epistemological problems in path dependence research, our paper builds upon the basic observation that there are still substantial epistemological and methodological differences as to how path dependence should be properly operationalized in terms of empirical testing. From our point of view the main reason for this prevailing dissent is the futile attempt of capturing “path dependence as a whole” either (a) in one generalized all-encompassing theoretical mechanism or (b) within a single-method research design. Both Vergne and Durand (2010) and Garud et al. (2010) get caught in such an endeavor of searching for a single best (methodological) way for addressing path dependence.

In the vain of omitting this specific pitfall by embodying a more pragmatic approach to this issue, our paper addresses three basic research questions:

- (1) Are we able to isolate common mechanisms conventionally subsumed under the label of path dependence and formulate appropriate hypothetical statements?*
- (2) Can these common mechanisms be embedded in an axiomatic structure, which qualifies to be called a “theory”?*
- (3) Can we find ways to test the central propositions embedded in this axiomatic structure and if so, which methods are most appropriate?*

After some preliminary epistemological remarks in section two, we will try to answer the first question in section three, where we put forth an argument on theoretical convergence in path dependence research. In the following sections we will first present

a suggestion for a unifying axiomatic structure, which exhibits testable implications (section four). Based on these considerations we offer a more rigorous assessment of possible methodological strategies related to research in path dependence (section five). Eventually, we offer some concluding remarks (section six).

## **2 Mechanisms, Descriptions and the Testing of Theories**

Not all uses of the words „path“ or „path dependence“ within a social science context refer to the narrow theoretical conception this paper is dealing with. Many researchers just use them to metaphorically describe historical contingency and the conditionality of certain events or institutional configurations (see Goldstone (1998) for an example of this type of usage). Those researchers, however, who intentionally use “path dependence” as a *theoretical* conception, in contrast to a metaphorical or heuristic understanding, overwhelmingly locate their work in the tradition of David (1985, 2001) and Arthur (1989, 1994).

Such a *theoretical* perspective implicitly accepts the idea of nomothetical knowledge, even for the realm of the social sciences. In this context *nomothetical* implies that knowledge takes the form of theoretical mechanisms or propositions (i.e. mechanisms expressed in law-like statements; Bunge (1997), Mayntz (2004)). The major issue with such theoretical propositions is whether they are able to inform about empirical relationships – if so, they carry *explanatory power* or (equivalently) *empirical content*<sup>1</sup> (see: Bunge (1996, 166-169); Popper (1969)). In this paper we refer to single law-like statements as “theoretical propositions” or “hypothetical statements,” while *theories* are normally composed of a set of such theoretical statements in conjunction with a less obliging additional set of possible auxiliary hypotheses (Bunge (1967, 305-315)). The function of these auxiliary hypotheses is thereby twofold: they concretize the more

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<sup>1</sup> Theories are devoid of empirical content, i.e. they are tautological, if they (a) lack a domain for empirical application (they are pure “thought-experiments” in this case) or if they (b) are formulated in a way to guarantee the compatibility of the theory with any possible observation within a certain empirical domain. An example for (a) is provided by an understanding of economic models as “conceptual explorations” (Hausman (1992, 6)) in “counterfactual worlds” (Sugden (2000, 18)). From this point of view, all assumptions of a given model are to be understood as auxiliary hypotheses (“What *would* happen if this or that *were* the case?”); such a model therefore operates “without empirical commitment” (Hausman (1992, 6)). Examples for (b) are provided by sentences, which do not exclude any logical possibility like “if the weather does not change, it will stay the same” or “anything a person does is the result of an utility maximization process subject to unknown and flexible preferences.”

general laws for special cases, thereby allowing for testable empirical predictions, and – at the same time – restrict the scope or domain of the derived statement (the scope of the law of gravitation is much greater than that of the law of falling bodies, exactly *because* the latter follows from the former *under certain conditions*). This implies that different applications might require different compositions of auxiliary hypotheses. While both, auxiliary hypotheses and theoretical propositions can be conceived as theory-specific assumptions, the latter exhibit a specific structure, that is:

*For all x holds: if there is A, there is B, too (or formally:  $G:(x) (Ax \rightarrow Bx)$ )*

Law-like statements of this kind contain (a) general terms (A, B, x) in conjunction with (b) some proposed necessity (if-then; i.e.  $\rightarrow$ ). As indicated above, law-like statements of this form often cannot be tested directly but require the specification of additional auxiliary hypotheses in order to bear testable implications (this even holds for well-established theories such as classical mechanics; see: Bunge (1967, 22)).<sup>2</sup> In sum, *if path dependence is to be considered a theory it should contain at least one such law-like statement*, which is testable given that some additional assumptions are added to it.

Since our statement on how to conceive and conceptualize a theory might provoke premature objections, we would like to further clarify our understanding of the role hypothetical statements in the context of path dependence research. Even though we believe that path dependence as a *theoretical* conception does indeed contain law-like statements (in what follows we will try to show that it even qualifies to be called a “theory”), we argue that practical research in path dependence cannot be exhaustively described by a set of theoretical propositions but also deals with historical phenomena from an ideographic viewpoint, i.e. is aiming to supply good descriptions of specific situations or processes. Also we do not, by our insistence on the possibility of nomothetic knowledge, imply that ideographic descriptions are per se of a lesser scientific merit. Quite on the contrary, all sorts of topics may be empirically investigated by ideographic approaches, whose application is often a methodological necessity, for example when the phenomena of interest constitute unique events. It would be absurd to claim that such unique events are not of scientific interest: just think of World War I, the Oil-Shock or floodwater-prevention at a certain river.

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<sup>2</sup> In the social sciences it is often difficult to differentiate between law-like, theoretical statements and auxiliary hypotheses. This constitutes a regrettable characteristic trait of the social sciences, which can render theories untestable.

But while acknowledging the merits of ideographic approaches, such descriptions regularly make use of known or assumed regularities (that is, *mechanisms*), even though the point in case is to give an ideographic account. On the other hand, every experiment requires the utilization of one of the archetypes of ideographic research: a *protocol*. These examples already indicate the major shortcoming of the nomothetic-ideographic divide: all kinds of (empirical) scientific fields, no matter whether they are commonly located in the natural, social or cultural sciences, make use of both modes of inquiry. While these modes of thought cooperate in varying intensity and with varying relative importance across disciplines, their productive interaction as such shows that nomothetic and ideographic elements do not necessarily represent inherently antagonistic ontologies (as alleged by Garud et al. 2010) but *complementary* modes of scientific inquiry.

This issue is important since conceiving science dichotomically as either purely nomothetic, i.e. only accessible in terms of regularities (“laws”), or as purely ideographic, i.e. only accessible in terms of scrupulous descriptions, lies at the heart of the current debate on path dependence as illustrated by the following quotations:

“Methodologically, our path creation perspective suggests that it is important for a researcher to study processes in ‘real time’, i.e., place oneself at the time that events occurred even if one were looking at data gathered in the past. [...] It is equally important for a researcher to ‘follow the actors’ to study how actions become possible through entanglements.” (Garud et al. 2010, 770)

“The bottom line is: organization scholars will not be able to verify path dependence empirically if their argument relies on the ex post demonstration that something did happen contingently.” (Vergne & Durand 2010, 746)

Vergne & Durand (2010) seem convinced that contingent events, on which no law-like statements can be made, are in no case a legitimate part of science. They emphasize the nomothetic aspect of science, i.e. the idea that science is (only or primarily) characterized by the search for regularities in society and nature. Garud et al. (2010), on the other hand, make reference to social constructivism and urge us to observe the idiosyncratic processes of a given case, which represents the (only or primary) way to deepen our understanding of path dependence. From such a viewpoint, careful descriptive research is a necessity, while all too simplistic mechanisms are either superficial or misleading.

This debate, thus, resembles the classic dichotomy between a (purely) nomothetic and a (purely) ideographic approach, which is evidenced in a huge amount of cases in the history of philosophy and science. The most famous is possibly the German Methodenstreit between the German Historical School and the early proponents of Austrian Economics (see (Hodgson (2001))). An example for an antagonistic usage of the ideographic-nomothetic distinction within organizational research is provided by Burrell and Morgan (1979), who label it the “subjective-objective” divide and present it as a “meta-theoretical assumption” preceding any concrete research activity (Burrell and Morgan (1979, 8)). In contrast to these rather dichotomic approaches we propose a more pragmatic viewpoint, which is rooted in current developments in the philosophy of science, where the traditional nomothetic-ideographic dichotomy is deemed to be a philosophical chimera, which is as wrong as it is common among empirical researchers.

“To sum up, the nomothetic/ideographic dichotomy is a philosophical artefact, for every science is both nomothetic and ideographic.” (Bunge 1999, 33)

As outlined above, we argue that from a philosophical viewpoint as well as in actual research practice ideographic and hypothetical concepts are much more intertwined than most people would expect at first sight. Hence, it is easy to see that “mixing ontologies”, as criticized by Garud et al. (2010), can indeed be desirable: As we have seen this is no matter of “consistency,” but should rather be determined by the problem or question at hand – ideographic purism is, thus, not of much help. Vergne & Durand (2010), nonetheless, commit the mirror-inverted fallacy by proposing to reduce the amount of (ideographic) case-study research and to perceive the initial conditions of a path dependent process as either unimportant (if initial conditions are weak) or problematic (if initial conditions are strong). In doing so, they try to define away the most controversial component of path dependence from a purist nomothetic perspective: the (series of) unique events before positive feedback effects kick in.

In this section we tried to delineate how the nomothetic-ideographic ‘divide’ can be productively resolved, why occurrences of unique events inherently demand the latter approach and how a one-sided interpretation of this distinction may be misleading. In what follows we suggest aligning these two modes of thought as two rough methodological “building blocks,” whose relevance is determined by the concrete problem at hand. We will explore this issue more intensely in section four, but before

we have to outline our understanding of path dependence as a theoretical concept more specifically.

### **3 Path Dependence Theory: Common Ground**

First and despite the appropriateness of common complaints about the absence of conceptual clarity (see, for example, Mahoney (2000)), we argue that actually a kind of *theoretical convergence* has happened over the past decade. A growing consensus can be observed across disciplines and analytical levels on the question of what path dependence is or should be. Thereby positive feedback effects are of a central importance, since they link initial contingencies with an eventual state of hyperstability called “lock-in”. Path dependence is thus to be located in the realm of *mechanism-based theorizing*, which aims to explain social phenomena by identifying the processes through which they are generated (Davis and Marquis (2005)). On this level of abstraction path dependence is a theoretical umbrella term covering various processual empirical phenomena related to different social standards in form of technologies or institutions. It is thus comparable to similar terms commonly used in management and organization studies such as “absorptive capacity” (Cohen and Levinthal (1990)), “core competences” (Prahalad and Hamel (1990)), or “dynamic capabilities” (Teece, Pisano and Shuen (1997)). The eminent question is now whether this emerging consensus can be framed within a common axiomatic structure. We will expand on this issue in the subsequent sections.

In order to prepare some common theoretical ground, we analytically disassemble path dependence into the three parts or phases, which can be found in most of its recent applications (see, for example, Sydow et al. (2009); Vergne and Durand (2010)). Our focus on “contingency” and “self-reinforcement” is thereby compatible even with contributions skeptical towards phase models of path dependence such as Garud et al. (2010, 761), who acknowledge that these two building blocks “have been shaping the very use (or misuse) of this concept over time.”

#### *3.1 Contingency: Path Emergence and Creation*

In the beginning of path dependent processes there is contingency. It is at this stage where historical peculiarities – “small events” (Arthur (1989)) – matter most. For Arthur (1989, 117-118) these small events are of importance because, on the one hand,

they “are not averaged away and ‘forgotten’ by the dynamics – they may decide the outcome” but, on the other hand, they “are outside the ex-ante knowledge of the observer – beyond the resolving power of his ‘model’ or abstraction of the situation”; the latter is what makes small events responsible for the non-ergodicity of path dependent processes. In phase models of path dependence such as developed by Sydow et al. (2009), the period of contingency lasts until a “critical juncture” (Mahoney (2000)) is reached and positive feedback kicks in.

Consistent with Arthur’s definition of small events are thus both “unpredictable, non-purposive, and somewhat random events” (Vergne and Durand (2010, 741)) and actors that are “able to improvise and bricolage their ways through an emergent process” (Garud et al. (2010, 764)). This is not only true from a researcher’s perspective but as well for the actors involved in the process: what appears as purely random for one observer may be attributed causally to intentional actions by another one.

In terms of methodology, the contingent phase of path emergence and creation is always subject to historical explanation. From this perspective it is not surprising that Garud et al. (2010), whose concept of “path creation” clearly focuses on this phase, favor narrative approaches.

### *3.2 Self-reinforcement: Positive Feedback*

Regarding positive feedback as a constitutive element of path dependent processes, the extant literature differs in wording and categorizing but not in essence; Saxenian (1999, 106) even states that “path dependency without a mechanism is nothing more than a recognition that history matters.” Consequently, scholars using path dependence in the tradition of David and Arthur prominently feature concepts such as “self-reinforcement” (Arthur (1994); Vergne and Durand (2010)), “positive feedback” (David (2001); Sydow et al. (2009)), and “increasing returns” (Arthur (1989); Pierson (2000); Campbell-Kelly (2001); Kay (2006); see also Arthur (1994, 112) pointing to a variety of further labels). Especially the latter notion of “increasing returns” has inspired criticism (Arrow (2000)) and is prone to misunderstandings, as its clear-cut mathematical meaning interferes with its metaphorical usage, mainly in the field of political science (see, for example, Pierson, (2000); Thelen (2003); Kay (2006)).

While we thus contend that most of the different labels for positive feedback could be used interchangeably, we nevertheless suggest abstaining from using the term

“increasing returns” unless it is exactly specified. The reason for this is that positive feedback effects may, but must not, come with increasing returns. They are also possible with constant or even decreasing returns, which is not to be confused with negative feedback. Even with decreasing returns, there might still be an increase in the variable under question, which can be seen in the most classic example for path dependence: the standard S-curve of technology diffusion is the result of ongoing positive feedback, but shows all three possible kinds of return structures at different points in time (see also Figure 1).

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Insert Figure 1 about here  
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The second difference – in addition to wording – lies in a growing number of attempts to categorize different causes for positive feedback. Sydow et al. (2009), for example, list coordination, complementarity, learning, and adaptive expectation effects, each of which encompasses several different types of positive feedback that can be found elsewhere in the literature. Among those are direct and indirect network effects/externalities (Katz and Shapiro (1985); Liebowitz and Margolis (1994); Shapiro and Varian (1999)), dynamic capability development (Leonard-Barton (1992); Teece et al. (1997); Schreyögg and Kliesch-Eberl (2007)), and certain types of strategic co-evolution (Burgelman (2002, 2009); Koch (2008)).

From a methodological perspective, however, all these categorizations should not obscure the common conceptual core: positive feedback. Identification and investigation of particular positive feedback effects and their impact on the overall development is in turn an empirical task; one that even allows for applying a broad repertoire of methods.

### *3.3 Stable Outcome: Lock-in*

In a nutshell, lock-in is a situation where no viable – in terms of switching efforts – alternative to a given social standard can be realized. Referencing Giddens (1984), Sydow et al. (2009, 694) argue that a lock-in may be of a predominantly cognitive, normative, or resource-based nature and become a de facto irreversible state. For the organizational realm, Sydow et al. (2009, 695) “suggest conceptualizing the final stage of a path dependent process in a less restrictive way – as a predominant social influence,

leaving some scope for variation.” Using different sets of auxiliary hypotheses, an issue we will expand on in the subsequent section, can accommodate these slight differences in interpretation.

From a methodological viewpoint, the state of lock-in is virtually inseparable from the previous stages of positive feedback and path creation/emergence: even the empirical question whether positive feedback can still be found in situations of alleged lock-in requires identification and measurement of these very effects. There may be differences between the two phases regarding the stability of a given situation (stochastic versus deterministic), the auxiliary hypotheses needed to test the postulated mechanism(s) or the latter’s specific formulation, but their methodological core – a focus on mechanism testing – is basically equivalent. The specific question whether any other alternative would have been or still was viable or even superior compared to the status quo, might in turn require ideographic reasoning similar to the issue of path creation/emergence – an issue we will address in section five.

#### **4 The Axiomatic Structure of Path Dependence: A Suggestion**

While theoretically we have followed the common distinction between three consecutive phases of path dependence theory (Sydow et al. (2009)), *methodologically* we differentiate two partially overlapping and reciprocally related conceptual building blocks (see Figure 2): The first building block deals with emergent or intentional actions – historically contingent small (and not so small) events – responsible for initiating and directing a path dependent process. These are responsible for the non-ergodicity of path dependent processes in general. Methodologically this requires approaches that are open for idiosyncrasies in historical chains of events, something Mahoney (2000, 509) refers to as “reactive sequences”. As already mentioned, the narrative case study approach put forward by Garud et al. (2010) is perhaps the most prominent but definitely not the only approach for such an endeavour. Alternatively, “contextualist analysis” (Pettigrew (1990)) or “systematic process analysis” (Hall (2003)) could be applied, which strive for generalization by identification of patterns while being responsive to historical idiosyncrasies (see also Bennett and Elman (2006)).

Several extant studies describing cases as path dependent apply such an ideographic approach. Schreyögg, Sydow and Holtmann (2011), for example, use an entirely historical approach to describe rise and decline of the Bertelsmann book club in Germany as a case of organizational path dependence. Also several examples in the

volume on path dependence and creation, edited by Garud and Karnoe (2001), pursue purely ideographic research methodologies (see, for instance, Kenney and von Burg (2001) or Porac, Rosa, Spaniol and Saxon (2001)).

However, as in any historical analysis, ideographic descriptions of path emergence and creation processes cannot be tested in a narrow sense but can only be contested by presenting additional (counter-)evidence and/or developing alternative explanations. Whether a particular case is one of path emergence or creation is an empirical question depending – among other things – on the agent(s) under study. Thus, it is difficult to tell whether disputes on path creation can ever be resolved (see the debate on the QWERTY-example in David (1985); Liebowitz and Margolis (1990); Frost and Egri (1991); David (2001)) since additional evidence might anytime be added to an established argument, thereby possibly changing its implications.

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Insert Figure 2 about here  
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The second building block covers ergodic law-like positive feedback mechanisms reduce the range of available alternatives and thus managerial discretion over time. On a general level, mechanisms could be described as “sequences of causally linked events that occur repeatedly in reality if certain conditions are given” (Mayntz (2004, 241)). They are thus “recurrent processes”, accounting for how a set of specified initial conditions leads to a specific outcome. It is in this context that a more concise testing of path dependence becomes possible.

Examples for studies trying to test law-like positive feedback mechanisms within path dependent processes are Koch, Eisend and Petermann (2009) and Blinn (2009). The former tests the tendency of probands in a controlled experiment “to neglect future developments at the expense of information on present situations” (Koch et al. 2009, 79). In their experiment, Koch et al. manipulate the complexity of a fictitious decision environment in a mobile service setting to compare the actual decision paths of the probands with a given optimal one. Blinn (2009) in turn demonstrates that mechanism testing need not be restricted to experimental research designs. He tests positive feedback mechanisms responsible for the persistence of dubbing in the film industry by comparing the respective dynamics in different countries.

However, the approach of “mechanism testing” in building block II does not necessarily imply that ideographic descriptions as such are of no further importance; quite on the contrary, the (novel) facts they provide might be well-suited or even necessary for testing theoretical statements. So they are still useful for path dependence research at this stage, but exhibit a different methodological purpose: In the phase of contingent path creation or emergence (building block I), their aim is to supply precise descriptions of actual events, while in the context of mechanism testing (building block II) they can be utilized to evaluate theoretical claims. This second building block therefore *demand*s a different case study design, which tries to establish the idea of mechanism testing within case study research (see Gerring (2004) or Flyvberg (2006) for a comparison of different approaches). While such research strategies are often limited in their representativeness, they are still suitable for refuting theoretical claims, due to the asymmetry between verification and falsification (one black swan suffices to refute the claim that all swans are white). So if research designs are adequately specified and executed, these approaches will allow for the testing of theoretical claims.

The advantage of restricting theory testing in a narrow sense to our second conceptual building block is best illustrated by the attempt of Vergne and Durand (2010, 748) to formulate an “all-encompassing” mechanism capturing “path dependence as a whole“. They present the following two theoretical statements as a starting point for putting path dependence to a test:

*“For any set of initial conditions, if contingent events put B far enough ahead of A, and the path is later reinforced, then the process is locked-in on B”*

*“By contraposition, for any set of initial conditions, if the process is not locked-in on B, then either contingent events did not put B far enough ahead, or self-reinforcement did not occur on path B (e.g., it was stronger for A)”.*

The inclusion of contingency in the if-clause of these stylized mechanisms basically renders them nearly tautological: They lack empirical content and are, thus, basically untestable.<sup>3</sup> Taking the ideographic nature of contingent initial conditions into account,

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<sup>3</sup> The only possible way to refute the above hypotheses is to identify a situation where self-reinforcement holds for B, but B is not locked-in, *although contingent events have put B “far enough” ahead of A*. We suppose that this last condition related to contingent events is only accessible through ideographic-

for both statements any empirical result may be attributed to the existence or absence of “contingent events”, that is some “random factor”. Our proposal to methodologically acknowledge the ideographic nature of initial contingency and to preserve empirical testing to the aspect of self-reinforcement is particularly helpful to avoid such loopholes, which root in the desire to test path dependence as a whole and result in an immunization against critique.

#### *4.1 A simple axiomatic structure for path dependence as a theoretical concept*

Of course, abstract theoretical mechanism categories such as coordination, complementarity or learning effects (Sydow et al. (2009)) need to be linked to particular empirical phenomena. In such a scenario, mechanisms of positive feedback (in contrast to contingent actions and events prevailing in the first conceptual building block) can be integrated in testable theoretical statements. However, while in many applications positive feedback effects are localized or analyzed, their presence as such is only rarely the controversial, that is hypothetical, part of the argument. Quite on the contrary, the typical conjecture in path dependence research is related to specific *outcomes* as they are determined or influenced by positive feedback effects. Moreover, the broad variety of objects tackled in the context of path dependence (technological standards, social norms, organizational routines, or more generally: *social standards*) hints at the diversity of processes, which exhibit positive feedback effects. How this diversity can be integrated into a single and consistent axiomatic structure is by no means clear and seems to have motivated much of Vergne and Durand’s (2010) critique.

In what follows we try to fill this shortcoming in current conceptions of path dependence by providing an axiomatic framework, which takes into account a series of criteria featuring prominently throughout this paper. These criteria are mainly (1) testability, (2) consistency and (3) integrability, that is the ability to integrate superficially different research areas related to path dependence into a common structure. A fourth criterion is that (4) an axiomatic framework should pose the same central questions as they can be found in applied research on path dependence, i.e. it

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descriptive studies. The element of uncertainty associated with “contingent events” is redirected to the phrase “far enough ahead” in the above formulation: How can we “measure” whether B has been put “far enough” ahead of A by contingent events if our only tools are descriptions of contingent events? As long as the answer to this question remains dubious the above formulations lack testability.

should resemble the focus on outcomes as they are influenced by positive feedback effects.

Taking these criteria as a foundation for an axiomatic reconstruction of our theoretical arguments as provided in section 3, we arrive at the following *generic proposition*:

*For all (x) holds CP: If “positive feedback” (PF) is at work and a series of competing and incommensurable social standards x are available, then one of these standards will tend to dominate.*

This suggestion for a *generic proposition* resides in our second conceptual building block and has a series of features: First, it focuses on outcomes without claiming the sub-optimality of outcomes. The latter is, thus, a possible but not a necessary result of path dependent processes: If these processes are really non-ergodic, there is no way to rule out a situation where the “best” solution will succeed (albeit one might say that its quality is not the main reason why it succeeded in the first place). Second, it resembles a very basic claim often found in path dependence research, which is applicable to a variety of settings. Third, it incorporates a ceteris paribus clause (CP) – an issue we will explore on a later stage. Fourth, it seems possible to test the above conjecture, if some central terms, like *positive feedback* or *social standards*, are appropriately defined. Such definitions normally take the form of auxiliary hypotheses. Moreover, one can take advantage of the above formulation by thinking of positive feedback in a very abstract way (as put in the generic proposition), while clarifying different notions of positive feedback in a series of additional auxiliary hypotheses. Consider the following four definitions, addressing different situations out of which positive feedback effects allegedly arise:

*PF<sub>external</sub>: Whenever  $x_i$  is adopted by some adopter  $a_j$ , then  $x_i$  becomes more attractive for all adopters.*

*PF<sub>internal</sub>: Whenever  $x_i$  is adopted by some adopter  $a_j$ , then  $x_i$  becomes more attractive for  $a_j$  in the future.*

*PF<sub>complementary</sub>: If possible adopters want to utilize  $y$  and  $y$  can only be utilized in conjunction with  $x_i$ , then  $x_i$  becomes more attractive (for those adopters who want to utilize  $y$ ).*

*PF<sub>expectational</sub>: If possible adopters believe that  $x_i$  will dominate in the future, then  $x_i$  becomes more attractive in the present (for those adopters who believe that  $x_i$  will dominate).*

These definitions allow for a variety of cases to be integrated in the generic proposition presented above.  $PF_{external}$ , for example, is an abstract definition of coordination and network effects (e.g. Katz and Shapiro (1985); Shapiro and Varian (1999)) and  $PF_{internal}$  is implicit in all instances of learning or habituation effects (see already David 1985 or more recently, Eberl-Kliesch and Schreyögg 2007). Note the auxiliary character of these definitions specifies the generic proposition for a certain application (thereby restricting the domain of the derived statement). The crucial issue with these definitions is, thus, whether they actually apply to a given situation: only in such a case it makes sense to test the derived statement. Note also that the above definitions are interchangeable and compatible with each other, which implies that two or more of these variations may apply to a given object. Additionally, it seems likely that some forms of positive feedback may regularly interact, such as, for example,  $PF_{expectational}$ ,  $PF_{internal}$  and  $PF_{complementary}$  in software markets (cf. Table 1, Shapiro/Varian (1999) and the related discussion on so-called “vapor-ware” in Robertson, Eliashberg and Rymon (1995) and Bayus, Jain and Rao (2001)).

To complete our generic axiomatic structure for path dependence research we still lack a definition for a social standard. We suggest a very broad, general definition which is still in line with the various applications found in the field of path dependence research:

*Social Standard: A technology or rule informing human conduct, which can be replicated.*

This differs from a more casual understanding of social standard in the sense of widely accepted social behavior but serves as an umbrella term for potentially path dependent phenomena such as technological standards, social norms or organizational trajectories. Note that this definition restricts the generic mechanism to matters of human conduct. In order to introduce more artificial, non-social variants of path-dependence – the Polya-Urn may serve as a classical example – it is possible to replace the above definition by a more abstract variant. Such an abstract variant could then relate the aspect of replication directly to the formal properties of observed objects (e.g. red vs. blue balls in a Polya-Urn).

Taking our generic proposition along with the basic definitions provided in this chapter we arrive at a roughly sketched axiomatic structure, which satisfies the criteria laid out in the beginning of this section. The following sections are dedicated to further refining this framework. More specifically, we tackle the role of auxiliary hypotheses, the *ceteris paribus* clause introduced above and the relation of our generic proposition to the phase-model of path dependence as developed in section four.

#### *4.2 Auxiliary hypotheses and ceteris paribus clauses*

We have already emphasized that the role of auxiliary hypotheses is to clarify the domain of a given theory: auxiliary hypotheses tell whether we should expect a given mechanism to apply to a specific situation. The utilization of a varying set of auxiliary hypotheses suggested by our conceptualization is thereby quite in line with the manifoldness of topics commonly associated with path dependence research. This illustrates that the multiplicity of possible applications for path dependence as a theoretical conception is due to the utilization of different, but compatible, auxiliary hypotheses, which address different social patterns and subsume these distinct cases under a single theory. Table 1 gives a stylized overview on how some rather prominent cases can be systematized within such a framework.

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Insert Table 1 about here  
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The manifoldness of different problems tackled by path dependence as a theoretical concept thereby not only allows for, but also demands a certain degree of methodological diversity, since concrete methods always have to be tailored to the problem at hand (we will explore on this issue in section five).

Contrary to auxiliary hypotheses, *ceteris paribus* clauses represent a general statement of caution. They say it might be that a theory or a specific proposition fails to produce the expected results because of unforeseen exogenous forces. While generally *ceteris paribus* clauses often restrict the testability of a given theory, they seem to be a “necessary evil” (at least in the social sciences), whose necessity is invoked by what is commonly referred to as the Duhem-Quine problem.<sup>4</sup>

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<sup>4</sup> The Duhem-Quine problem basically asks whether we can expect axiomatic systems, i.e. our theories, to be exhaustive. The general answer, given by philosophers as well as social scientists, is that we cannot

An appropriate way to deal with *ceteris paribus* clauses is the following: If a researcher resides to a *ceteris paribus* clause to defend a theoretical claim confronted by conflicting empirical results, one must not refer to the *ceteris paribus* clause in its general form, but to a specific exogenous factor located in the realm of the *ceteris paribus* clause. One may expatiate an additional auxiliary hypothesis (and add it to the theory as stated before the test), thereby enhancing the axiomatic structure of the theory in general. Such a procedure ensures that the *ceteris paribus* clause is not used as a vehicle for the immunization against critique, but is utilized in a constructive way to extend the precision of the theory when viewed as a set of complementary statements.

A simple example is as a case involving three competing technologies ( $x_1$ ,  $x_2$ ,  $x_3$ ) in a market associated with positive feedback effects. Let us further assume the starting positions of these three technologies to be that  $x_2$  is widely used (say, roughly 70% of adopters use  $x_2$ ), while the other two technologies only play a minor role. Given this information we can conclude that it is most probable that  $x_2$  will soon dominate the market. Now suppose that the government shows interest in regulating the market and finds that  $x_2$  – in contrast to  $x_1$  and  $x_3$  – is in some way hazardous to the environment and, therefore, bans  $x_2$  completely. While such a “government-ban” is obviously an exogenous factor, only an auxiliary hypothesis anticipating this governmental action upfront would have prevented the theory from being “falsified” by such an event. In such a case, we could resort to the *ceteris paribus* clause, which must be concretized in the form of a new and specific auxiliary hypothesis (e.g. “no government intervention in the market”). Via such an understanding *ceteris paribus* clauses can help to refine and concretize theories by exposing new auxiliary hypotheses restricting the domain of the law-like statement one would like to test.

#### *4.3 From generic to more concrete mechanisms*

The previous section emphasizes the necessity to concretize theories – to provide them with more precise formulations and more complete sets of statements describing not only the proposed hypothetical mechanisms but also the circumstances under which the respective propositions are expected to hold. It is for these reasons that our *generic*

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assure the completeness of theories. If this is indeed the case then every theory has a *ceteris paribus* clause as a necessary element: It might always be the case, that the supposed theoretical mechanisms are indeed correct, but one has overlooked some decisive auxiliary hypothesis to adequately restrict the domain of a specific application.

*account* of path dependence as a theoretical concept laid out in section 4.1 obviously needs further refinements. In this section we propose a simple modification with respect to the phase model of path dependence sketched in section three. Table 2 provides a short overview about the three phases and their relationship to the two conceptual building blocks introduced at the beginning of this chapter.

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Insert Table 2 about here  
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Relating the conceptual differences depicted in Table 2 to our generic proposition allows modifying and concretizing the latter with respect to the different phases of contemporary models of path dependence: the stochastic nature of phase two demands a probabilistic mechanism and the deterministic nature of phase three (after the lock-in of a certain standard) demands a more traditional non-probabilistic mechanism. Note, however, that ‘deterministic’ does refer to the structural features of the general proposition, which is formulated in a non-probabilistic way, but does not imply that the development is *solely* determined by the core mechanism – also the case-specific auxiliary hypotheses embodied in the respective formulation play an equally decisive role. Keeping these qualifications in mind, we arrive at the following statements describing the behavior of a given social standard in the context of positive feedback in phases two and three.

*Phase 2: For all (x) holds CP: If PF is at work, some competing social standards  $x$  are available and the rate of adoption of  $x_i$  is higher than the rate of adoption of competing standards, then it is more probable that  $x_i$  will tend to dominate.*

*Phase 3: For all (x) holds CP: If PF is at work and a social standard  $x_i$  dominates, then  $x_i$  will stay dominant.*

Note that this refinement leads to two different mechanisms – one probabilistic, one deterministic – which are most probably also accompanied by (at least slightly) different auxiliary hypotheses. Note also that both statements are framed as *ceteris paribus* laws allowing for the creation of additional auxiliary hypotheses. We think a major task of empirical research related to path dependence is to expatiate and concretize these auxiliary hypotheses, which is also relevant for differentiating the domains of these two hypothetical mechanisms.

Distinguishing between probabilistic and deterministic mechanisms however also implicates another, more idiosyncratic empirical task: identifying the “critical junctures” (Mahoney 2000; Sydow et al. 2009) that separate the different phases of path dependence in a certain empirical domain. Due to its idiosyncratic nature, this task in turn requires ideographic research methodology, strengthening our overall point that at least two epistemologically different methodologies are necessary to capture path dependence as a whole.

In this section we tried to show how to align different methodological approaches to path dependence research by differentiating two methodologically distinct building blocks and how to synthesize different theoretical applications in terms of a common axiomatic framework. In the following section we will thus try to derive and systematize implications in terms of concrete methodological suggestions for researching path dependence.

## **5 Delineating Methodological Suggestions**

How does the unified theoretical framework developed in the previous section relate to the extant methodological diversity (see Vergne and Durand (2010)) in path dependence research? Paradoxically, we would argue, such a straightened account of different methodological building blocks in path dependence theory allows for productively and consistently applying a variety of methods. In this context, the two different methodological building blocks developed in section four are particularly helpful by separating two distinct types of problems – which mostly require different methodological tools – without dichotomizing their distinctiveness. In this spirit, our suggestion is based on the rather general idea that the concrete research method has to be tailored to the problem at hand. To accomplish this task, distinguishing between two methodological building blocks guides methodological division of labor *and* integration both within and between research projects that empirically investigate potentially path dependent phenomena.

Such an approach would however require to abandon the prevalent competitive perspective on methodology that proclaims exclusivity of certain approaches and stands in the way of the more cooperative position advocated here. Furthermore, our theoretical framework and the associated methodological building blocks suggest perceiving methodological diversity not only as a complication but, above all, as a practical necessity, which is rooted in the complementarity of different methodological

approaches. Consequently, Table 3 gives an overview of those methodological approaches we deem both particularly relevant and promising for applying the theoretical framework developed above.

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Insert Table 3 about here  
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As far as *case studies* are concerned, we differentiate between (1) *narrative case studies*, which are characterized by the aim to give a detailed and illuminating ideographic description of a certain and decisive (series of) event(s) and (2) *comparative case studies*, which are implemented to test hypothetical claims due to a refined research strategy (see Gerring (2004); Flyvberg (2006); Ruddin (2006)). This definition implies that those studies, which compare different cases for primarily explorative reasons belong to the set of *narrative case studies*: Although they engage in some kind of “comparison,” the evaluation of theoretical claims is not their primary focus. Our theoretical analysis shows that both versions of case study research can be useful for path dependence as a theoretical concept, but, however, each conception will be useful in its own way.

Due to their ideographic orientation *narrative case study designs* seem to be predominantly important in the phase of path creation/emergence – an aspect already emphasized in section 3. Moreover, *narrative case studies* are useful when the number of events is small and their importance for future development is high, since in such cases a detailed and thoughtful description of actual events is most illuminating. Such events might (but need not) be found at the edge between the different phases, especially to identify the point when positive feedback kicks in and when it effectively leads to lock-in. But narrative case studies or similarly ideographic approaches are also necessary to explain those cases, in which the deterministic predictions of phase three did *not* hold, i.e. to decide whether we have a case of “unlocking” or „path-breaking“ (e.g. Sydow et al. 2009) or whether there was no path dependence in the first place. Generally speaking, the area of path creation and decisive events reshaping the role of positive feedback effects is where narrative case studies can contribute most to a profound understanding of path dependent processes and developments.

In contrast to narrative case studies, *comparative case studies* allow integrating several different cases in a single research design, thereby also facilitating the potential

refutation (that is the “testing”) of theoretical mechanisms. The general strategy of such approaches is to delineate theoretical predictions for a variety of cases, and in turn, to investigate whether the predicted differences or similarities between different cases do really hold. However, as mentioned above, many studies carrying the label “comparative” do in fact not follow this particular route, but have a more explorative character and therefore do, despite the labeling, not fall in this category. A main advantage of *comparative case study designs* in this specific sense is that they allow for mechanism-testing in a rather messy real-world environment, where a series of intermediating and possibly conflicting forces are at work in addition to positive feedback effects. Mainly for this reason *comparative case study designs* seem most promising for expatiating additional auxiliary hypotheses and thereby further clarifying the axiomatic structure of path dependence as a theoretical concept. Since the “fuzziness” inherent in comparative case studies provides the best first-hand knowledge on how to concretize one’s *ceteris paribus* clause in the form of specific, but generally relevant, new auxiliary hypotheses (Ragin and Byrne (2008), Fiss (2009, 2010)).

Following Yin’s (1994) classical line of argument, *controlled (laboratory) experiments* are somehow complementary to *comparative case studies* in terms of dealing with auxiliary hypotheses. While comparative case studies mostly cannot control the parameters influencing a certain development in addition to positive feedback, and thereby have potential to explore these additional factors, *experiments* are primarily dedicated to controlling such factors or keeping them constant. Due to this methodological complementarity, experiments can be utilized to explore the effects of positive feedback in a much less „fuzzy“ laboratory environment, where positive feedback effects may be studied without the need to account for a broad variety of possible exogenous factors; effectively, experiments allow studying positive feedback in a rather *pure form*, abstracting from the fuzzy and complicated nature of real-world developments, where positive feedback is just one parameter among a series of possibly relevant factors. In this context the theoretical mechanisms proposed in the previous sections seem to be a useful guide for the design of such experiments.

Another methodological approach, also connected to the idea of comparative case studies, but of a more longitudinal nature, is to state and assess *real-world prognoses*. In a real-world prognosis a given theoretical proposition is tested in a very risky (one might also say „Popperian“) way, namely by announcing prophecies about real-world developments in a given market, institution or industry. Some time (e.g. a few months

or years) later, this prophecy is re-evaluated by asking whether the hypothetical prediction of real-world developments has been corroborated or falsified. In the former case one may speak of a theoretical success, while in the latter case one has to examine the historical developments in search for those factors or parameters, which led to the failure of the prediction. In such a case, this research strategy will lead to a framework similar to that of comparative case study designs, where real-world processes are examined for factors disturbing the prevalence of positive feedback effects. Again this might lead to the expatiation of additional auxiliary hypotheses and contribute to a clearer axiomatic structure of path dependence as a theoretical concept. Note, however, that there are still two decisive differences between comparative case study research and real-world-prognoses: While the former analyzes the development of a variety of cases ( $N > 1$ ) *ex-post*, the latter looks mostly at a single case ( $N = 1$ ) and makes an *ex-ante* prediction about some expected developments.

As a final methodological approach, *simulations* have the significant drawback that they are, strictly speaking, not an empirical method, but a way to examine the behavior of dynamic systems with respect to different parameter values. So the connection between empirical phenomena and simulations is rather loose and mostly restricted to choosing or estimating plausible model specifications, initial conditions and constants. Nonetheless, we believe that simulations can contribute to an enhanced understanding of path dependence as a theoretical concept by allowing the exploration of the weights different parameters acquire in dynamic processes, where one of these parameters are positive feedback effects. In fact many dynamic models exhibit notions of positive feedback: for instance, an iterative prisoner's dilemma game, where Tit-for-Tat is playing against Tit-for-Tat (see Axelrod 1984), or some simple predator-prey models, which can effectually be described as a sequence of positive and negative feedback loops (see Holling 1973). Useful simulation results nevertheless mostly rest on a careful formulation of the relevant axiomatic system, which acts as a blue-print for the setup of the associated dynamic systems. It is therefore no surprise that one of the most interesting applications of simulations in the realm of path dependence (Sterman and Wittenberg 1999) is connected to the Kuhnian concept of a scientific paradigm (Kuhn 1996), where a respectable set of hypothetical mechanisms and auxiliary hypothesis already exists. In sum we think that *simulations* might be useful for getting an impression about the weights of different parameters in real-world processes, where positive feedback effects constitute one of these parameters. However, in its current

state we think that the axiomatic structure of path dependence as a theoretical concept is too loose in order to successfully conduct simulation-based research; providing an avenue to clear-cut axiomatic foundations for such research in the future, we deem to be one of our main contributions.

While the methodological viability of simulation-based research is therefore rather limited at the moment, the somewhat similar approach of using *counterfactual models* (like models in economics, as proposed by Vergne and Durand (2010)) is also found in research on path dependence (see the work on „history-friendly“ modelling, e.g. Malerba, Nelson, Orsenigo, and Winter (1999)). Thereby, it seems unlikely that such models are helpful for conducting empirical investigations, since the thought-experimental character of such models drastically reduces their empirical testability (see, for example, Sugden (2000)). Indeed many economic models are rather good examples for empirically irrelevant thought-experiments as mentioned in section 2. It is for this reason that we did not include counterfactual models as a suggestion for further improving empirical research.

## **6 Conclusions**

This paper contributes to current path dependence research on three levels: *First*, it outlines an axiomatic framework for path dependence as a theoretical conception providing an operationalizable framework for empirical research. Hence, it answers the question “what to test” in empirical research on path dependence. *Second* it suggests a series of possibly useful methods, thereby also assigning a specific research purpose to any of these methods. Thus, it answers the question “which methods to choose” in empirical research on path dependence with respect to the concrete questions or problems at hand. *Third*, the paper shows how to complementary incorporate these methods in a common research program on path dependence. In this spirit, it answers the question “how to synthesize the observed methodological diversity” by providing a general framework which relates an operationalizable axiomatic structure to a set of promising methodical suggestions.

In our view, distinguishing – but not dichotomizing – two methodologically different conceptual building blocks (ideographic and nomothetic) in a theoretical conception of path dependence is compatible with the observed manifoldness of topics and examples subsumed under the heading of path dependence: While the theory is organized around a very general theoretical idea, namely that positive feedback effects lead to some stable

pattern despite the initially contingent events in the path creation/emergence phase, it basically places no restrictions on the potential contexts, in which such a path dependent development might arise. From an epistemological viewpoint, applicability within a variety of settings is not a problem as such but rather preferable to alternative situations where no such setting exists (e.g. for many models in economics). Moreover, our analysis shows that the two conceptual building blocks proposed not only harmonize methodological diversity and a variety of distinct applications but are also compatible with contemporary three phase-models of path dependence (e.g. Sydow et al. (2009); Vergne and Durand (2010)). Finally we argue, that such a view resolves, at least in part, the tensions normally associated with the nomothetic-ideographic “divide” in current debates on methodological issues.

It is important to note that the ergodic nature of positive feedback effects does not compensate for the non-ergodicity of path emergence and creation processes: on the whole, path dependent phenomena are ex-ante non-ergodic processes, requiring a combination of different methodologies for empirical investigation. Consequently, we argue for a variety of methods used rather complementary than competitively and with distinct foci in terms of research strategy as outlined in the previous section to advance research on path dependence as a *theoretical* conception. Indeed, a rigorous understanding of non-ergodicity in path dependence inherently requires the methodological separation we suggest: if all theoretical propositions on path dependence contain the “contingent factor” associated with the path creation/emergence phase, their testability will be in constant doubt.

In this sense our approach assists in avoiding the confusion of contingent factors and law-like mechanisms and allows for a harmonious division of labor between different methodologies. A recent example for the potential of integrating both methodological building blocks is the above mentioned study of Blinn (2009; see also Schreyögg and Blinn (2008)) on dubbing in the film industry. Blinn (2009) both historically analyzes the idiosyncratic origins of dubbing in different countries *and* tests mechanism-based explanations for its persistence against alternative explanations such as country size. However, such a methodological differentiation does not come without costs, since it also demands a higher and more diversified level of methodological literacy among the whole set of scholars. If this requirement is not met, increasing methodological diversity might easily lead to conceptual misunderstandings, mutual ignorance (“walling-off”) or

even heated controversies between those researchers who differ in terms of their methodological preferences.

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## Tables

Table 1

Systematizing prominent cases of path dependence within the suggested axiomatic structure

<i>Generic Proposition:</i> For all (x) holds CP: If “positive feedback” (PF) is at work and a series of competing and incommensurable (social) standards x are available, then one of these standards will tend to dominate.				
Auxiliary hypothesis	$PF_{external}$	$PF_{internal}$	$PF_{complementary}$	$PF_{expectational}$
Exemplary case #1	Polya Urn (Arthur 1989)			
Exemplary case #2		QWERTY (David 1985)		
Exemplary case #3		Windows (Shapiro/Varian 1999)		

Table 2

Epistemological and conceptual differences between different phases of path dependence

Phases	Role of testable mechanisms	Degree of uncertainty	Conceptual building block	“What happens?”
Phase 1 Path-Creation/ Emergence	None (unidentifiable)	Contingent	Ideographic-explorative (building block I)	Distributing initial conditions
Phase 2 Positive Feedback	Probabilistic mechanism	Stochastic	Nomothetic-testing (building block II)	Law-like behavior and responsiveness to exogenous shocks
Phase 3 Lock-In	Non-Probabilistic mechanism	Deterministic	Nomothetic-testing (building block II)	Law-like behavior and low(er) responsiveness to exogenous shocks

Table 3

Suggestions for methodological strategies in path dependence research

<i>Methodological Approach</i>	<i>Predominantly relevant in phase</i>	<i>Research strategy</i>
(1) Narrative case-studies	- Path creation - junctures between different phases - Dissolution of path dependence (“path breaking”)	Provide descriptive accounts on the origins of certain paths or of decisive events leading to or breaking up lock-in.
(2) Comparative case-studies	Positive Feedback and Lock-In	Test theoretical propositions and evaluate the role of exogenous factors in real-world environments <i>ex-post</i> .
(3) Experiments	Positive Feedback and Lock-In	Test theoretical propositions in their allegedly „pure“ form by controlling exogenous factors in laboratory environments.
(4) Real-world prognoses	Positive Feedback and Lock-In	Test theoretical propositions and evaluate the role of exogenous factors in real-world environments via <i>ex-ante</i> predictions about future developments.
(5) Simulations	Positive Feedback and Lock-In	Explore the behavior of dynamic systems with varying model-specifications and parameter-settings (which exhibit positive feedback effects) and the weight different parameters acquire within such systems.

## Figures

Figure 1

Returns structure(s) of a standard S-curve technology diffusion process.

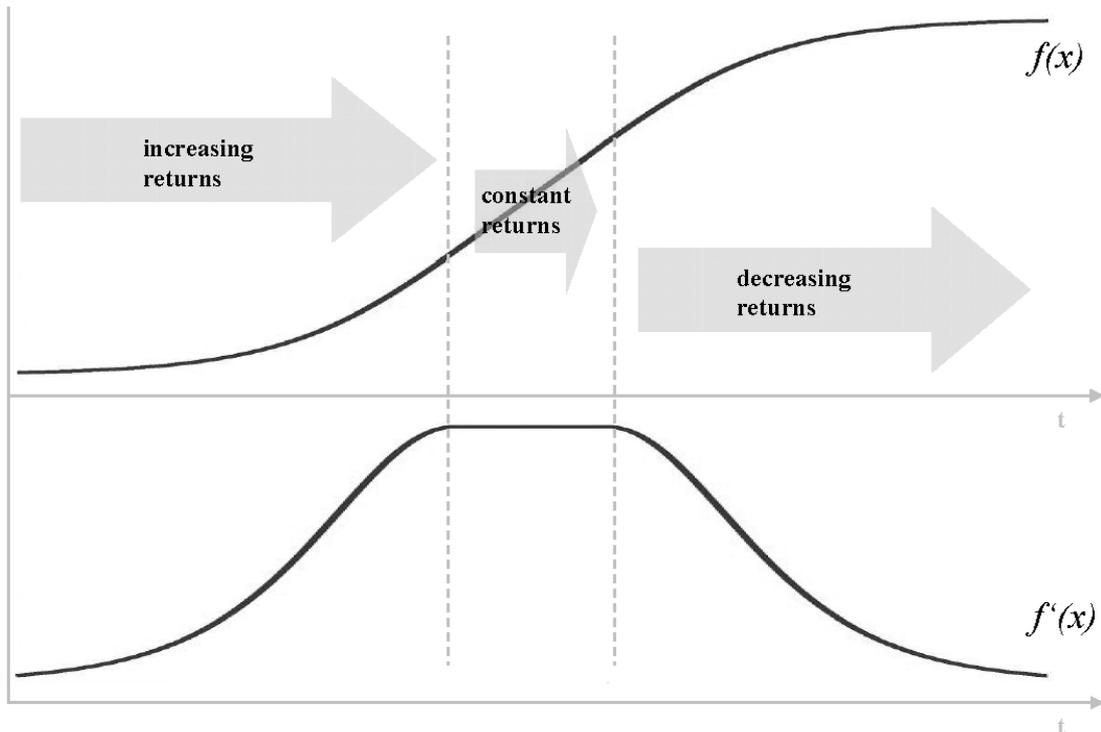


Figure 2

Conceptual building blocks and methodological approaches (inspired by Sydow et al. 2009)

