Theorizing Path Dependence: A Review of Positive Feedback Mechanisms in Technology Markets, Regional Clusters, and Organizations

Leonhard Dobusch* (leonhard.dobusch@fu-berlin.de)

Elke Schüßler* (elke.schuessler@fu-berlin.de)

Freie Universität Berlin, Department of Management, Boltzmannstr. 20, 14195 Berlin

Acknowledgements: Previous versions of this article have been presented at various workshops such as the 23rd EGOS Colloquium 2007 and have been discussed widely in the context of the Pfadkolleg Research Center at Freie Universität Berlin, Germany. We are thankful for all the useful feedback we have received there. We are particularly indebted to Jörg Sydow, Jakob Kapeller, Sigrid Quack, Arndt Sorge, Jan Jacobs, Stefan Kirchner, and Sanneke Kuipers for their detailed comments on our article.

*Authors in alphabetical order as both have contributed equally to the development of this paper

DRAFT AUGUST 2012

Final version forthcoming in *Industrial and Corporate Change*

Theorizing Path Dependence: A Review of Positive Feedback Mechanisms in Prominent Cases

The concept of path dependence has often been criticized as vague and only narrowly applicable. Although we can find some very refined definitions of the concept, we also find a wide range of empirical phenomena being described as path-dependent. We argue that more detailed accounts of the positive feedback mechanisms that form paths can take path dependence beyond this state of being overdetermined, but under-specified. Reviewing three well-described cases of path-dependent dynamics in technology markets, regional clustering, and organizations, we define a core set of positive feedback mechanisms that constitute path dependence at different analysis levels and clarify the relationship between positive feedback and increasing returns. We show that path-dependent processes, that is, processes driven by positive feedback that veer toward rigidity or lock-in, can be (but do not have to be) found under many labels, including structural inertia, coevolution, or institutional persistence. We conclude that a precise definition of path dependence does not need to be at odds with the concept's widespread use in understanding organizational and industrial development processes.

1 Introduction

The concept of path dependence has become increasingly employed in the social sciences and in economics (e.g. Lamberg and Tikkanen, 2006; Schneiberg, 2007; Antonelli, 2008; Gruber 2010), being used in fields as diverse as historical or comparative institutionalism (e.g. Mahoney, 2001; Hall, 2003; Thelen, 2003), regional economics (e.g. Martin and Sunley, 2006; Sydow et al., 2010), technological innovation (e.g. Dosi, 1982; Dolata, 2009), or strategic management (Schreyögg and Kliesch-Eberl, 2007; Koch, 2008; 2011) to show how 'history matters' in producing institutional, regional, technological, or organizational patterns over the longer term (e.g. Puffert, 2002; Vanloqueren and Bareta, 2009). As a theoretical framework, path dependence provides an explanation for potentially problematic long-term outcomes that deliberately de-centralizes agency by referring to a system-logic of self-reinforcing processes triggered by contingent events (David, 1985; Arthur, 1989).

Path dependence has recently been criticized as lacking conceptual clarity and being applied to mean different things in too wide a range of cases (Page, 2006; Vergne and Durand, 2010; Martin, 2010). Some scholars have therefore sought to offer more formal definitions of specific characteristics of path dependence to differentiate it from related concepts, such as 'imprinting', 'structural inertia' or 'escalating commitment' (Sydow et al., 2009; Vergne and Durand, 2010). While contributing to conceptual clarity, this strategy of demarcation has decreased the concept's empirical applicability, and is thus at odds with its widespread use in describing processes (e.g. Manning and Sydow, 2011; Thrane et al., 2010; Reinstaller and Hölzl, 2009). Our aim in this article is to allow for both tight definitions and wide use by integrating the concept into wider research on organizational and industrial evolution. Defining path dependence as a process triggered by a contingent events, then moved along through positive feedback mechanisms until it results in rigidity or lock-in, we want to focus and specify what Pierson (2004: 21) notes as *"the crucial feature of a historical* *process that generates path dependence"* – that is 'positive feedback' (or 'self-reinforcement').

Specifically, we argue that positive feedback or self-reinforcement can both be specified as a necessary condition for path dependence, and can act as an integrating factor – as a conceptual' bridge' to other theories that explain evolutionary processes characterized by increasing stability which can lead to 'lock-in'. We start from a generic definition of positive feedback as an increase in the likelihood of an action happening at t_1 if the same action has been conducted by the same (or other) actors at t_0[1]. We hold that path dependence, rather than being a marginal concept that can only be identified under highly controlled methodologies (Vergne and Durand, 2010: 737), can serve to explain many different *"processes of a diminishing scope of action that unintentionally develop their own pull and are driven by positive feedback"* (Sydow et al., 2009: 698). Accepting positive feedback as a core explanans, cases previously described under such labels as "regional lock-in" (Grabher, 1993), "increasing returns" (Aharonson et al., 2007), or "nonlinear strategic dynamics" (Burgelman and Grove, 2007) can be classified as being cases of path dependence. In theoretical terms, what matters is that the path dependence construct pays attention to which dynamics lead to which kinds of outcomes, whereas other constructs focus more on early events (e.g. imprinting) or final outcomes (e.g. structural inertia).

In this article we work towards a more systematic treatment of positive feedback as a causal mechanism in path-dependent dynamics (Davis and Marquis, 2005; Pajunen, 2008). After briefly summarizing the recent debate about path dependence, we review the positive feedback mechanisms that have been theoretically discussed and empirically elaborated in three important fields: technology markets; regional clustering of firms and institutions; and organizational and strategic processes. We find a list of 'typical' positive feedback mechanisms that work on and between the local and the system/population analysis levels and can be corroborated and distinguished from other factors, particularly increasing returns, which are at best temporary characteristics of positive feedback mechanisms that define their speed of operation. We demonstrate that if the object to be explained – a rigidified action pattern – is clearly defined and the causal mechanisms – network effects or increasingly shared cognitions – are carefully spelled out at the different relevant analysis levels, path dependence can indeed be widely applied as an explanatory concept. This discussion is relevant not just to path dependence researchers, but to anyone interested in understanding organizational and industrial development processes.

2 Reviewing Path Dependence and Positive Feedback Mechanisms

The notion of path dependence in social and economic processes has gained increasing attention in several fields of research. About 10 percent of all articles published between 2003 and 2007 in the major management studies journals reference the concept directly, compared to about 6 percent between 1998 and 2002 (Vergne and Durand, 2010), while Walker (2000: 126) refers to path dependence as *“one of the most exciting ideas in contemporary economic geography”* (quoted in Martin, 2010: 2). The concept originates from the technology development and diffusion field, where David (1985) and Arthur (1989; 1990) modeled non-ergodic, historically-determined processes as an alternative to the widespread economic assumptions of equilibrium and efficiency. This thinking has also been applied to understanding institutional development in both economics (North, 1990; David, 1994) and in political science (e.g. Collier and Collier, 1991; Thelen, 1999; Pierson, 2000).

Despite these definitions, the label ‘path dependence’ has often been assigned to cases based merely on anecdotal empirical evidence. Furthermore, critical voices have raised conceptual questions as to the effects of actor involvement (e.g. Garud and Kumaraswamy, 2010; Stack and Gartland, 2003), of whether change is possible (e.g. Crouch and Farrell, 2004; Boas, 2007), or the inefficiency of paths (Vergne and Durand, 2010). As a response to some of these issues, Vergne and Durand (2010) have proposed attending more closely to specific properties such as the influence of initial conditions, types of triggering events and of sustaining mechanisms, or the levels of analysis that can be used to distinguish path dependence from other 'history matters'-based explanations such as imprinting or structural inertia, which they argue should be controlled for in experimental research or simulations.

While a more 'scientific' treatment of path dependence is indeed valuable, the recent attempts to differentiate path dependence from other theoretical arguments may not necessarily support this goal. While, for instance, Vergne and Durand (2010) argue that path dependence is triggered by "contingent events", they assert that structural inertia is triggered by "firm founding"; that path dependence is sustained by "self-reinforcement"; and that institutional persistence is due to the "stickiness of institutions". But how can we know, for instance, that institutional stickiness has not been caused by self-reinforcing processes, or that firm founding was not a contingent event in explaining the structural dynamics that result in organizational hyperstability? Sydow et al. (2009) pursue a similar demarcation strategy that does not result in mutually exclusive categories.

Instead, we propose to focus on positive feedback mechanisms as the core theoretical construct for path dependence research, independent of preferred methodologies or disciplinary contexts. While it has recently been argued that both positive and negative feedback mechanisms together constitute a path-dependent process (Page, 2006; Vergne and Durand, 2011), most researchers agree that demonstrating path dependence requires the carefully spelling out of its self-reinforcing dynamics driven by positive feedback (Pierson, 2004; Bennett and Elman, 2006; Sydow et al., 2009; Beyer, 2010; Vergne and Durand, 2010). In order to address the research question of 'What positive feedback mechanisms drive path-dependent processes at different analysis levels and in different social settings?' our paper compares and contrasts positive feedback mechanisms in different contexts and on different analysis levels, so as to theorize the construct in a way that is both conceptually precise and more useful for further empirical research.

Positive feedback in technology markets. Many cases of technological standardization such as the QWERTY keyboard (David, 1985), the DVD (Dranove and Gandal, 2003), or mobile telecommunication standards (Koski and Kretschmer, 2005) have been attributed to positive feedback processes and characterized by increasing returns to adoption that occur for a variety reasons. First, many technology products have high set-up costs but low manufacturing costs, which fall rapidly as sales increase, and these *dynamic economies of scale* enable first movers to reinvest their returns in product innovation, making further growth more likely. Second, *network effects* mean products often become more attractive the more widely they are adopted: *direct* network effects are at work (for example) where the utility of using a telephone increases with the number of other network subscribers, whereas *indirect* network effects describe the situation where the variety and quality of complementary goods, as ancillaries to the main product, increases with its greater adoption, thus increasing the attractiveness of the underlying technology for both current and potential users (Katz and Shapiro, 1985). Third, there are customer *learning effects*: users of a particular technology who have become familiar and thus *"grooved in"* to the product (Arthur, 1996: 103) are more likely to purchase subsequent versions. Fourth, agents' returns may be affected not only by other agents' past choices, but also by their future decisions: in an increasing returns market, agents' *expectations about others' future choices* may affect the adoption of one or other technology (Arthur, 1989).

Positive Feedback in regional clusters. Path dependence is often evoked in explaining regional clustering, which typically involves institutional as well as inter-organizational processes and thus lies at a meso-level of analysis between technology markets and organizations. Positive feedback has been used to explain different phenomena – such as the success and specialization of regional clusters (e.g. Aharonson et al., 2007), the inability of a region to adapt to changes (Grabher, 1993), or learning processes in a clustered region (Bathelt and Boggs, 2003) – sometimes explicitly under the label of path dependence and sometimes without employing the concept. Different mechanisms are discussed according to whether the focus is to explain a positive dynamic towards clustering or the actual (or potential) resultant rigidity. These include, individual level *coordination effects* and *complementarity effects* at the institutional level, which are similar to direct and indirect network effects discussed above. In addition, *learning effects* connect the individual and institutional levels via mental models: learning is susceptible to path dependence in how new information is 'selected out' or filtered into existing mental maps. At the collective level, organizations learn indirectly by observing the successful behavior of others, and may be encouraged by uncertainty or normative pressures to imitate them.

Positive feedback in organizations. In the still-young field of research into path dependence in organizations, Sydow et al. (2009) discuss four *"self-reinforcing"* mechanisms: *coordination effects*, *complementarity effects*, *learning effects*, and *adaptive expectations* which resemble those discussed above, but in the context of organizational rules, resources, practices and strategies. They can be triggered by rational, utility-driven behavior - but can also result from emotional reactions, cognitive biases and political processes. However management research describes similar processes without referring to path dependence: Miller (1992), for instance, presents the Icarus paradox, in which successful strategies become reinforced (both cognitively and structurally) until organizations get 'stuck' and then decline, arguing that such *"architectures of simplicity"* (Miller, 1993) are, in part, caused by successful top managers decreasing the breadth of their information searches. Similarly, in his many studies on Intel (to which we refer in more detail later) Burgelman (e.g. 2002: 326) outlines the co-evolutionary lock-in between Intel and the PC market brought about by "*a positive feedback process that increasingly ties the previous success of a company's strategy to its existing product-market environment, thereby making it difficult to change strategic direction.*" In inter-organizational terms, Porac et al. (e.g. 1989; 1995) show how self-reinforcing interpretive activity led to the emergence of shared mental models among Scottish knitwear organizations. These examples are typical variants of path-dependent processes in which early actions or decisions are reinforced through success and eventually firms become locked-in onto a chosen path, a situation which is detrimental when environmental conditions change.

3 Method: Reviewing Prominent Cases

We have revisited three illustrative cases of positive feedback dynamics, rereading them with a critical eye on how different authors have identified positive feedback mechanisms in different contexts and at different levels of analysis:

- Microsoft's dominance in desktop software markets, to illustrate positive feedback in technology markets;
- Silicon Valley, to illustrate positive feedback in regional clustering based on institutional and (inter-)organizational developments;
- Intel, as a case of positive feedback in organizing and strategizing.

Our aim is to review the rich and oft-described empirical data for the following reasons. First, we are able to gain a comparative cross-case perspective on the path dependence construct, which is typically applied to only one case at a time due to the time-consuming nature of holistic analyses (Dorado, 2005). Second, relying on many different studies of one case allows us to at least partially compensate for any biases in individual studies.

3.1 Case and Material Selection

Our selection of *"most likely cases"* (Ruddin, 2006: 809) follows a theoretical sampling logic (Yin, 1994; Flyvbjerg, 2006) – if we cannot identify positive feedback mechanisms at different analysis levels leading to stability in these cases, which have attracted so much scholarly attention in this context, it would probably be even harder elsewhere. Microsoft is not only *"everyone's favorite example"* (Shapiro and Varian, 1999: 24) for phenomena such as lock-in and increasing returns in a technology market, but also transcends mere technological compatibility arguments with mechanisms that have been described at both the local and population levels. While the literature on Microsoft often refers explicitly to positive feedback, it does not generally use path dependence as a theoretical framework. The literature on Silicon Valley as a regional clustering case integrates technological and organizational positive feedback dynamics with discussion of the path-dependent institutional dynamics common in political science and economic geography, so path dependence is often referred to explicitly. The Intel case illustrates the organizational mechanisms that lead to strategic lock-in: but while positive feedback is mentioned in the literature, structural inertia and co-evolution have been the concepts predominantly applied in this case.

We selected literature on the basis of a combination of theoretical and empirical keywords. We searched in a selection of literature data bases for "path dependence/y", "lock-in", "increasing returns/positive feedback", "self-reinforcement" and "mechanism" as theoretical key words in all three cases, looking for each in combination with two to three different case-specific keywords. Having identified key authors for each case, we then drew on their references for further sources, leading us to papers not explicitly referring to our theoretical keywords. In collecting material and filtering mechanisms from the literature we relied on the 'saturation' principle as defined and used in qualitative research (Strauss and Corbin, 1990; Arts, 2003): some may find this approach eclectic (even untenable), but it has been widely used by sociology and political science scholars (e.g. Layder, 1998; Arts, 2003).

3.2 Analytical Procedure

We review the empirical arguments made in the literature with respect to explaining the stable patterns exhibited by each case and the underlying mechanisms in operation to reconstruct our own descriptions and analyses. First, we constructed a chronological history of the most important events in each case and distilled information on the path- or pattern-constituting mechanisms proposed in the literature. Second, we listed the mechanisms mentioned in each study, mostly keeping to the original wording, discarding articles that referenced our search terms but which lacked any original empirical analysis. Third, we compared and clustered the mechanisms thus identified into more abstract mechanism categories, and harmonized their labeling in the light of the theoretical discussion presented above, using slightly adapted versions of those suggested by Sydow et al. (2009): (1) *coordination effects,* covering utility resulting from others following the same path; (2) *complementarity effects*, stemming from two or more otherwise independent social processes; (3) *expectation effects*, similar to self-fulfilling prophecies; and (4) *investment and learning effects* due to the accumulation of specialized but non-transferable stocks of investment or knowledge. As a fourth and last step, we evaluated the mechanisms we found in the literature on each case in terms of two operational levels - the local and the population.

4 Positive Feedback Mechanisms in Different Contexts

4.1 PC Operating Systems: One Path-dependent Market, Multiple Mechanisms

The Path. The dominance of Microsoft Windows and Office in the personal computer (PC) software market is so visible and strong that these programs have been called "*de-facto* *standards"* (Takahashi and Namiki, 2003). High switching costs mean both the market as a whole and organizational and individual adopters are affected by path dependence in the sense of having (very) limited room for maneuver despite the existence of alternatives that are at least functionally equivalent. PC operating systems have became one of the outstanding empirical examples of path dependence in technology markets where positive feedback mechanisms lead ex-ante unpredictability to develop towards an ex-post state of stable equilibrium (Shapiro and Varian, 1999; Varian et al., 2004). Given its great economic importance, Microsoft's antitrust trial in the United States has generated enormous scholarly attention (e.g. Katz and Shapiro, 1998; Klein, 2001; Liebowitz and Margolis, 2001; Reddy et al., 2001; Werden, 2001).

Contingency. When IBM introduced its first PC in 1981 (using Microsoft DOS as its operating system) it entered an existing but rather small market. CP/M was the leading operating system at the time, but quickly lost market share and eventually 'died' around 1985, despite being technically compatible with IBM's PC. In their analysis, Gandal et al. (1999: 92-93) argue that it was not obvious whether DOS was technically superior to CP/M: far more important in terms of its adoption was the availability of complementary software and the relationship between IBM and the business community that followed IBM's lead (see also Langlois and Robertson, 1992). In 1984, when Apple Computer bundled its technically superior Mac Operating System (MacOS) together with its computer hardware, it was unable to replace the IBM PC/MS DOS combination as the industry standard; explanations range from incorrect strategies (Apple licensed neither its operating system nor its computer hardware) to the existing network effects of the large already-installed base of Microsoft and IBM-compatible PCs. When the introduction of Windows 95 and Windows NT4 coincided with the failure of IBM's OS/2 in the mid 1990s, alternative operating systems became increasingly marginalized (Koski and Kretschmer, 2004: 8), so that, notwithsatnding major technical improvements in such open source operating systems as GNU/Linux, Windows has remained unchallenged as the de-facto standard over many OS generations since it became dominant in 1995.

Mechanisms. The greatest barrier to the adoption of both historical (MacOS, OS/2) and contemporary (MacOS, Linux) alternatives to Windows, was and is not quality, but the lack of complementary products (especially at the application level) and switching costs (Varian et al. 2004: 37; 21; see also Koski and Kretschmer, 2004). Even such path dependence skeptics as Liebowitz and Margolis (2001: 191) acknowledge the positive reciprocal association between the operating systems and application software. The long pre-announced introduction of Windows 95 also illustrates the importance of expectations in network markets: as Shapiro and Varian note: "In a very real sense, the product that is *expected* to become the standard *will* become the standard. Self-fulfilling expectations are one manifestation of positive-feedback economics and bandwagon effects" (1999: 13-14; emphasis in the original). The small (but persistent) minority of individuals who have made the effort to switch to Linux or MacOS contrasts with the monoculture of Windows desktop PCs found in nearly all large organizations (MERIT 2006).[2] At least some of the mechanisms (such as indirect network effects or learning) appear to interact heavily with organizational environments. Table 1 lists the literature on which our case illustration is based and the respective mechanisms we identified.

Source	Mechanisms (wording as in the article)
Akemann (1999)	- economies of scale - complementary products - direct network effects - indirect network effects - product specific investments
Besen/Farrell (1994)	- self-fulfilling expectations - installed base advantage (building an early lead) - supply of complementary goods - product preannouncements

Campell-Kelly (2001; 2003)	- high front-end R&D costs and marginal manufacturing and distribution costs (economics of increasing returns) - strategic new platform pricing (*“tipping”*) - network effects - bundling of complementary products
Economides (2001)	- network effects/externalities by availability of complementary components (*“applications barrier to entry”*) - powerful (anti-competitive) actions as a result but not as a precondition of network market inequality
Gilbert/Katz (2001)	- production economies of scale - network effects - applications barrier to entry - (forced) bundling of complementary products due to market power
Katz/Shapiro (1998)	- network effects as demand-side economies of scale, including complementary products (*“virtual networks”*) - practices like *“tying, predation, or exclusive dealing”* as a consequence of positive feedback - self-fulfilling expectations as a form of positive feedback - drivers of expectations include installed bases, current, product attributes, producer reputations, and product preannouncements
Kretschmer (2004)	- network effects through indirect channels (*“in conjunction with complementary products”*) - end-users and IT personnel create an individual and firm-wide expertise for a particular operating system - direct network effects (*“data exchange”*)
Liebowitz/ Margolis (2001)	- network effects - complementarity between operating system and applications
Lopatka/ Page (1995)	- entry barriers from large installed base (direct network externalities) - entry barriers from availability of application software (indirect network externalities) - “the two sorts of entry barriers ‘magnify and reinforce each other’” (p. 326) (complementarity effects) - expectations of buyers and suppliers - investment in human capital (sunk costs) - anticompetitive licensing restrictions *“to solidify monopoly position”*
Schilling (1999)	- learning curve effects - network externality effects (also due to complementary goods) - signaling effects (likelihood of adoption)
Takahashi/ Namiki (2003)	- direct and indirect network effects - use of Windows OS standard as a basis for anticompetitive practices
Windrum (2001; 2004)	- installed base effects - complementarity between vertically related products

Table 1: Mechanisms found in the literature on PC operating systems

Despite differences in wording, most scholars seem to agree on the sets of mechanisms that operate at the local and population levels (Table 2). Local level investment and learning effects are reciprocally linked to population level mechanisms: individual and organizational actors take non-transferable investments in licenses (‘sunk costs’) or learning into account when making (re-)adoption decisions, which produces macro-level complementarity in the form of a growing pool of specialized software, service providers and personnel (see also Bednar et al. 2011; Vergne and Durand 2011). Expectation effects serve to drive coordination and complementarity effects, as adopters follow the path they expect the herd will take, thus enhancing network or installed base effects (Farrell and Saloner, 1986; Koski, 1999). These mechanisms differ in their modes of operation: while coordination and complementarity effects are often attributed to 'increasing returns', i.e. a phase of escalating self-reinforcement as soon as one alternative is widely expected to become the market standard, this cannot be claimed for the other mechanisms. Nevertheless, to the extent that learning is tied to specialized application software or training facilities, this acquisition of non-transferable skills at the individual and organizational levels contributes to installed-base effects at the market-level

Mechanisms	Category	Level
- direct network effects/externalities (Akemann, 1999; Campbell-Kelly, 2001; 2003; Economides, 2001; Gilbert/Katz, 2001; Katz/Shapiro, 1998; Kretschmer, 2004; Liebowitz/Margolis, 2001; Takahashi/Namiki, 2003; Schilling, 1999) - installed base advantage (Besen/Farrell, 1994; Lopatka/Page, 1995; Windrum, 2001; 2004);	Coordination effects	Population
- complementary products (Akeman, 1999; Besen/Farrell, 1994; Campbell-Kelly, 2001; Katz/Shapiro, 1998; Schilling, 1999) - application barrier to entry (Economides, 2001; Gilbert/Katz, 2001; Liebowitz/Margolis, 2001) - indirect network effects/externalities (Akeman, 1999; Kretschmer,2004; Lopatka/Page, 1995; Takahashi/Namiki, 2003) - complementarity between vertically related products (Windrum, 2001; 2004) - reinforcement of different entrance barriers (Lopatka/Page, 1995)	Complementarity effects	Population
- self-fulfilling expectations (Besen/Farrell, 1994; Katz/Shapiro, 1998; Lopatka/Page, 1995) - signalling effects (Schilling, 1999)	Expectation effects	Population
- economies of scale due to product specific investments (Akemann, 1999; Campbell-Kelly, 2001;2003; Gilbert/Katz, 2001) - product specific expertise/learning (Kretschmer, 2004; Schilling, 1999; Lopatka/Page, 1995)	Investment and learning effects	Local

Table 2: Categorization of mechanisms in PC Operating Systems

4.2 Silicon Valley: A Case of Path-Dependent Regional Clustering, Path Creation, or Both?

The Path. The 'Silicon Valley' area around San Francisco Bay, birthplace of some of the world's largest electronics firms, has been used already by Arthur (1994) to illustrate path-dependent regional clustering processes. While in post-war times a number of other regions (such as Route 128 with MIT and Harvard in Boston) have had even greater concentrations of engineers, research facilities and successful firms, Silicon Valley won the race to become the leading semiconductor technology center (Kenney and von Burg, 1999; 2000; 2001). In 1976, thirty-one of thirty-six U.S. semiconductor firms were located there, and in 1988, the Valley had attracted 40% of all US venture capital (Cohen and Fields, 1999). Kenney and von Burg (2001: 128) have recognized Silicon Valley as an ideal case for examining the strengths and weaknesses of path-dependent explanations because of the interplay of self-reinforcing dynamics and intentional agency in this setting.

Contingency. Before World War II, the region around Stanford University combined high-tech firms, entrepreneurship and university involvement (Sturgeon, 2000) and formed an "already prepared environment" for what was to develop during and after the war (Kenney, 2000; Kenney and von Burg, 2001). The opening of Shockley Transistor - the first major semiconductor enterprise - in Palo Alto in 1955 has been said to have set the critical cluster dynamic in motion. Unable to find capital for starting his own business on the East Coast, William Shockley was convinced to return to the Bay area by the 'father of Silicon Valley', Frederick Terman, then professor, Dean of engineering and Provost at Stanford University (Leslie and Kargon, 1996). Fortunately (in hindsight) Shockley turned out to be a poor manager, and a line of spin-offs from Shockley Transistor led to the foundation of such firms as Fairchild Semiconductor, Intel, National Semiconductors, and AMD (Cohen and Fields, 1999; Kenney and von Burg, 1999).

***Mechanisms*.** Since Marshall's (1920) work on industrial districts, clustering processes, both within and beyond the Silicon Valley *"master cluster"* (Cooke, 2002), have been attributed to direct and indirect network effects also called *"agglomeration economies"* (e.g. Perroux, 1950; Arthur, 1990; Krugman 1991; Arthur, 1994; Zhang, 2003). Increasing returns result because co-location creates a pool of highly qualified labor and specialized suppliers; improves access to capital and services; ensures proximity to customers; and enables the exchange of knowledge, information and contracts within social networks (Aharonson et al., 2007). While these effects clearly involve positive feedback dynamics at the population (in this case, cluster) level, other arguments stress the importance of key actors (see Table 3).

Source	Mechanisms (wording as in the article)
Aharonson et al. (2007)	- positive feedback loops or virtuous cycles as concentration of firms creates beneficial scale and - information externalities by attracting additional labor and other inputs and facilitating the exchange of ideas - more ideas are generated for local diffusion as spatial concentration of firms within a - technological specialization increases
Arthur (1990; 1994)	- unbounded increasing returns to agglomeration: net benefits of firms being close to other firms increases with the number of firms - more firms in one location imply better infrastructure, deeper labor markets, better legal and financial services, higher availability of spare parts and thus reduced inventory costs, social networks emerge for the exchange of knowledge - other benefits due to geographical differences, such as differences in transportation costs, raw materials, factor prices, climate, proximity to markets
Bresnahan et al. (2001)	- agglomeration economies - direct external effects: learning from neighboring firms or customer-supplier relationships - indirect external effects: supply of key inputs such as capital, labor - social increasing returns to human capital - 'new economy' positive feedback complementary to 'old economy' institutions
Hakanson (2005)	- concentration of specialized and complementary epistemic communities - easy access to interesting opportunities by individual jobseekers and entrepreneurs and resulting high rate of firm formation - social and psychological barriers make firms and individual entrepreneurs stick to their original location - diseconomies of agglomeration: rising prices, congestion, local competition
Kenney and von Burg (1999; 2001)	- Economy 1: technological discontinuities and new economic opportunities create the seeds for spin-off entrepreneurship - Economy 2: institutional infrastructure (venture capitalists, professional services) aims at the creation of new firms - self-reinforcing, virtuous cycles between Economy 1 and 2: reinvestments of capital enable and are enabled by the success of startups - Moore's Law and Metcalfe's Law: technological paradigm of semiconductors provide recurring opportunities for entrepreneurs - imitation of success of early founders in peer network - clustering of specialized suppliers deepens the local knowledge base and supports existing firms
Saxenian (1990; 1994; 1999)	- vertically integrated self-sufficient firms - interdependence and close ties as a source of innovation

Table 3: Mechanisms found in the literature on Silicon Valley

Kenney and von Burg (1999; 2001) attribute the growth of Silicon Valley to the cluster's continuous ability to create new firms, based on recursive relationships between 'Economy 1' institutions – established firms, universities, and corporate research laboratories – and

‘Economy 2’ actors – entrepreneurs, venture capitalists, lawyers, consultants, etc.. A booming Economy 1 creates the seeds for spin-off entrepreneurship, which are then exploited by Economy 2, in turn making the local environment even more conducive to new firm creation. Adding to these arguments on inter-organizational effects, Hakanson (2005) suggests that agglomeration is based on the development of local, specialized epistemic communities rather than on abstract spillover effects, but stresses that its powerful negative side-effects (such as increased congestion or high rents) need to be offset by benefits for individual entrepreneurs.

Saxenian (e.g. 1990; 1994; 1999) sees no evidence of cluster level path dependence, and focuses instead on the flexible, decentralized, non-inert organizational structures that have enabled Silicon Valley’s entrepreneurs to create new business opportunities. If anything, she locates path dependence in the autarkic management models of the large established semiconductor firms, against which entrepreneurs revolted in a wave of semiconductor startups in the 1980s (Saxenian, 1990). Others also stress the importance of individual and organizational mechanisms that do not necessarily involve positive feedback, rather than cluster-level agglomeration effects that do. The Silicon Valley case offers a good illustration that positive feedback dynamics do not contradict notions of intentional agency, and also points to the interaction of different positive (and negative) feedback dynamics at different levels of analysis (Table 4). Interestingly, negative externalities – in the form of diseconomies of agglomeration – occur in the Silicon Valley cluster, they do not counter its development because of complementary positive feedback dynamics on other analysis levels.

Mechanisms	Category	Level
- direct network effects/externalities: the value of locating in a given area increases with the number of other similar firms in the area due to knowledge spillovers and the proximity of customers and suppliers (Aharonson et al., 2007; Arthur, 1990; 1994; Bresnahan et al., 2001)	Coordination effects	Population

- indirect network effects/externalities: the supply of key inputs increases with the number of firms in the same location (Aharonson et al., 2007; Arthur, 1990, 1994; Bresnahan et al., 2001) - complementarity between Economy 1 and 2 (Kenney and von Burg, 1999; 2001) - complementarity between existing institutions and new firms (Bresnahan et al., 2001) - social increasing returns (Bresnahan et al., 2001)	Complementarity effects	Population
- expected value of co-locating based on direct and indirect network effects (Arthur, 1990; 1994; Bresnahan et al., 2001) - imitation of successful peers causes high firm formation rates (Hakanson, 2005)	Expectation effects	Population
- successful investment causes further success and investment (Kenney and von Burg, 1999, 2001) - non-transferable social ties and knowledge leads to location inertia (Hakanson, 2005)	Investment and learning effects	Local

Table 4: Categorization of mechanisms in Silicon Valley case

4.3 Intel Corporation: A Locked In Company?

The Path. Although most empirical work dealing with the Intel case has been undertaken by one scholar, Robert Burgelman (1991, 1994, 1996, 2002, and together with Andrew Grove, 1996, 2007), the longitudinal data he provides is very rich. He identifies Intel as an example of *"co-evolutionary lock-in"* and describes trajectories of emergent corporate strategies without actually referring to path dependence, but to a *"strategically dominant logic"* (Prahalad and Bettis, 1986) and *"structural inertia"* (Hannan and Freeman, 1984). In more recent work, Burgelman (2003) distinguishes the changing strategic foci of three epochs in Intel's development: period I (1968-1985), with a strong focus on memory chips; period II (1985-1998), with a focus on microprocessor chips; and period III (since 1998), focused on the building block of the internet. The first strategic lock-in occurred towards the end of period I, when top management remained focused on memory chips as the company's core business, even though its share of revenues had already declined in comparison with that earned by microprocessors. The second strategic lock-in (late period II) was due to the strong link between the company's growth and that of the PC market, which had been pushed by the new CEO Andrew Grove, who had succeeded Gordon Moore after Intel's strategic re-positioning in 1987. Intel's revenues grew from $1.9 billion to $25.1 billion between 1987 and 1998, and its net income from $248 million to $6.9 billion. Grove centralized Intel's organization structure and reduced autonomous strategic action in a top-down process he called "*vectoring*" (Burgelman, 2002: 326). Bottom-up processes – like that which led to the original success of the microprocessor in the early 1980s – only rarely succeeded in this new organizational environment, except for Intel's engagement in the chipset business in the mid-1990s (Burgelman, 2002: 332-335).

Contingency. In the first period, a resource allocation rule that systematically assigned scarce production capacities to product activities that maximized manufacturing margins prevented Intel from failing as an organization in spite of its strategic misalignment (Burgelman, 1991: 245). The change in top management meant that external market pressure for strategic re-positioning finally translated into organizational change. In the second period, Intel deliberately controlled its core product market, and while this led to success in its dominant business area, Intel's narrow and top-down strategic focus was a barrier to new ventures in other business areas. As in the transition between the first two periods, external changes – the declining growth of the PC market – again indicated the need for strategic re-positioning.

Mechanisms. The mechanisms described by Burgelman present Intel as a case of lock-in at the organizational strategy level. Although situations differed, many of the underlying inertial mechanisms (cf. Table 5) were similar in both transition periods.

Source	Mechanisms (wording as in the article)
Burgelman (1991)	- holding to the ‘self-evident truths’ that are no longer true - survival motivates conservatism
Burgelman (1994)	- sunk investments in R&D as basis for the company’s learning curve - emotional attachment to previously successful product lines - bounded rationality in high-velocity environments
Burgelman (1996)	- complementarity between organizational functions and technical competencies - competencies leading to initial competitive advantages become a source of failure later on
Burgelman and Grove (1996)	- ‘inertial aftermath of success’: relying on previously successful competencies
Burgelman (2002)	- investments in certain R&D fields are justified by previous investments in the same fields - co-evolutionary lock-in with development of markets of complementary products (PCs) - escalation of commitment in investment decisions - complementarity of independent ‘strategic thrusts’ - following corporate strategy facilitates career advancement of people who will then continue following the same strategy
Burgelman (2003)	- co-evolutionary lock-in of corporate strategy with company’s structural context - complementarity between induced strategy and personnel development
Burgelman and Grove (2007)	- inertial induced strategy making due to strategic actions based on existing distinctive competencies - corporate strategy induces strategic actions by executives deeper in the organization that are aligned with it
Gawer and Henderson (2007)	- complementarity between corporate strategy and market development

Table 5: Mechanisms found in the literature on Intel

The locus of positive feedback lies either in individuals’ (cognitive) spheres or at the organizational level: in either case, inertial effect results from the difficulty of transferring accumulated investment over to other contexts. Emotional attachment to a strategy (Burgelman, 1994: 41-43), for example, grows over the years and is, by definition, non-transferable to another strategy, as it results from the strategy’s idiosyncratic characteristics. Individual and organizational learning leads to inertia only insofar as it is specialized on a certain domain and has accumulated over time, just as, even though they turn into sunk costs if they become non-transferable, a spiral of investments constitutes a positive feedback mechanism.

Burgelman (1991: 250) further identifies complementarity between the organization’s regular career advancement structure and the alignment of initiatives with official strategies allows managers to take advantage of organizational learning. In the second case of strategic lock-in recursive and self-reinforcing feedback loops between Intel's strategic (investment) decisions and the market environment resulted in a co-evolutionary lock-in (Burgelman, 2002: 349).

Not all mechanisms easily fit into our pre-defined categories that as depicted in Table 6. "*Bounded rationality in high-velocity environments*" (Burgelman, 1994), for example, does not necessarily seem to be a case of positive feedback, which is why we only reluctantly include it in the category of 'expectation effects'. As in the Silicon Valley case, (strategic) agency – which some might call 'path creation' – played an important role at Intel. Strategic agency in early, contingent phases triggered positive feedback mechanisms which were originally welcomed, but which then kept in place an inefficient strategy that became harder and harder to change. Subsequently, different positive feedback mechanisms meant that actors - both at the top management and at other organizational levels -were mainly restricted to following the chosen path: 'path breaking' was only made possible via personnel changes or the *"autonomous strategic action"* of a few individuals.

Mechanisms	Category	Level
- complementarity between strategy and market development (Burgelman, 2002; 2003; Gawer and Henderson, 2007)	Complementarity effects	Local and population
- complementarity between organizational functions and technical competencies (Burgelman, 1996) - complementarity of independent "strategic thrusts" (Burgelman, 2002) - corporate strategy induces strategic actions by executives aligned with it (Burgelman and Grove, 2007)	Complementarity effects	Local
- holding on to 'self-evident truths' (Burgelman, 1991; 1996) - emotional attachment to strategy (Burgelman, 1994) - 'inertial aftermath of success' (Burgelman and Grove, 1996) - escalating commitment in investment decisions (Burgelman, 1994; 2002) - strategic actions based on existing distinctive competencies (Burgelman and Grove, 2007)	Investment and learning effects	Local
- bounded rationality in 'high velocity environments' (Burgelman, 1994) - complementarity between strategy and personnel development (Burgelman, 2002; 2003)	Expectation effects	Local

Table 6: Categorization of mechanisms in the case of Intel

7 Discussion

7.1 A Core Set of Positive Feedback Mechanisms

Our case review provides empirical examples for all of the pre-defined mechanism categories in different social contexts and on different levels of analysis. This allowed us both to extend the scope of applicability of the mechanisms outlined by Sydow et al. (2009) and to specify their levels of operation, and also to see how they often interacted in forming an organization's historical path. In this, we echo suggestions by Page (2006) and Vergne and Durand (2011) that a path can be the result from of the interactions of perhaps many different mechanisms.

While coordination, expectation, and complementarity effects always involve the interaction of different actors and the resultant diffusion of technologies, institutions or routines at the organizational level, learning and investment effects usually work at local levels. In our cases, irreversible local-level investments interacted with the resulting network effects at the population level to rigidify path-dependent action patterns. In the case of Microsoft's dominance in the software market, organizational adopters who accumulated capabilities specific to complementary software applications made spirals of investments in learning and so strengthened complementarity effects at the market level. In the Silicon Valley case, we can see that both coordination and complementarity effects at the cluster level were based on individual-level emotional/social and financial investments and expectations. At Intel, continuously increasing investments into a distinct technological design interacted with associated organizational incentive structures to form a rigid complementary system. We have therefore been keen to abstain from all-too inclusive concepts like 'demand-side economies of scale' that blur the distinctions between different mechanisms which can be analytically valuable.

Furthermore, Arrow's (2000) argument that path dependence is mainly characterized by quasi-irreversibility is only part of the story – rather we suggest that path dependence is essentially determined by a combination of local irreversibilities and nonlinearities at both levels (cf. Bassanini and Dosi, 2001: 57), possibly further reinforced by negative feedback (Page 2006). Population level lock-ins - such as a dominant technological designs (Tushman and Anderson, 1986) – thus always go hand in hand with positive local level feedback, for example, in form of spirals of irreversible investments and expectation effects.

Distinguishing mechanisms at different levels also allows us to make the distinction between the roles of individual actors and macro-level structural effects at different phases of path-dependent processes (Sydow et al., 2009). In the positive feedback phase, individual actors are no longer able to strategically influence population level outcomes, or are trapped in local level action patterns, at least for a time. At the same time, path-dependent dynamics are embedded in other vertical and horizontal processes that form the background conditions against which positive feedback mechanisms work. These conditions can result from, interfere with or impact upon these mechanisms, and can also be strategically influenced by actions that amplify or dampen their effect (cf. Arthur 1994: 127-128; Garud and Karnoe, 2003; Stack and Gartland, 2003; Garud et al., 2010). In the Intel case, for instance, the change of CEO disrupted the positive feedback dynamic.

7.2 The Role of Increasing Returns

Implicit in the distinction between our mechanisms' different operational levels is a more nuanced explanation of (at least temporary) increasing returns at population or market levels (for a formal differentiation see Page, 2006), which rest, to a significant extent, on sub-market-level mechanisms that may, in fact, accumulate constant or decreasing returns. Greener (2005) already criticizes Pierson (2000) for incorrectly assuming that path dependence is the 'study of increasing returns', as the persistent dominance of increasing returns would take away any opportunity for change, and suggests path-dependent systems might go through a period of increasing returns in their creation phase, but then enter a period of constant returns in the reproduction phase (see also Mahoney, 2000; Thelen, 2003) – which also fits with Sydow et al.'s (2009) phase models of path-dependent processes.

Although increasing returns were not explicitly measured in any of our cases – a common issue in empirical studies of path dependence – we contend that none of the cases exhibits a mechanism that constantly produced increasing returns. In the software market, increasing returns (and their anticipation) seem to play a role in establishing market dominance at the macro level and redistributing power at the micro level, but the mechanisms reproducing this dominance - such as organizational learning spirals - do not necessarily have increasing returns structures. Moreover, it is difficult to identify the nature of a returns structure when looking at the reinforcement and stabilization of organizational structures, strategies and institutions: both the Silicon Valley and Intel cases exhibited the accumulation of certain variables over time with fluctuating intensity, but it is hard to tell whether this happens with increasing, constant or decreasing returns to scale.

The fact that some authors equate path dependence with "*increasing returns economics*" (e.g. Campbell-Kelly, 2001) may in part be attributed to their imprecise use of terms and concepts. As Arthur (1994: 112) points out: "*Self-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.*" But self-reinforcement is not the same as increasing returns: self-reinforcement mechanisms may be accompanied by increasing returns, but also with constant or even decreasing returns – although this latter should not be confused with negative feedback. Even with decreasing returns, the variable under question is still increasing – returns are just lower than in increasing or constant return phases. Ironically, this can be demonstrated in technology diffusion - the very field in which Arthur developed his theory of path dependence: a standard technology diffusion S-curve is the result of ongoing positive feedback, but displays all three return structure possibilities at different points in time. Accordingly, Metcalfe (1994) considers increasing returns as one (important) case of positive feedback in path-dependent selection processes, but uses the specific returns structure mainly to explain differences in the speed of selection processes (cf. Vergne and Durand, 2011). We therefore consider increasing returns as a factor that may result from or impact on positive feedback mechanisms, but not as a necessary condition (Page, 2006): while positive feedback is a feature of all the mechanisms that potentially lead to path dependence, the existence of increasing returns is not.

7.3 The Relationship between Path Dependence and 'Competing' Concepts

By focusing on the explanandum of path dependence - i.e. a stable pattern or shared social standard - and on positive feedback mechanisms as the explanans, we have shown not only how cases of path dependence can be presented more convincingly by drawing on a set of mechanisms that can typically be found on different analysis levels, but also that path dependence my underlie sets of evolutionary processes even when the concept is not explicitly used. There are, of course, many theoretical lenses researchers can use to analyze empirical data: the width of the field of research on organizational and industrial evolution means that path dependence is only one concept among many and, researchers may prefer to use others, depending on their discipline and analytical focus.

But this does not mean path dependence can only be developed as an explanation if an empirical case cannot be explained otherwise, e.g. by way of structural inertia or institutionalization (Vergne and Durand, 2010). While agreeing that not all institutionalization or organizational structuring processes are necessarily path-dependent, we argue that this concept may help to explain certain kinds of processes which have been given those labels. We thus follow Vergne and Durand's view (2010: 752) that, to make a plausible case of path dependence, it is necessary to specify for each path what self-reinforcement components are at play and over how long. We disagree, however, with their assertion that this can only be done under controlled conditions and requires a clear demarcation of path dependence from any other theoretical 'history matters' arguments.

Nor does developing a path dependence argument on the basis of positive feedback mechanisms necessarily imply determinism or even fatalism (cf. the critique by Garud and Kumaraswamy, 2010). Sydow et al. (2009) work on the premise that actors are knowledgeable agents, aware of their actions and the rules they follow, but that they still face the possibilities of *"unacknowledged conditions"* and *"unintended consequences of action"* (Giddens 1984: 294). Path dependence explains processes in which – consciously or unconsciously – such actors contribute to mechanisms exhibiting positive feedback and, in doing so, reduce the scope of variety for further agency (Koch, 2008). We hope our review of positive feedback mechanisms at different levels and in different social settings increases the applicability of path dependence as an explanatory concept for researchers' use.

8 Conclusions

We contribute to the recent debate on the use and value of the path dependence concept by focusing on positive feedback mechanisms as the concept's explanatory core. Specifically, we show how distinguishing different phases and levels of path-dependent processes might help to put the often misleading concept of increasing returns to new use –as a temporary phenomenon resulting from positive feedback at different levels. However, as we have reviewed only prominent or 'most likely' cases, all of which have related to high-technology, the accumulation of the different mechanisms we observed might be an artifact of our case selection and not characteristic of path dependence in general. Our guess is, however, that path dependence is rarely driven by just a single mechanism: there will usually be interaction – and mutual reinforcement – between local and population level mechanisms. But it is not only individual level behaviors that lead to unintended population level effects – local level mechanisms may themselves follow positive feedback patterns leading to firm lock-in, as the Intel case shows.

Reviewing three well-known cases of positive feedback dynamics in different fields, we find that even a precise definition of path dependence may be widely applicable. In contrast to recent attempts to differentiate path dependence from other concepts (e.g., structural inertia or co-evolutionary lock-in) we suggest seeking to integrate at least some of these approaches by using positive feedback as both an explanatory variable and as a conceptual bridge. The positive feedback concept can be used in controlled experiments or simulations, as Vergne and Durand (2010) suggest, as well as in historical case studies (Bennet and Elman, 2006). Again, we suggest researchers should use the concept where it is appropriate, rather than allowing it to become a corset that is both methodologically and conceptually too constricting, although we agree that simulating positive feedback mechanisms and boundary conditions at different analysis levels and in different settings would be a promising avenue for further path dependence research.

Following up on this point, our study does not allow us to test and measure empirically such variables as the duration of increasing returns, the leeway of strategic agency under positive feedback, or boundary conditions. Such research would extend the scope of our case review to provide an even more nuanced picture of positive feedback mechanisms and path dependence.

We have focused in this article on the interaction between different positive feedback dynamics on different levels: exploring negative feedback mechanisms as complementary factors remains a task for further research. In addition to formal and simulation-based approaches (Page, 2006; Vergne and Durand 2010), qualitative case analyses would provide important insights on whether and how positive and negative feedback dynamics interact; a similar case-revisiting method such as the we have applied might also be helpful in this regard.

Our focus on mechanisms has also meant that we have largely neglected the question of how paths are triggered and what actually constitutes lock-in, and only allowed us to address briefly the issues of contingency and the associated idiosyncratic aspects of individual path-dependent processes. Further research should investigate different types of lock-in more closely to be able to derive a more precise conceptual definition and to study the relationship between mechanisms and triggers and lock-ins. Finally, relying only on secondary data, we were unable to examine the micro-dynamics of the operations of causal mechanisms in detail, as outlined in the works of, for example, Mayntz (2004), Craver and Bechtel (2007) or Pajunen (2008). But, again, we hope that the core set of mechanism categories expatiated in this article may lay the ground for their analysis in more depth in future research.

We conclude that the concept of path dependence is more than “a concept in search of a case” (Kay, 2005, p. 569), but rather that its explanatory power, when based on a self-reinforcing dynamic, can help integrate different theoretical concepts dealing with stability in organizational and industrial evolution processes.

References

Aharonson, B. S., J. A. C. Baum and M. P. Feldman (2007), Desperately seeking spillovers? Increasing returns, industrial organization and the location of new entrants in geographic and technological space, *Industrial and Corporate Change*, **16**(1), 89-130.

Akemann, M.P. (1999), Microsoft's licensing agreements: theory and evidence on the sale of MS-DOS and Windows, *The Journal of Corporation Law*, Spring 1999, 553-602.

Antonelli, C. (2008), Pecuniary knowledge externalities: the convergence of directed technological change and the emergence of innovation systems, *Industrial and Corporate Change*, **17**(5), 1049-1070.

Arthur, W. B. (1989), Competing technologies, increasing returns, and lock-in by historical events. In: *The Economic Journal*, **99**, 116-131.

Arthur, W. B. (1990), Silicon Valley locational clusters: When do increasing returns imply monopoly? In: *Mathematical Social Sciences*, **19**(3), 235-251.

Arthur, W. B. (1994), *Increasing Returns and Path Dependence in the Economy*. Michigan: The University of Michigan Press.

Arthur, B. W. (1996), Increasing returns and the new world of business, *Harvard Business Review*, July-August, 100-109.

Arrow, K. J. (2000), Increasing returns: Historiographic issues and path dependence, *European Journal of the History of Economic Thought*, **7**(2), 171-180.

Arts, Bas (2003), Non-State Actors in Global Governance: Three Faces of Power, Bonn: Max Planck Society.

Bassanini, A. P. and Dosi, G. (1999), Competing technologies, international diffusion and the rate of convergence to a stable market structure,

Bassanini, A.P. and Dosi, G. (2001): When and how chance and human will can twist the the arms of Clio: An essay on path dependence in a world of irreversibilities, in R. Garud and P. Karnoe (eds.), *Path Dependence and Creation*, Mahwah, New Jersey: Lawrence Erlbaum Associates, 41-68.

Bathelt, H. and Boggs, J.S. (2003), Toward a reconceptualization of regional development paths: Is Leipzig's media cluster a continuation of or a rupture with the past?, *Economic Geography*, **79**, 265–93.

Bednar, J., Page, S.E. and Toole, J. (2011), Revised-Path Dependence. *Political Analysis*, in press.

Bennett, A. and C. Elman (2006), Complex causal relations and case study methods: The example of path dependence, *Political Analysis*, **14,** 250-267.

Besen, S.M. and J. Farrell (1994), Choosing how to compete: Strategies and Tactics in Standardization, *The Journal of Economic Perspectives*, **8**(2), 117-131.

Beyer, J. (2010), The same or not the same - On the variety of mechanisms of path dependence, *International Journal of Social Science*, **5**(1), 1-11.

Boas, T. C. (2007), Conceptualizing continuity and change. The composite-standard model of path dependence, *Journal of Theoretical Politics*, **19**(1), 33-54.

Bresnahan, T., A. Gambardella and A. Saxenian (2001), 'Old Economy' inputs for 'New Economy' outcomes: Cluster formation in the New Silicon Valleys, *Industrial and Corporate Change*, **10**(4), 835-860.

Burgelman, R. A. (1991), Intraorganizational ecology of strategy making and organizational adaptation: Theory and field research, *Organization Science*, **2**(3), 239-262.

Burgelman, R. A. (1994), Fading memories: A process theory of strategic business exit in dynamic environments, *Administrative Science Quarterly*, **39**, 24-56.

Burgelman, R. A. (1996), A process model of strategic business exit: Implications for an evolutionary perspective on strategy, *Strategic Management Journa*l, **17**, 193-214.

Burgelman, R. A. (2002), Strategy as vector and the inertia of coevolutionary lock-in, *Administrative Science Quarterly*, **47**, 325-357.

Burgelman, R. A. (2003), Strategy making and evolutionary organization theory: Insights from longitudinal process research, Stanford University, Graduate School of Business, Research Paper No. 1844.

Burgelman, R. A. and A. S. Grove (1996), Strategic dissonance, *California Management Review*, **38**(2), 8-28.

Burgelman, R. A. and A. S. Grove (2007), Let chaos reign, then rein in chaos – repeatedly: Managing strategic dynamics for corporate longevity, *Strategic Management Journal*, **28**, 965-978.

Campbell, J. L. (2004), *Institutional Change and Globalization,* Princeton and Oxford, Princeton University Press.

Campbell-Kelly, M. (2001), Not Only Microsoft: The Maturing of the Personal Computer Software Industry, 1982-1995, *Business History Review*, **75**, 103-145

Campbell-Kelly, M. (2003): From airline reservations to Sonic the Hedgehog: A history of the software industry, Cambridge, Mass. and London: MIT Press.

Cohen, S. S. and G. Fields (1999), Social capital and capital gains in Silicon Valley, *California Management Review*, **41**(2), 108-130.

Craver, C.F. and Bechtel, W. (2007), Top-down causation without top-down causes, *Biology and Philosophy,* **22,** 547-563.

David, P. A. (1985), Clio and the economics of QUERTY, *American Economic Review*, **75**(2), 332-337.

David, P. A. (1994), Why are institutions the 'carriers of history'? Path dependence and the evolution of conventions, organizations and institutions, *Structural Change and Economic Dynamics*, **5**(2), 205-220.

Dobusch, L. (2008), Migration Discourse Structures: Escaping Microsoft's Desktop Path, in Russo, B., E. Damiani, S. Hissam, B. Lundell, B. and G. Succi (eds.), *Open Source Development, Communities and Quality*, Series: IFIP International Federation for Information Processing, Vol. 275, 223-235

Dobusch, L. (2010): ‚Kaskaden der Komplementarität: Pfadabhängigkeit organisationaler und technischer Strukturen, *zfbf*, **62**, 422-451.

Dolata, U. (2009), Technological innovations and sectoral change: Transformative capacity, adaptability, patterns of change: An analytical framework, *Research Policy,* **38**(6), 1066-1076.

Dorado, S. (2005), Institutional entrepreneurship, partaking, and convening, *Organization Studies*, **26**(3), 385-414.

Dosi, G. (1982), Technological paradigms and technological trajectories: A suggested interpretation of the determinants and directions of technical change. *Research Policy*, **11**(3), 147-162.

Dranove, D and N. Gandal (2003), The DVD-vs.-DIVX standard war: Empirical evidence of network effects and preannouncement effects, Journal of Economics and Management Strategy, **12**(3), 363-386.

Economides, N. (2001), The Microsoft Antitrust Case, *Journal of Industry, Competition and Trade*, 1(1), 7-39.

Farrell, J. and G. Saloner (1986), Installed Base and Compatibility: Innovation, Product Preannouncements, and Predation, *The American Economic Review*, **76**(5), 940-955

Ferraro, F., J. Pfeffer, R. I. Sutton (2005), Economics language and assumptions: How theories can become self-fulfilling. *Academy of Management Review*, **30**(1), 8–24

Flyvberg, B. (2006): Five misunderstandings about case-study research, *Qualitative Inquiry*,

12(2), 219-245

Frost, P. J. and C. P. Egri (1991), The Political Process of Innovation, *Research in Organizational Behavior*, **13**, 229-265

Gandal, N., S. Greenstein and D. Salant (1999), Adoptions and orphans in the early microcomputer market, *Journal of Industrial Economics*, **47**(1), 87-105.

Garud, R. and P. Karnøe (eds.), (2001), *Path dependence and creation*, London: Routledge.

Garud, R., A. Kumaraswamy, and P. Karnøe (2010), Path dependence and creation, *Journal of Management Studies*, **47**(4), 760-774.

Gawer, A. and R. Henderson (2007), Platform owner entry and innovation in complementary markets: evidence from Intel, *Journal of Economics and Management Strategy*, **16**(1), 1-34

Giddens, A. (1984): The constitution of society: Outline of the theory of structuration, University of California Press.

Gilbert, R. J. and M. L. Katz (2001), An economist's guide to U.S. v. Microsoft, *Journal of Economic Perspectives*, **15**(2), 25-44.

Greener, I. (2005), State of the art. The potential of path dependence in political studies, *Politics*, **25**(1), 62-72.

Gruber, M. (2010), Exploring the origins of organizational paths: Empirical evidence from newly founded firms, *Journal of Management*, **36**(5), 1143-1167.

Hakanson, L. (2005), Epistemic communities and cluster dynamics: On the role of knowledge in industrial districts, *Industry and Innovation*, **12**(4), 433-463.

Hall, P. A. (2003), Aligning ontology and methodology in comparative research, in J. Mahoney and D. Rueschemeyer (eds.), *Comparative historical research in the social sciences*, New York: Cambridge University Press, 373-406.

Hannan, M. T. and J. Freeman (1984), Structural inertia and organizational change, *American Sociological Review*, **49**, 149-164.

Katz, M. L. and C. Shapiro (1985), Network externalities, competition and compatibility, *The American Economic Review*, **75**(3), 424-440.

Katz, M. L. and C. Shapiro (1998), Antitrust in software markets, paper presented at the Progress and Freedom Foundation conference 'Competition, Convergence and the Microsoft Monopoly', February 5, 1998.

Kay, A. (2005), A critique of path dependency in policy studies, *Public Administration*, **83**(3), 553-571.

Kenney, M. (2000), Understanding Silicon Valley: Anatomy of an Entrepreneurial Region.

Stanford: Stanford University Press.

Kenney, M. and U. von Burg (1999), Technology, entrepreneurship and path dependence: Industrial clustering in Silicon Valley and Route 128, *Industrial and Corporate Change,* **8**(1), 67-103.

Kenney, M. and U. von Burg (2001), Paths and regions: The creation and growth of silicon valley, in R. Garud and P. Karnoe (eds.), *Path Dependence and Creation*, Mahwah, New Jersey: Lawrence Erlbaum Associates, 127-148.

Koch, J. (2008), Strategic paths and media management - A path dependency analysis of the German newspaper branch of high quality journalism, *Schmalenbach Business Review,* **60**, 50-73.

Koch, J. (2011), Inscribed Strategies: Exploring the Organizational Nature of Strategic Lock-In, Organization Studies **32**, 337-363.

Koski, H. (1999), The installed base effect: Some empirical evidence from the microcomputer market, *Economics of Innovation and New Technology,* Vol. **8**, 273-310.

Koski, H. and T. Kretschmer (2004), Survey on competing in network industries: Firm strategies, market outcomes, and policy implications, *Journal of Industry, Competition and Trade*, Bank Papers, 5-31.f

Koski, H. and T. Kretschmer (2005), Entry, standards and competition: firm strategies and the diffusion of mobile technology, *Review of Indstrial Organization*, 26(1), 89-113..

Kretschmer, T. (2004), Upgrading and niche usage of PC operating systems, *International Journal of Industrial Organization*, **22**, 1155-1182.

Krugman, P. (1991), *Industry and Trade*. Cambridge, Mass.: MIT Press.

Lamberg, J. and K. Pajunen (2010), Agency, institutional change, and continuity: the case of the Finnish civil war, *Journal of Management Studies*, **47**(5), 814-836.

Lamberg, J. A. and H. Tikkanen (2006), Changing sources of competitive advantage: cognition and path dependence in the Finnish retail industry 1945-1995, *Industrial and Corporate Change*, **15**(5), 811-846.

Langlois, R. N. and P. L. Robertson (1992), Networks and innovation in a modular system: Lessons from the microcomputer and stereo component industries, *Research Policy,* **21**, 297-313.

Layder, D. (1998), Sociological practice: linking theory and social research, London and Thousand Oaks: Sage.

Leslie, S. W. and R. H. Kargon (1996), Selling Silicon Valley: Frederick Terman's model for

regional advantage, *The Business History Review*, **70**(4), 435-472.
Liebowitz, S. J. and S. E. Margolis (2001), Winners, Losers & Microsoft: Competition and Antitrust in High Technology – Revised Edition. Oakland: The Independent Institute.
Lopatka, J. E. and Page, W. H. (1995), Microsoft, monopolization, and network externalities: some uses and abuses of economic theory in antitrust decision making, *Antitrust Bulletin*, Summer 1995, 317-370.
Lowery, D. (2007), Why do Organized Interests Lobby? A Multi-Goal, Multi-Context Theory of Lobbying, *Polity*, **39**(1), 29-54
Mahoney, J. (2000), Path dependence in historical sociology, *Theory and Society*, **29**, 507-548.
Mahoney, J. (2001), Beyond correlational analysis: recent innovations in theory and method, *Sociological Forum*, **16**(3), 575-593.
Manning, S., & Sydow, J. 2011. Projects, paths, and pratices: Sustaining and leveraging project-based relationships. Industrial and Corporate Change, 20(5): 1369-1402.
Marshall, A. (1920), Industry and Trade. A study of industrial technique and business organisation; and of their influences on the conditions of various classes and nations (8th ed.). London: Macmillan & Co.
Mayntz, R. (2004), Mechanisms in the analysis of social macro-phenomena, *Philosophy of the Social Sciences*, **34**(2), 237-259.
Martin, R. (2010), Roepke Lecture in Economic Geography—Rethinking regional path dependence: Beyond lock-in to evolution, *Economic Geography* **86**(1): 1-27.
Martin, R. and P. Sunley (2006), Path dependence and regional economic evolution, *Journal of Economic Geography*, **6**, 395-437.
MERIT (Hrsg./2006): Study on the Economic impact of open source software on innovation and the competitiveness of the Information and Communication Technologies (ICT) sector in the EU – Final report. Online: http://ec.europa.eu/enterprise/ict/policy/doc/2006-11-20-flossimpact.pdf [08.03.2007]
Metcalfe, J. S. (1994), Competition, Fisher's principle and increasing returns in the selection process, *Journal of Evolutionary Economics*, **4**, 327-346.
North, D. C. (1990), *Institutions, Institutional Change and Economic Performance*, Cambridge: Cambridge University Press.
Page, S. E. (2006),Path dependence, *Quarterly Journal of Political Science*, **1**, 87-115.
Pajunen, K. (2008): The Nature of Organizational Mechanisms, *Organization Studies*,

29(11): 1449-1468.

Pettigrew, A. (1973), *The Politics of Organizational Decision-making*, London: Tavistock

Perroux, F. (1950), Economic Space: Theory and Applications, *Quarterly Journal of Economics*, **64**, 89-104.

Pierson, P. (2000), Increasing returns, path dependence, and the study of politics, *American Political Science Review*, **94**, 251-267.

Pierson, P. (2004), Politics in Time: History, Institutions, and Social Analysis. Princeton: Princeton University Press.

Prahalad, C. K and R. A. Bettis (1986), The dominant logic: A new linkage between diversity and performance, *Strategic Management Journal*, **7**, 485-501.

Puffert, D. J. (2002), Path dependence in spatial networks: The standardizations of railway track gauge, *Explorations in Economic History*, 39, 282-314.

Rao, H. and J. Singh (2001), The construction of new paths: Institution-building activity in the early automobile market, in R. Garud and P. Karnøe (eds.), *Path dependence and creation*, London: Routledge, 243-267.

Reddy, B., D. Evans, A. Nichols and R. Schmalensee (2001), A monopolist would still charge more for Windows: A comment on Werden, *Review of Industrial Organization*, **18**, 263-268.

Reinstaller, A. and W. Hölzl (2009), Big causes and small events: QWERTY and the mechanization of office work, *Industrial and Corporate Change*, 18(5), 999-1031.

Ruddin, L.P. (2006), You Can Generalize Stupid! Social Scientists, Bent Flyvbjerg, and Case Study Methodology, *Qualitative Inquiry*, **12**(4), 797-812

Saxenian, A. (1990), Regional networks and the resurgence of Silicon Valley, *California Management Review*, Fall 1990, 89-112.

Saxenian, A. (1994), Regional Advantage. Culture and Competition in Silicon Valley and Route 128, Cambridge, Mass.: Harvard University Press.

Saxenian, A. (1999), Comment on Kenney and von Burg, Technology, Entrepreneurship and Path Dependence: Industrial Clustering in Silicon Valley and Route 128, *Industrial and Corporate Change*, **8**(1), 105-110.

Schilling, M. (1999), Winning the standards race: Building installed base and the availability of complementary goods, *European Management Journal*, **17**(3), 265-274.

Schneiberg, M. (2007), What's on the path? Path dependence, organizational diversity and the problem of institutional change in the US economy, 1900-1950, *Socio-Economic Review*,

5, 47-80.
Schreyögg, G. and M. Kliesch-Eberl (2007), How dynamic can organizational capabilities be? Towards a dual-process model of capability dynamization, *Strategic Management Journal,* **28**, 913-933.
Shapiro, C. and H. R. Varian (1999), Information Rules: A Strategic Guide to the Network Economy, Cambridge, Mass.: Harvard Business School Press.
Strauss, A. L. and J. M. Corbin (1990), Basics of Qualitative Research. Grounded Theory Procedures and Techniques, Newbury Park: Sage.
Sturgeon, T. J. (2000), How Silicon Valley came to be, in M. Kenney (ed.), *Understanding Silicon Valley: Anatomy of an Entrepreneurial Region,* Stanford: Stanford University Press, 15-47.
Sydow, J., Schreyögg, G. and Koch, J. (2009), Organizational path dependence: opening the black box, *Academy of Management Review,* **34**(4), 689-709.
Sydow, J., F. Lerch and U. H. Staber (2010), Planning for path dependence? The case of a network in the Berlin-Brandenburg optics cluster, *Economic Geography* **86**(2): 173-195.
Takahashi, T. and F. Namiki (2003): Three attempts at 'de-Wintelization': Japan's TRON project, the US government's suits against Wintel, and the entry of Java and Linux, *Research Policy*, 32, 1589-1606.
Thelen, K. (1999): Historical institutionalism in comparative politics. Annual Review of Political Science, **f**, 369-404.
Thelen, K. (2003), How Institutions Evolve: Insights from Comparative Historical Analysis, in J. Mahoney and D. Rueschemeyer (eds.), *Comparative historical research in the social sciences*, New York: Cambridge University Press, pp. 208-240
Thrane, S., S. Blaabjerg, et al. (2010), Innovative path dependence: Making sense of product and service innovation in path dependent innovation processes, *Research Policy,* 39(7), 932-944.
Tushman, M. L. and P. Anderson (1986), Technological Discontinuities and Organizational Environments, *Administrative Science Quarterly*, **31**, 439-465
Vanloqueren, G. and P. V. Bareta (2009). How agricultural research systems shape a technological regime that develops genetic engineering but locks out agroecological innovations, *Research Policy,* 38(6), 971-983.
Varian, H. R., J. Farrell and C. Shapiro (2004), *The Economics of Information Technology: An Introduction*. Cambridge, Mass.: Cambridge University Press.

Walker, R. (2000), The Geography of Production, in E. Sheppard and T. Barnes (eds.), *A Companion to Economic Geography*, Oxford: Blackwell, pp. 113–132.

Werden, G. (2001), Microsoft's pricing of Windows and the economics of derived demand monopoly, *Review of Industrial Organization*, **18**, 257-262.

Windrum, P. (2001), Late entrant strategies in technological ecologies: Microsoft's use of standards in the browser wars, *International Studies of Management and Organization*, **31**(f1),87-105.

Windrum, P. (2004), Leveraging technological externalities in complex technologies: Microsoft's exploitation of standards in the browser wars, *Research Policy*, **33**(3), 385-394.

Woerdman, Edwin (2004), Path-dependent climate policy: the history and future of emissions trading in Europe, *European Environment*, **14** (5), 261-275.

Vergne, J. and R. Durand (2010), The missing link between the theory and empirics of path dependence: Conceptual clarification, testability issue, and methodological implications, Journal of Management Studies, **47**(4), 732-759.

Vergne, J. and R. Durand (2011), The Path of Most Persistence: An Evolutionary Perspective on Path Dependence and Dynamic Capabilities, *Organization Studies*, **32**(3), 365-382.

Yin, R. K. (1994), *Case Study Resfearch. Design and Methods*. Thousand Oaks: Sage.

Zhang, J. (2003), Growing Silicon Valley on a landscape: an agent-based approach to high-tech industrial clusters, *Journal of Evolutionary Economics*, **13**, 529-548.

Endnotes

[1] This definition is compatible with works that do not differentiate between positive feedback and self-reinforcement (e.g. Pierson 2004; Sydow et al. 2009) and with Page's (2006: 88) distinction between the terms, which holds that self-reinforcement can be considered a special case of positive feedback. Crediting the usefulness of Page's distinction between the two concepts, in the remainder of this paper we will refer only to "positive feedback" as the more general term, without actively making a distinction between the two concepts in our analysis.

[2] Only recently have some exceptional examples, such as the municipality of Munich (Dobusch, 2008), switched their desktop software to open source software alternatives.