STRIKING NEW PATHS:
THEORY AND METHOD IN PATH DEPENDENCE RESEARCH[1]

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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 – path creation/emergence and positive feedback/lock-in mechanisms –, each of which rests on different epistemological foundations, 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 deriving 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)), some of the most fundamental and still unresolved controversies have been merely imported from economics into organizational research. In a way, these disputes boil down to the questions what is path dependence and how can it be measured?

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 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.[2] 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 differentiate this perspective from historic process studies. In the end we have three recent articles all published in

[2] Note that narrative case studies designs constitute only a sub-set of the full methodological potential of case study research in general.

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 hypotheses and (b) is driven by a debate on concrete methods, whereas the more fundamental questions – the epistemological nature and the axiomatic structure of path dependence – remains diffuse. Hence, such an approach does not advance a rigorous discussion of the issue of "testability" since the clear expatiation of the alleged mechanisms as well as a pedantic analysis of these mechanisms are both necessary preconditions for identifying 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 this debate as an exemplification for epistemological problems in path dependence research, our paper builds upon two basic observations: 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. The theoretical core are positive feedback mechanisms, which 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. 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.

Second, in spite of growing theoretical convergence, there are still substantial epistemological and methodological differences as to how path dependence should be properly operationalized in terms of empirical testing (see also Kay (2006), in addition to the three recent contributions mentioned above). The main reason for this prevailing

dissent, from our point of view, 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 – a tendency not unrelated to the lack of conceptual clarity often bemoaned by the critics (and practitioners) of path dependence research. 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 we suggest operationalizing the common tripartite structure of path dependence in form of two distinct conceptual building blocks: (1) path emergence/creation[3] and (2) positive feedback/lock-in. These different building blocks most probably require the application of immanently different methods Our contribution to the ongoing debate is therefore twofold: First we analyze the epistemological structure of the problems as they appear in these two building blocks to determine the prevailing epistemological modes of thought suitable for those areas. In doing so we are able to clarify and justify some common methodological preferences observable in path dependence research. In a second step we expatiate a clear-cut axiomatic structure, which allows a more rigorous discussion of the testability of path dependence as a theoretical concept.

The paper is structured as follows: First we review some general properties of empirical testing in the social sciences with special reference to path dependence (section two) to substantiate the relevant epistemological questions in this context. Afterwards we discuss how theories on path dependence emerge and the role of case study research in this context (section three). In section four we put forth our argument on theoretical convergence in path dependence research, followed by a suggestion how to synthesize this theoretical convergence into a unifying axiomatic structure, which exhibits testable implications (section five). Additionally, such a structure allows for a more rigorous assessment of possible methodological strategies (sections six). Eventually, we offer some concluding remarks (section seven).

[3] While we recognize that others (e.g. Garud and Karnøe (2003); Garud et al. (2010)) conceptualize agency as an emergent property of dynamic path creation processes, we use the terms here differently: for us, whether a path is considered to be "created" or "emergent" is an empirical question, depending not least on the agent(s) in focus.

2 Empirical Testing and Path Dependence

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 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, 2000) and Arthur (1989, 1994).

When discussing path dependence as a *theoretical* conception, a further terminological remark is a precondition for answering the major epistemological question, whether “path dependence” contains any empirical content or is not part of the endeavor called “empirical science”[4] (see: Bunge (1996, 166-169); Popper (1969)). In accordance with the standard terminology in philosophy of science we refer to single law-like statements – including classic hypotheses – as “theoretical” or “hypothetical statements”, while “theories” are normally composed of a set of such theoretical statements in conjunction with a less obliging additional set of auxiliary hypotheses (Bunge (1967. 305-315)). While both, auxiliary hypotheses and theoretical statements can be conceived as theory-specific assumptions[5], law-like (theoretical) statements exhibit a specific structure, that is:

[4] 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 assumption 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 logical possibilities 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 preferences.”

[5] 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.

For all x holds: if there is A, there is B, too (or formally: G:(x) (Ax → Bx))[6]

Law-like statements of this kind contain (a) general terms (A, B, x) in conjunction with (b) some proposed necessity (if-then; i.e. →). Note that this basic structure also holds for non-empirical sciences, like mathematics or logic ("for every number n, there also exists (n+1)"). The main characteristic of *empirical* science, however, is that these statements propose theoretical relationships, which may be subject to empirical testing. Most of these law-like statements can rarely be tested directly but require the specification of additional auxiliary hypotheses (this even holds for well-established theories such as classical mechanics; see: Bunge (1967, 22)). Thus, 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.

However, although we believe that path dependence as a *theoretical* conception does indeed contain law-like statements of this kind, we argue that practical research in path dependence cannot be reduced to a set of hypotheses but also deals with historical phenomena from an ideographic viewpoint, i.e. with the aim to give a good description of a certain situation or process. Note that this does not 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. Actually ideographic investigations often incorporate implicit hypotheses and might lead to (novel) facts relevant for generating or evaluating hypotheses (and, thus, may become relevant for *testing* in a more narrow sense). Thus, in research practice ideographic and hypothetical approaches are more intertwined than most people would expect at first sight.

According to an understanding of "theories" and "laws" in the particular sense of law-like statements, it is still an open question whether some part of what is currently subsumed under the label of "path dependence" fits this definition of a "theory" or "theoretical conception". Supposing that at least some of the mechanisms regularly (and maybe implicitly) alleged in the context of path dependence can be explicitly specified by formulating law-like theoretical statements, it qualifies to be called "theory" in its more narrow, epistemological meaning. Hence, path dependence as a theory connects a

[6] We interpret statements like this as law-like statements in this paper, i.e. not as general "numerical" statements. The difference between these two is that law-like statements also propose some kind of fixed (often unobservable) mechanism, while numerical statements assert some regularity in observations, which may be (accidentally) true or not.

set of – maybe partially contested – theoretical statements, which refer to hypothetical mechanisms. From this point of view, the general question whether "path dependence as a whole" was "testable" is all too imprecise to be answered unambiguously. On the contrary, the more concise and thus more relevant questions seem to be the following:

(1) Are we able to isolate common mechanisms from different cases 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 hypotheses embedded in this axiomatic structure and if so, which methods are most appropriate?

We will try to answer the first question in sections three (with respect to theory creation in general) and four (with respect to path dependence), while sparing the second and third question until sections five and six.

3 On the Genesis of Path Dependence as a Theoretical Conception

Discussing the genesis of path dependence as a theoretical conception raises the question how appropriate law-like statements on path dependence can be derived.[7] For this task, the role of case study research is critical. Across disciplines there is a rich literature debating the pros and cons of case study research in general and different case study designs (with different methodological implications) in particular (see, for example, Yin (1994); Gerring (2004); Flyvbjerg (2006); Eisenhardt and Grabner (2007); Siggelkow (2007); Piekkari, Welch, and Paavilainen (2009)). Without resolving these ongoing debates we aim to show why the genesis of path dependence as a theoretical conception is closely related to case study research, especially to narrative research designs as advocated by Garud et al. (2010), which strongly resemble the basic characteristics of an ideographic approach to science, and why this is sound from an epistemological perspective. In short we argue that path dependence as a theoretical conception can be derived from a series of historical case studies by observing similar patterns, which are the basis for the generation of new hypotheses.

[7] It is important to note that classical philosophy of science is rather silent on this issue: The question how to create (appropriate) hypotheses is often located outside the realm of theory fo science.

Consider, as a first example, the research habits in geology: Geologists, in many cases, utilize data collected by intricate activities related to deep boreholes. While doing so they look for possibly generalizable "patterns" in rocks and stone. If some general pattern is observed at various occasions, geologists ask "why?" and in turn formulate hypothetical explanations related to the observed patterns. Thus, they arrive at hypotheses on their subject matter by utilizing "abduction" (or: "explanatory inference"; see: Godfrey-Smith 2003). Once these hypotheses are expatiated as theoretical statements their implications may possibly be subjected to empirical testing in whatever concrete form.

Now replace "geologists" by "social scientists", "deep boreholes" by "case-studies" and "rocks and stone" by, for example, "organizations": The result of this operation gives a relatively good description of what organization scholars do when analyzing specific institutional settings in a search for general patterns. One such seemingly general pattern resulting of this activity is the idea of path dependence, making case study research a legitimate instrument, *at the very least*, for the construction and differentiation of theoretical hypotheses.[8] Path dependence theory's most classic example, the QWERTY keyboard layout (David (1985); Liebowitz and Margolis (1990)), is such an instance from which hypothesis have been created: the finding that QWERTY is subject to an interesting structural feature, labeled path dependence, also created a theoretical conception describing this very feature as its by-product.

The early pragmatist philosopher Charles S. Peirce provided a general framework for this mode of scientific reasoning not later than in 1878. His main argument is that besides deduction (deriving some specific statements from a general rule) and induction (deriving some general rules from a series of specific cases) there is a third variant of logical reasoning he termed abduction. Abduction means deriving some actual cases (why is this rock composed as it is?) from an observed pattern (the rock has some features) and a hypothetical rule (these features may be explained by something, e.g. a meteor). According to Peirce this mode of reasoning is of high importance when it comes to the creation of hypotheses. Hence it is part of the, often neglected, "creative

[8] In fact we think that case study research can do more than that. But for the question at hand this minor argument is sufficient.

component" of scientific inquiry that nevertheless can be approached systematically (see also: Ketokivi and Mantere (2010)).[9]

The notion of abduction is expressed best by Peirce himself who explained his idea very intuitively (1931-1985, 5.189): "The surprising fact, C, is observed. But if A were true, C would be a matter of course. Hence, there is reason to suspect that A is true." Here again the hypothesis A is created as a by-product of the tentative explanation of C. Table 1 depicts the differences of deduction, induction and abduction, in a classical version and related to path dependence. According to our interpretation the far right column, i.e. the abductive mode, is what is utilized in the *creation, i.e. the development and differentiation,* of a theoretical conception of path dependence.

Insert Table 1 about here

In the case of the creation of path dependence theory we argue that researchers observe situations where alternatives of whatever nature are not viable for some specific reasons (the *result*), which they find „surprising", i.e. interesting (for whatever reasons; maybe because it is a suboptimal solution). Hence they try to explain this situation (the *case*) by referring to an alleged theoretical mechanism (the *rule),* which in this context is even compatible to a series of such cases.

In sum this illustrates that there exists an epistemologically valid framework – namely abduction – justifying the creation of path dependence as a theoretical conception by using "intricate activities" related to case studies. So if Vergne and Durand (2010) criticize the prominent position of case studies in path dependence research, their argument might be interpreted as saying that „there is too much theory creation (too much abduction), while the current research lacks appropriate testing". It is however epistemologically hardly plausible to argue that case study research is invalid or in inappropriate in the context of path dependence *in principle.* But if Garud et al. (2010),

[9] While inductively formulated hypotheses propose regularities (that is they answer "what"-questions, e.g. "what happens? – day follows night"), abduction delivers hypotheses gained from a broad observation of facts (e.g. through ideographic descriptions) trying to answer the associated "why"-questions ("why does day follow night?"). Answering such a why-question might result in or incorporate hypothetical allegations which can later be expatiated as concrete hypotheses. Goldstone (1998) discusses this issue in the realm of historical sociology; regrettably, he uses a completely different terminology and a different, predominantly metaphorical conception of path dependence.

on the other hand, are trying to suggest that narrative case studies are an exhausting methodological device for the questions at hand they might risk to remain stuck in *theory-creation* in the long run. In this spirit we would at first suggest to broaden the case study repertoire as exemplified by Gerring (2004), thereby complementing narrative case studies with other case study approaches suitable for theory testing, as well. However, a more comprehensive analysis of this issue requires a delineation of path dependence as a theoretical conception as a precondition.

4 Path Dependence Theory: Common Ground

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, 4), who acknowledge that these two building blocks "have been shaping the very use (or misuse) of this concept over time."

4.1 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, "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, 11)) and actors that are "able to improvise and bricolage their ways through an emergent process" (Garud et al. (2010, 8)). 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.

4.2 Self-reinforcement: Positive Feedback Mechanisms

Regarding positive feedback mechanisms 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)).[10] 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 mechanisms 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 is still 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).

[10] See also Arthur (1994, 112), who pointed out that "[s]elf-reinforcement goes under different labels in (...) different parts of economics: increasing returns; cumulative causation; deviation-amplifying mutual causal processes; virtuous and vicious circles; threshold effects; and nonconvexity."

Insert Figure 1 about here

The second difference – in addition to wording – lies in a growing number of attempts to categorize positive feedback mechanisms. Sydow et al. (2009), for example, list coordination, complementarity, learning, and adaptive expectation effects, each of which encompasses several different types of mechanisms 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 of different mechanisms should not obscure the common conceptual core: positive feedback. Identification and investigation of particular positive feedback mechanism is in turn an empirical task; one that even allows applying a broad repertoire of methods.

.4.3 Stable Outcome: Lock-in

In a nutshell, lock-in is a situation where no viable – in terms of switching efforts – alternative to a given technology, institution or strategy 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; while on the market level a lock-in can gain "deterministic character" in form of (technological) monopoly, in 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."

Methodologically, however, the state of lock-in is virtually inseparable from the previous stages of positive feedback mechanisms 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 mechanisms. 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 –

mechanism testing – is basically equivalent. The 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 the subsequent section.

5 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): *First*, there are 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. 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 challenged 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 dependence can ever be resolved (see the debate on the QWERTY-example in David (1985); Liebowitz and Margolis (1990); Frost and Egri (1991); David (2000)) since additional evidence might anytime be added to an established argument, thereby possibly changing its implications.

Insert Figure 2 about here

Second, ergodic law-like positive feedback mechanisms reduce the range of available alternatives and thus managerial discretion over time. On the abstract, 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. In the context of path dependence only those mechanisms are of interest that integrate the idea of self-reinforcement or positive feedback, making the growth or accumulation of at least one variable over time a necessary condition for identifying a mechanism. It is in this context that a more concise testing of path dependence becomes possible.[11]

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, 20-21) 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.[12] Taking the ideographic nature of contingent initial conditions into account,

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[11] 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. In this sense they are still useful for path dependence research at this stage but exhibit a different methodological purpose: In the case of theory creation their aim is to supply precise descriptions of actual events, whereas in the context of mechanism testing they can be utilized to evaluate theoretical claims, thus also *demanding a different case study design* when moving from the more "historical" or ideographic approaches to those, which try to establish the idea of mechanism testing within their frameworks (see Gerring (2004) for a comparison of different approaches).

[12] 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". It is particularly for avoiding such loopholes, which result in an immunization against critique (and from the desire to test path dependence as a whole), that we propose to methodologically acknowledge the ideographic nature of initial contingency and to preserve empirical testing to the aspect of self-reinforcement. This can be done by separating mechanism testing from the ideographic descriptions relevant for the path creation phase.

5.1 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 operationalized, that is, 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, or hypothetical, part of the argument. Quite on the contrary, the typical conjecture in path dependence research is related 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 criterions featuring prominently throughout this paper. These criterions 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

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, i.e. random factors? As long as the answer to this question remains dubious the above formulations lack testability.

central questions as they can be found in applied research on path dependence, i.e. it should resemble the focus on outcomes as they are influenced by positive feedback effects.

Taking these criterions as a fundament for an axiomatic reconstruction of our theoretical arguments as provided in section 4, we arrive at the following *generic hypothesis* of path dependence research.

> *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 hypothesis* 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.[13] 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 hypotheses), 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:

> *$PF_{external}$: Whenever x_i is adopted by some adopter a_j, then x_i becomes more attractive for all adopters.*

[13] It is easy to see why this should be the case: While the notion of sub-optimality is often invoked to question the emphasis on efficient solutions evolving spontanously out of market settings (as it is often found in economics) and, hence, features prominently especially in discussions transgressing disciplinary borders, it cannot be an integral part of the central conjectures associated with path dependence. The latter claim follows immediately from the notion of a contingent starting point and the non-ergodicity of the supposed process, since if this process is really non-ergodic (as we believe it to be) 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.

$PF_{internal}$: Whenever x_i is adopted by some adopter a_j, then x_i becomes more attractive for a_j in the future.

$PF_{expectational}$: 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).

$PF_{complementary}$: 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).

These definitions allow for a variety of cases to be integrated in the generic hypothesis 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, which cannot be proven to be wrong – these are not falsifiable, only the generic hypothesis is. The crucial issue with these definitions is whether they actually apply to a given situation; from an epistemological viewpoint such auxiliary hypothesis thus define the scope of the theory. 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 well interact regularly, such as, for example, $PF_{expectational}$ and $PF_{external}$ in software markets (cf. the related discussion on so-called "vapor-ware" in Robertson et al. (1995) and Bayus et al. (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 and which can effectively be applied to technological standards, social norms or organizational trajectories alike:

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

Taking our generic hypothesis along with the basic definitions provided in this chapter we arrive at a roughly sketched axiomatic structure, which satisfies the criterions 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 mechanism to the phase-model of path dependence as developed in section four.

5.2 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. Ceteris paribus clauses, on the other hand, represent a general statement of caution. They say it might be that a theory or hypothetical mechanism 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 philosophers call the Duhem-Quine problem.[14]

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 but also further restricting its domain. Such a procedure ensures that the ceteris paribus clause is not used as 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

[14] 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 assure the completeness of theories. If this is indeed the case then every theory (at least in the social sciences) 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 adaequately restrict its domain.

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 completely unrelated to positive feedback effects. 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.

5.3 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 these mechanisms are expected to hold. It is for these reasons that our *generic account* of path dependence as a theoretical concept laid out in section 5.1 obviously needs further refinements.[15] In this section we propose a simple refinement in relation to the phase model of path dependence sketched in section four. 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.

Insert Table 2 about here

Relating the conceptual differences depicted in Table 2 to our generic mechanism 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 social standard) demands a more traditional non-probabilistic mechanism. Thus, we arrive at the following statements statement describing the behavior of a given social standard in the context of positive feedback in phases two and three.

[15] The account itself is however useful to illustrate the structure of path dependency on an abstract level, thereby providing a good illustration of the theory in abstract form and a constructive starting point for discussing potential research designs.

Phase 2: For all (x) holds CP: If PF is at work, some competing social standards ***x*** *are available and the degree of adoption of* x_i *is higher (than before and/or than the competing standards), then it is more probable that* x_i *will tend to dominate.*[16]

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 dependency is to expatiate and concretize these auxiliary hypotheses since this 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 differentiating 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 the following section we will thus try to derive and systematize implications in terms of concrete methodological suggestions for researching path dependence.

6 Delineating Methodological Suggestions

Methodologically, extant path dependence research is very diverse, including a wide variety of different approaches (see Vergne and Durand (2010)). Table 3 gives an overview of those methodological approaches we deem both particularly relevant and promising for applying the theoretical framework developed above.[17]

[16] It might be possible to replace „dominate" by „survive" for settings were different social standards are not necessarily incommensurable or complementary but neutral to each other. While such a case seems improbable to us it should not be ruled out completely in such a general acccount.

[17] While *counterfactual models* (like models in economics, as proposed by Vergne and Durand (2010)) may also be applied as methodological tools in research on path dependence (see the work on „history-

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Insert Table 3 about here

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 may also be utilized to test hypothetical claims due to a refined research strategy (see Gerring (2004); Flyvbjerg (2006); Ruddin (2006)). 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 – 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 must 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 why 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 understand of path dependent processes and developments.

In contrast to narrative case studies, *comparative designs* allow integrating several different cases in a single research strategy, thereby also facilitating the evaluation and testing of theoretical mechanisms. A main advantage of *comparative case study designs*

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friendly" modelling, e.g. Malerba, Nelson, Orsenigo, and Winter (1999)), it seems unlikely that they are helpful for conducting empirical investigations, since the structuring of such models along the lines of a „thought-experiment" drastically reduces their empirical testability (see, for example, Sugden (2000)). Indeed most of them are rather good examples for empirically irrelevant thought-experiments as discussed in section 2. It is for these reasons, that we did not include counterfactual models as a suggestion for further empirical research.

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 (2008), Fiss (2009, 2010)).

Following Yin’s (1994) classical line of argument, (3) *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 has 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 (4) *real-world prognoses*. In a real-world prognosis a given hypothesis 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, that is 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 lead 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, (5) *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 choosing plausible 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 simulation-based research in the future, we deem to be one of the main contributions of this paper.

7 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. *Third*, it shows how to complementary incorporate these methods in a common research program on path dependence. In this spirit, it partially answers the question "how to implement the chosen methods" by providing a general framework which relates an operationalizable axiomatic structure to a set of promising methodical suggestions.

In our view, distinguishing 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 mechanisms lead to some stable pattern despite the initial contingent events in the path creation phase, it basically places no restrictions on the potential starting points of such a path dependent development (due to the "black-box" character of the path creation phase). 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) or where all possible settings may be "explained" by tautological arguments, indicating a lack of empirical content (e.g. "if the weather won't change, it will basically stay the same"). Moreover, our analysis shows that the two conceptual building blocks proposed also harmonize with contemporary three phase-models of path dependence (e.g. Sydow et al. (2009); Vergne and Durand (2010)). We argue that there is a major methodological difference between phase one ("path creation/emergence") and phases two and three ("positive feedback" and "lock-in"), while there are only minor differences between the two latter phases (mostly related to the degree of uncertainty associated with the respective mechanisms).

It is important to note that the ergodic nature of positive feedback mechanisms 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 would argue for a variety of methods used rather complementary than competitive and with distinct foci in terms of research strategy as outlined in the previous section in order 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 hypothetical statements on path dependence contain the "contingent factor" associated with the path creation/emergence phase, their testability will be in constant doubt.

It is for these reasons that we advocate that the construct of path dependence should not be "tested as a whole" but with a careful consideration how a concrete research question aligns on the different parts or phases of the construct of path dependence. If interpreted appropriately we think that this paper provides a useful guide for succeeding in this admittedly difficult task.

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Tables

Table 1

Deduction, induction, abduction, and path dependence

	Deduction	*Induction*	*Abduction*
Classical Example	*Rule:* All the beans in this bag are white. *Case:* These beans are from this bag ---------- *Result*: These beans are white.	*Case*: These beans are (randomly selected) from this bag. *Result*: These beans are white. ---------- *Rule*: All the beans from this bag are white.	*Rule*: All the beans from this bag are white. *Result*: These beans are white. ---------- *Case*: These beans are from this bag.
Path Dependence (PD)	*Rule*: Where PD holds alternatives are not viable. *Case*: QWERTY is path dependent. ---------- *Result*: No alternatives to QWERTY are viable.	*Case*: QWERTY is path dependent. *Result*:Alternatives to QWERTY are not viable. ---------- *Rule*: Where PD holds alternatives are not viable.	*Rule*: Where PD holds alternatives are not viable. *Result*: In the case of QWERTY alternatives are not viable. ---------- *Case*: QWERTY is path dependent.

Table 2

Epistemological and conceptual differences between different phases of path dependence

Phases		Role of testable mechanisms	Degree of uncertainty	Conceptual buildung 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)	Lawlike behavior and responsiveness to exogenous shocks
Phase 3	Lock-In	Non-Probalistic mechanism	Deterministic	Nomothetic-testing (building block II)	Lawlike behavior and low(er) responsiveness to exogenous shocks

Table 3

Suggestions for methodological strategies in path dependnce research

Methodological Approach	*Number of cases*	*Predominantly relevant in phase*	*Research strategy*
(1) Narrative case-studies	N = 1	- Path creation - Between path emergence and dependence ("critical juncture") - 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	N > 1	Path emergence and dependence	Test hypothetical mechanisms and evaluate the role of exogenous factors in real-world environments *ex-post*.
(3) Experiments	Not relevant	Path emergence and dependence	Test hypothetical mechanisms in their allegedly „pure" form by controlling exogenous factors in laboratory environments.
(4) Real-world prognoses	N = 1	Path emergence and dependence	Test hypothetical mechanisms and evaluate the role of exogenous factors in real-world environments via *ex-ante* predictions about future developments.
(5) Simulations	Not relevant	Path emergence and dependence	Explore the behavior of dynamic systems with varying 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.

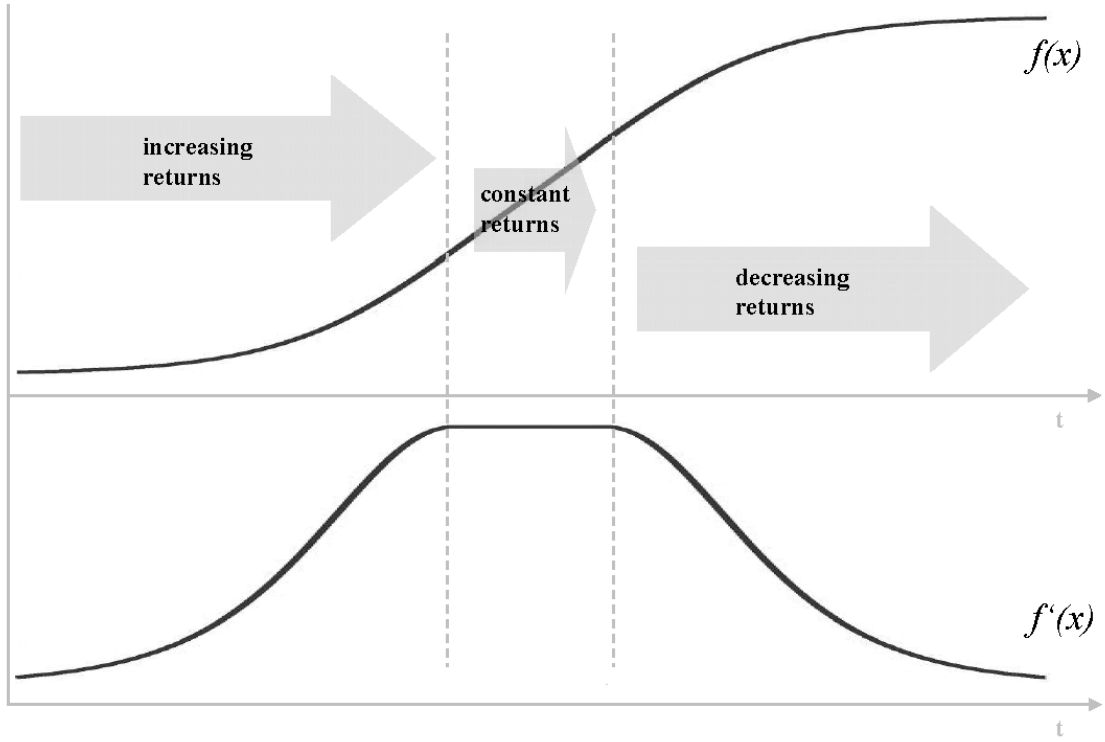

Figure 2:

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