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Path dependence research in regional economic development: Cacophony or knowledge accumulation?

Martin Henning, Erik Stam, Rik Wenting

Utrecht University
Urban & Regional research centre Utrecht

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Martin Henning
Department of Human Geography, Lund University
and
School of Business, Economics and Law, University of Gothenburg

Erik Stam (corresponding author)
Utrecht University School of Economics
Postal address: Kriekenpitplein 21-22, PO Box 80125, 3508 TC Utrecht, The Netherlands.
Phone: +31 302537894. Email: e.stam@uu.nl

Rik Wenting
Utrecht University School of Economics

Abstract
The concept of path dependence has gained momentum in the social sciences, particularly in economic geography. In this paper, we explore the empirical literature on path dependence and path creation in regional economic development. We offer a critical reflection on these studies and outline commonalities and problems in research designs and empirical testing. Our review suggests that the popularity of the concept of path dependence in regional studies has led to a cacophony of studies rather than a purposeful accumulation of knowledge around the concept. To remedy this situation, we identify gaps and suggest guidelines for future empirical research on the role of path creation and path dependence in uneven regional development.

Keywords: path dependence, path creation, regional development, economic geography

1. Introduction

The concept of path dependence has gained momentum in recent years. Figure 1 shows the number of published articles found by the Web of Science search engine when using the keywords 'path dependence' or 'path dependency'. The total number of articles published per year has rapidly increased, from 6 in 1991 to 43 in 2001 and 113 in 2009. It is especially striking how the number of social sciences articles published per year on path dependence increased from 1 in 1991 to 30 in 2001 and 87 in 2009.[1] Since the mid 1990s, economists and geographers have been important contributors to this research field. In economics, the seminal works by Paul David (*American Economic Review* 1985) and Brian Arthur (*Economic Journal* 1989) are widely regarded as landmark studies on path dependence. Indeed, the works by David and Arthur could be regarded as highly influential in what has become a major and distinct research field today.

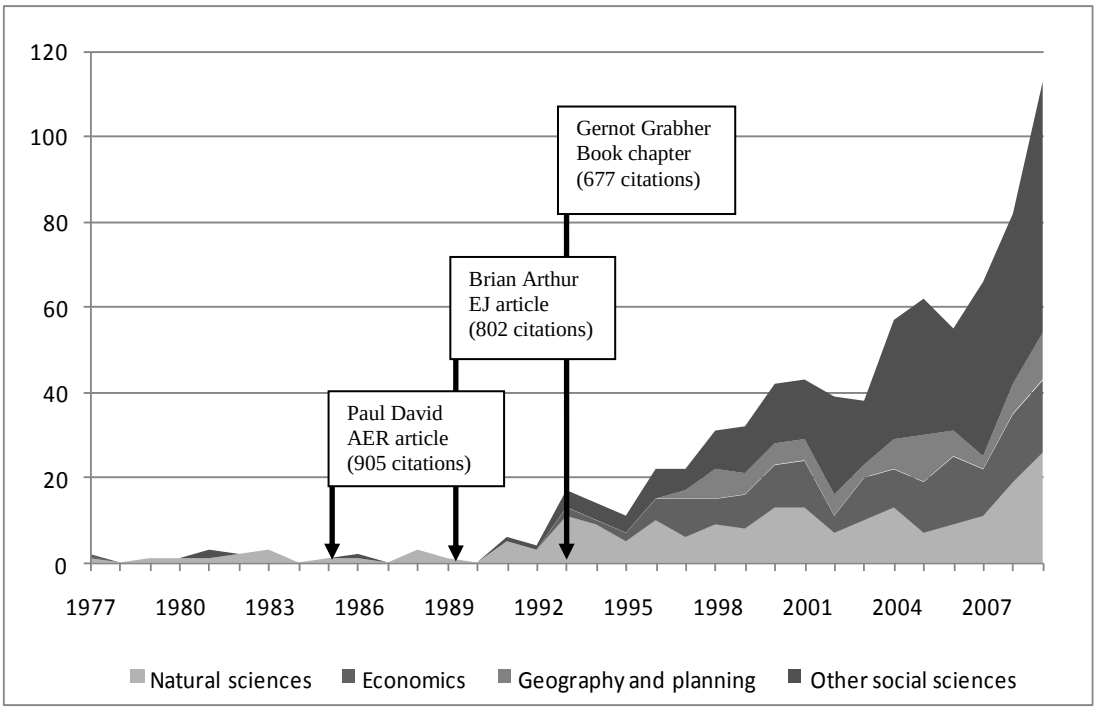

Fig. 1. *Number of scientific articles published on path dependence by discipline (1977-2009). Source: own calculations from Web of Science data.*

Although many important contributions on path dependence focus on theoretical aspects, the empirical interest in path dependence has also increased. This is especially true regarding the literature on *regional* path dependence. In fact, a number of research contributions suggest that path dependence has profound implications for technological, institutional, and industrial transformation. Economic geographers widely refer to Gernot Grabher's (1993) work on the Ruhr area as one of the first studies to implement path dependence in a regional context. Following the regional path dependence research since Grabher's study, this paper undertakes an exploration of influential empirical studies on the topic. The main issue we venture to investigate is whether the popularity of the concept of path dependence in regional studies has led to a cacophony of studies, or whether the increased attention has led – or could lead – to progressive knowledge accumulation about uneven regional development. From our discussion, we also try to pinpoint some important empirical issues for the next steps in research on regional path dependency. From these suggestions, we propose an agenda for future research.

The outline of the paper is as follows. In the next section, we briefly discuss the concept of path dependence. In sections three and four, we reflect on some of the most prominent regional empirical studies and outline commonalities and differences in research questions. We also discuss some common problems in the current empirical literature on regional path dependency. Section five summarises our findings and suggests three particular avenues for future research on regional path dependence.

2. The concept of (regional) path dependence

David's (1988) and Arthur's (1994) formal models of path dependence are commonly viewed as canonical in the path dependence literature (Martin, 2010). These two standard models of path dependence share three important commonalities, which together define a formal interpretation of path dependence. First, improbable events have a long-run effect on economic structures.[2] Second, mechanisms such as increasing returns or network externalities persistently reinforce the situations created by chance events, a phenomenon often known as lock-in. Third, external shocks can disrupt the persistence of the locked-in pattern. Path dependence can thus be viewed as a non-ergodic process, or, in other words, a process where the current situation is dependent on its own history, but not to the extent that it eventually will, or can, return to its previous state.[3] A degree of irreversibility and self-reinforcing mechanisms characterise path development processes.

In its most general guise, the concept of path dependence in the social sciences has come to signal that 'history matters' to the development and outcome of social phenomena. However, the popularity of a scientific concept is no guarantee of knowledge accumulation. Page (2006, p. 87) even goes as far to say that 'In becoming a trendy way to say that history matters, path dependence no longer provides any analytic leverage.' We agree that the recognition that 'history matters' is far from sufficient for gaining an improved understanding of social phenomena. Path dependence, however, goes beyond such *past* dependence (Antonelli, 1997). Whereas the concept of *past* dependence can be used to analyse the determinate effects of the past (see for example Comin *et al*., 2010), path dependence can be used to offer an understanding of why some optional developments are followed, or intentionally chosen, over others. In essence, the most important difference between these two concepts is that path dependence conditions, but does not determine, a specific outcome. When doing empirical research on path dependence, it is therefore crucial to move beyond describing past dependence and to discover the reinforcement mechanism that leads to path dependence (Sydow *et al*., 2009).

The path dependence framework has often been used to describe the dominance of certain products or technologies over others. The classical example used by David (1985; 1988) is how the QWERTY keyboard came to dominate the market due to the workings of network externalities and quasi-irreversible investments. This market domination continued even after the mechanical obstacles that necessitated the QWERTY design disappeared, in spite of its ergonomic inferiority to new keyboard designs. The QWERTY case has been complemented by many other examples of path-dependent technological development (see e.g., Garud and Karnøe, 2001). Most of the empirical research on economic path dependence focuses on the reinforcement of paths and lock-in situations. From an evolutionary perspective, one implication of this prevailing interpretation of path dependence is therefore its emphasis on path dependence as *limiting* variety in the economy, for example by creating a dominant product design or technological regime.

The concept of path dependence is, in our view, particularly useful in explaining two types of empirical phenomena. First, the path dependence concept may be used to explain suboptimal outcomes in the economy. This is the most common application of path dependence in economics. 'Suboptimal' outcomes should be compared to an optimal state that would be

achieved under perfect market conditions. Suboptimality thus involves market failure (David 1985; 2001). In this context, path dependence can be viewed as a mechanism that drives one product to be dominant over others even when a superior substitute is introduced at a later stage. Indeed, this process is an integral part of the archetypical QWERTY keyboard path dependence story.[4] Second, path dependence may be used to explain why change goes in a particular direction. The development of a pattern or sequence of outcomes may take place through *change and transform* itself via specific paths. This dimension of path dependence specifically addresses the sequence of historic development paths and how path dependence can be viewed as a process defining an ever-narrowing window of available choices. Breaking out and establishing new paths is quite possible in the beginning of the process but becomes increasingly difficult over time.[5] In this interpretation of path dependence, the previous structure does not inhibit change but rather defines opportunities and limits for change. Previous paths have set quasi-irreversible foundations for the direction of future change, as exemplified by technological development (David, 1985; Dosi and Nelson, 2010). In other words, the diversification or creation of paths, can also be thought of as an evolutionary branching process in which new paths build upon existing related paths (Boschma and Frenken, 2011). To this date, few empirical studies have looked at how new regional path-dependent trajectories arise from inherited regional knowledge bases, something that would mark a more evolutionary approach to path development. However, a relatively new and growing stream of literature understands path dependence in technological and capability development as an evolutionary branching process (Cattani, 2006; Garnsey *et al*., 2008; Bryce and Winter, 2009).

Strongly related to this is the question of 'de-locking' out of the regional lock-in situations that arise from path-dependent processes. Inspired by previous research in the field, Martin and Sunley (2006, p. 420) discuss five ways of escaping regional lock-in situations: indigenous creation (of new paths), heterogeneity and diversity, transplantation from elsewhere, diversification into (technologically) related industries and the upgrading of existing industries. Martin and Sunley (2006) note that most geographical work has focussed on the first strategy. However, there has been increasing interest, especially among the proponents of evolutionary economic geography, on the second and, to some degree, the fourth lock-out strategies. These strategies are well-aligned with the Schumpeterian-inspired arguments that novelty and innovation often arise from new combinations and that 'related variety', i.e. the regional presence of related (but different) industries, provides scope for such new combinations (see, for example, Frenken *et al*., 2007; Boschma and Iammarino, 2009). Indeed, "the delocking of a local industrial path may arise endogenously […] if local firms switch to a different, perhaps related, sector of activity on a new path that is perceived as affording more profitable opportunities" (Martin 2010, pp. 6-7). However, comparative empirical knowledge on which types of regional industrial structures are more conducive to breaking out of lock-in situations is still lacking. Many of the lock-out scenarios sketched by Martin and Sunley (2006) may potentially pertain to specialised regions as well as regions characterised by a high degree of variety and related variety.

Recently, the social sciences literature on path dependence has focused on two additional and interesting aspects of the path dependence discussion. First, contributors have discussed the role of agency and intentionality in path-dependent processes. According to these views (for example Sydow *et al*., 2010), which are often connected to micro evidence about individual behaviour, agents intentionally choose to establish (or *create*) path dependent processes, recognising the potential benefits of the concerted actions of individuals within path-dependent reinforcing structures. In this spirit, these agent-centred approaches add a new dimension to the sources of path dependence, compared to the more traditional literature discussed above. In fact, Garud *et al*. (2010) distinguish between "path dependence" and "path creation" as being frameworks based on different ontological foundations, where path creation allows for the purposeful establishment and reinforcement of paths by actors.

Secondly, Schneiberg (2007) has problematized the notion of path dependence in discussing the presence of institutional features, organizational forms and other reminiscences of 'paths not taken'. The fact that one path, whether institutional or technological, will dominate the evolution of a system does not mean that experiments from other paths will be eroded. On the contrary, these reminiscences may later become the foundations of future re-combinations with dominant paths. Such arguments do not invalidate path dependence arguments but rather re-direct the view on the establishment of new paths from linear processes to processes of combination, re-combination and change.

3. Themes in regional path dependence studies

The study by Schneiberg (2007) discusses some regional aspects of 'paths not taken'. Indeed, by placing path dependency in a spatial context, scholars have developed *regional* path dependence research into quite a distinct literature, which encompasses contributions from the rather novel approach of evolutionary economic geography (Boschma and Frenken, 2006; Boschma and Martin, 2010) as well as more institutional and political economy approaches (MacKinnon *et al*., 2009). Most economic geographers employ the path dependence concept to explain why change takes a particular direction, focusing on the path-dependent development of regional economies. In particular, it is common to analyse how regional industrial structures change, or fail to change, as a consequence of path dependence in industrial, technological, or institutional development. Below, we identify and discuss three common themes in regional path dependence research: regional path dependence and lock-in, disruptive events and regional path dependence, and regional technological path dependent change as a branching process.

3.1 Regional path dependence and lock-in

Research contributions commonly indentify path dependence based on the empirical observation of continued behaviour by economic agents that is similar to their past behaviour, in settings where the conditions of the business environment have changed dramatically. This results, for example, in the persistence of regional industrial or institutional structures (*e.g.*, Grabher, 1993; Meyer-Stamer, 1998; Bathelt and Boggs, 2003; Hassink, 2005). Many of these studies identify regional path-dependent development from empirical observations of regional lock-in. Notably, Grabher's (1993) study of regional path dependence in the Ruhr area distinguishes between cognitive, functional, and political lock-in. Lock-in caused the Ruhr-based steel and coal industry to disregard the signs of a shifting international market orientation, which increasingly favoured low wage countries. Moreover, Meyer-Stamer (1998) and Bathelt and Boggs (2003) found that the opening of a regional economic system previously closed to international competition (Brazilian textiles and metal engineering clusters and Leipzig's publishing cluster) did not necessarily cause rapid adaptive behaviour on the part of established cluster firms and eventually led to the decline of these sectors. Furthermore, Bathelt (2001) described the development paths in Boston's high-tech economy since the 1960s and specifically addressed the way in which Boston's Route 128 region was able to recover from major structural crises in the early 1990s. Interestingly, not all previously successful sectors proved able to renew themselves. The once thriving minicomputer industry, in particular, was presented as an industry that was 'not willing to give up their focus on proprietary technologies and was, thus, subject to being locked into an inefficient technological trajectory.' (Bathelt, 2001, p. 307; see also Kenney and Von Burg, 1999).

These types of empirical studies on regional path dependence attribute the lack of change to lock-in on various levels of the regional economic structures (e.g., firm, industry, or institutions). Such a perspective on path dependence is closely related to the "sailing ship effect" identified by Rothwell and Zegveld (1985), which contends that firms confronted by a change in their competitive environments remain loyal to their old technology and

organisational routines. Indeed, 'rather than attempting to capitalize on the possibilities offered by the emergence of a new superior substitute technology, they vigorously defend their position through the accelerated improvement of the old technology.' (Rothwell and Zegveld, 1985, p. 41). Grabher (1993) found a similar conservative reaction among German steel industry managers and politicians, as investments in the Ruhr area's steel industry increased despite a growing awareness of international competition in the 1970s. A similar situation has been found in the watch industry in the Swiss Jura region. Though once a world leader in the watch industry, its networks, which promoted innovation in the mechanical technological system, became disorganised and disintegrated during the technological transition of the global watch industry towards microelectronics (Glasmeier, 1991). Regional lock-in through path dependence may be evidenced by the empirical observation of continuation and conservation of old methods of production, particularly when confronted by radically different situations that would require adaptability and change.

3.2 Disruptive events and regional path dependence

Many regional scholars have addressed the issue of how and when a locked-in stable state can be de-locked (e.g., Hassink, 2005; 2007; Hassink and Shin, 2005; Martin and Sunley, 2006; Castaldi and Dosi, 2006). In fact, many studies address situations of regional change but do so mainly through the analysis of exogenously episodic or shock-induced renewal (e.g., Bathelt and Boggs, 2003; Meyer-Stamer, 1998). In this version, the establishment of a new path is regarded as a consequence of random or external events.[6] In a similar vein, Braunerhjelm and Feldman (2006), in their synthesis of studies on regional cluster emergence, claim that the establishment of a new industrial path is a sequential process with an evolutionary logic: a triggering event coupled with an entrepreneurial spark sets a process of coevolution in motion, in which technology, institutions, and business models arise and reinforce the increasing returns that improve the competitive advantage of the region in terms of attracting talent, investments, and firms. Bathelt and Boggs (2003, p. 269) argue that 'in addition to incorporating sudden political and sectoral/technological ruptures, a model of regional development paths must allow for technologically unrelated regional actors.' The emergence of new sectors, then, is not always related to the existing regional industrial base. Such a view is in part consistent with Storper and Walker's (1989) Windows of Locational Opportunity (WLO) model, which argues that new industries require few specific locational inputs in their emergence stage. This allows them to locate in regions with varying industrial bases. However, even though the WLO model offers opportunities for many regions, it rules out new industry development in regions without generic inputs (Boschma and Van der Knaap, 1999; Boschma and Frenken, 2006).

Among others, Bathelt and Boggs (2003) emphasise crisis-driven discontinuities and ruptures in the regional context. Through a description of the development of the Leipzig media cluster, they show that a series of sectoral, technological and political crises may force actors to rebundle local assets into new combinations that generate growth. Key to their understanding of regional development paths is the notion that regional paths are shaped by the expanding and contracting industries in the region and that the evolution of industries is driven by technological development. Like Bathelt and Boggs (2003), Meyer-Stamer (1998) argues that a crisis event broke the stable and path-dependent development of three industrial clusters (i.e., textiles, metal engineering, and ceramic tiles) in Santa Catarina, Brazil, where firms were highly vertically integrated and there was little cooperation between firms. The opening of the Brazilian economy to international competition in 1990 forced firms to be more cooperative and make use of the 'learning-by-interacting benefits of close interfirm cooperation and a dense flow of information, and the creation of specific supporting institutions.' (p. 1508). Interestingly, some clusters were better able to adapt than others. Neither the frameworks by David and Arthur, nor the regional lock-in literature discussed above, address endogenous new path development (Martin, 2010). However, we contend that a broader interpretation of the regional path dependence concept is compatible with several

modes of endogenous regional rejuvenation and how regions may establish new industrial paths.

On a grander scale, scholars have discussed the economic impacts of dramatic changes in the very fundamental properties of capitalist growth, for example, in the frameworks of techno-economic paradigms (Freeman and Perez, 1988; Freeman and Louça, 2001) or technology shifts (Schön, 2010). Even if such shifts most likely change the prerequisites for new regional paths, whether these shifts take place as incremental changes or as disruptive events in the economy is widely debated.[7] Regardless, such shifts can be thought of as potential starting points of new regional development paths, especially if connected to the WLO approach discussed above (Boschma, 1997). Even if scholars have, to some extent, investigated the geographical implications of these pervasive institutional and/or technological shifts in the capitalist economy (for example Boschma, 1997; Lundquist *et al.*, 2008), to our knowledge, little empirical research explicitly connecting the establishment of new regional development paths to these grand shifts in the economy has been carried out. A recent exception is Paruchuri and Ingram's (2012) study on the effect of the September 11 WTC attacks on business founding rates, in which they found that this exogenous shock erased several institutional lock-ins, leading to substantially higher founding rates in the vicinity of Manhattan in the period after the shock (controlling for other potential explanatory variables). They argue that economic systems may get stuck in suboptimal equilibria due to path dependence and that destruction may sweep away this inertia and open the way for entrepreneurship.

3.3 Regional technological path-dependent change as a branching process

Considering evolutionary interpretations about how technological change takes place over time (Boschma and Frenken, 2006), regional path dependence can also be thought of as a branching process (Frenken and Boschma, 2007), specifically in the form of regional diversification from old to new industries (Neffke *et al*., 2011). In the traditional path dependence framework (David, 1985), path dependence can also be interpreted as a branching process, to the extent that external shocks lead to a switch from one path to the next. An evolutionary interpretation, however, would suggest that such switches are more likely to occur from an old path to a new path that is technologically related to the old one (Nooteboom, 2000; Boschma and Frenken, 2011). Related industries could, for example, benefit from the use of the same technologies or skills in the labour force. This suggests that the growth of a new sector in a region builds upon the resources inherited in the region rather than disregarding already existing structures to embark on a radically different path (Neffke *et al*., 2011).[8]

The evolutionary interpretation of regional path dependence is particularly concerned with regional structural change, i.e., changes in the industry composition of a region. When path dependence is viewed as a branching process of industrial or technological development, the analytical framework focuses on why and when certain regional paths are developed over others. Existing industries may, through related diversification, form the starting point for further regional structural change. In a longitudinal study of industrial development in the Swedish regions, Neffke *et al*. (2011) show that a new industry is more likely to be established in a region when it is related to the already existing regional industrial base in terms of skills and technologies. From a similar perspective, Boschma and Wenting (2007) show that the success of the British automobile manufacturers in Coventry-Birmingham can be traced back to the entrepreneurial roots of the area in bicycle, engine and coach manufacturing.[9] They find that the emergence and spatial formation of the British car industry closely followed the spatial structure of related established industries.

Empirical evidence suggests that industries can continue to evolve during seemingly stable general regional conditions (Martin, 2010). Studies dealing with path development through

regional diversification show that the border between path continuity and new path establishment is fuzzy. We synthesise the current literature along two dimensions: the degree of industrial continuity and the extent to which (external) shocks are relevant to understanding the establishment of new paths. We identify four specific types of regional development (see Table 1). The path dependence literature in regional studies often emphasises high industrial continuity but is open about whether new paths are triggered by (external) shocks or evolve in rather stable conditions through evolutionary regional branching. Lower levels of industrial continuity in regional industrial development can be both shock-induced – when a new industry settles down in a region without related industries (cf. Storper and Walker, 1989; Brezis and Krugman, 1997) – or continuous – when caused by the serendipitous matching of various regionally incumbent ideas. The latter is most likely to take place in dense urban areas as the effect of a varied regional economy (Jacobs, 1961; 1969; Storper and Venables, 2004).

Table 1. *Industrial continuity and shocks in regional path creation*

		Industrial continuity	
		High	Low
Shock induced	Yes	Regional path establishment as disruptive event	Virgin landscape; Window of Locational Opportunity
	No	Evolutionary regional branching	Jacobian serendipity

One major shortcoming of the regional path dependence literature is that, for a long time, the literature had little to say about the role of individual agency in affecting path-dependent processes. In a recent study, Sydow *et al*. (2010) show that purposeful action by individuals who are deliberately trying to achieve reinforcing mechanisms can result in regional path-dependent processes. They also show that parts of the Berlin-Brandenburg optics cluster have deliberately embarked on a path-dependent regional process, which still strongly relates to the already established regional industry structure. This suggests that the phenomenon of regional path dependence is becoming increasingly fuzzy. Researchers not only need to establish if and to what extent regional histories matter in a path-dependent way but also whether the path-dependent process has been created unintentionally or by purposeful action. In fact, there are reasons to consider separating regional path dependence from the deliberate creation of a new regional development path through agency, as discussed above. Before continuing our discussion about these aspects, we discuss some basic yet urgent issues in operationalising path dependence in a regional context: selecting the level of analysis and identifying path dependence mechanisms, defining new paths, and choosing appropriate methodologies and metrics.

4. Empirical issues in regional path dependence studies

4.1 The region and its levels of analysis

Our review of the regional empirical literature revealed multiple levels of regional path dependence analysis: (i) the micro level (such as the behaviour of entrepreneurs or firms in regions, cf. Stam, 2007), (ii) the level of networks, (iii) technology, and (iv) institutions. However, both the level of analysis and the fact that path dependence potentially arises from different sources or self-reinforcing mechanisms on different levels are important in an empirical situation. Because a regional economy contains individuals, networks (groups, firms), institutions and technologies, the region can in fact be seen as a bundle of several potential sources of path dependence on different levels. The fact that path dependence takes place in a region does not automatically imply that all sources of path dependence are best studied on the regional level. To understand path dependence and why it matters for *regional*

outcomes, it is essential to give these different levels of analysis and different sources of path dependence a more explicit spatial interpretation.

Importantly, the components of the canonical path dependence model can be interpreted spatially. Large initial fixed setup costs, dynamic learning effects, network externalities, and self-reinforcing expectations all have spatial dimensions (see also Martin, 2010). Fixed costs and the quasi-irreversibility of location set-up efforts bind a firm to a geographical location, and more so the more capital-intensive the industry that the firm belongs to. Although set-up costs are not enough to create self-reinforcing path dependence on their own, but rather create locational inflexibility, a heavy fixed investment could certainly be the starting point of a cumulative causation process. Dynamic learning effects and network externalities are part of a knowledge transfer system that is spatially "sticky". The expanding literature on localised knowledge spill-overs, dynamic regional externalities, and learning regions has stressed the regional boundedness of knowledge transfer, especially concerning the diffusion of tacit knowledge (Glaeser *et al*., 1992; Feldman, 2000; Rosenthal and Strange, 2004; Asheim, 1996; Gertler, 2003). In fact, positive dynamic agglomeration externalities could be interpreted as a self-reinforcing growth mechanism similar to the path dependence model.

Regional studies have so far emphasised a number of self-reinforcing mechanisms on the different levels of analysis. On the individual level, the development of habits or skills may be subject to positive reinforcement processes that result in path dependence. In networks of individuals and organisations, group thinking or collective cognitive perceptions may induce path dependence, as was the case in the Ruhr area. Similarly, organisational routines may create path dependence in firm behaviour.[10] In a theoretical discussion, MacKinnon *et al*. (2009) specifically highlight the role of institutions in regional lock-in processes, showing that path dependence issues are of common interest to evolutionary as well as institutional geography researchers. On the industry level, a path-dependent development may arise from sunk costs and network externalities in technology or through the cumulative establishment of labour market agreements. Additionally, the development of institutions, which can be found on a variety of levels in a region, may lead to lock-in situations.[11] Examples can also be found where the path dependence approach is used to explain regional path-dependent outcomes from several different levels and sources (see for example Grabher, 1993; Hassink, 2005).

Intra-regional variation may be large, and several paths may vie for dominance in a region. For example, we might assume that the regional dimension is important for how industries develop in regions, but we cannot assume that all industries in a region belong to the same path-dependent trajectory. Martin and Sunley (2006, pp. 410-411) highlight this by distinguishing between three types of regional path dependence studies: (1) one industry in many different locations, (2) one industry in a specific region, and (3) the development of a regional economy as a whole through time. To make matters more complex, path-dependent processes are likely to interact within and between levels of analysis. For example, institutional lock-in at the regional level may be found to influence political development and firm investment patterns (Grabher, 1993). Additionally, the development of individual work habits may be derived from firm-level organisational routines, which could themselves be subject to technological and institutional regimes on the industry and regional levels. Such interdependencies can be thought of as arising from upward and downward causation between the various levels of analysis (Martin and Sunley, 2010). Indeed, because different levels interact, this could lead to co-evolution in multiple areas (Hirsch and Gillespie, 2001), such as technological, cognitive, institutional, and industrial development. The more aggregated the level of analysis, the harder it may be to meet the empirical challenge to single out specific path dependent mechanisms and prove their importance in shaping long-run development.

There is, however, some empirical evidence supporting the view that path dependence has distinct regional features, external to the individual organisations present in the region. Several studies have found that the region as an aggregate is a meaningful level of analysis in

the path dependence discussion. For example, Essletzbichler and Winther (1999) use quantitative analysis to find path dependence in the regional technological development of the Danish food-processing industry. They argue that 'the dependence of technology on past and existing knowledge tends to move firms, regions and countries along relatively well-defined technological trajectories' (p. 179). Like Rigby and Essletzbichler (1997), they measure technology development as a paired movement in capital and labour productivity. Here, path dependence is identified from the empirical finding of the persistence of differences in technology development across regions over time (Essletzbichler and Winther 1999, p. 179). Historical studies have also revealed the necessity of taking the region as the unit of analysis in studying the role of path dependence in economic development (Hudson, 1989; Van Bavel, 2010).

4.2 The definition of (new) regional paths

Another important issue to be addressed when empirically studying regional path dependence is the definition of a development path, so that it may be singled out and analysed. It is crucial because the definition of the path will suggest which measurement methods are the most appropriate. More particularly, researchers need to be able to determine when a new path begins, when an old path simply renews or 'rejuvenates' itself and when a path ends (Martin, 2010). Different assumptions and definitions on these issues can make one empirical study of path dependence quite different from another, which hampers the comparability of results and the accumulation of insights.

Many studies on regional path dependence focus on the development of an individual industry or distinct set of related industries. It is, however, very complicated to disentangle when the path dependence trajectory begins, whether it is a completely new path or the continuation of an old path, and what constitutes the end of a path. In fact, because the empirical definition of a path is extremely difficult, it most likely has to vary according to the studied levels and mechanisms. Clearly, without being able to devise an empirical formula, we believe that it is of utmost importance that empirical studies explicitly clarify how the notion of a path is operationalised. Recently, the literature has started to address the issue that regional path dependence might not be a clear-cut or binary phenomenon but rather a matter of degree, from highly path-dependent to non-path dependent. For example, Neffke *et al.* (2011) argue that new industries can not only be regarded as either completely new or a continuation of the existing path but also as more or less related to the existing regional industrial base.

New paths may also completely supplant existing regional development paths. The break with an existing locked-in path through an exogenous shock can be seen as a form of "creative path destruction" (cf. Paruchuri and Ingram, 2012). Many studies, especially of old industrial areas, find that an exogenous shock becomes a solution to a prevailing problematic lock-in situation (e.g., Grabher, 1993; Meyer-Stamer, 1998; Bathelt and Boggs, 2003). However, lock-in, as defined by Arthur and David, is a steady state from which no change is likely and does not necessary imply decline. As such, the argument for regional lock-in seems to be similar to the argument for agglomeration diseconomies (Maggioni, 2006). It appears that regional industrial specialisation can only be considered a sign of lock-in if specialisation is accompanied by an increasing inflexibility and lack of openness to other regional development paths. In addition, the argument can be made that an industrial path in a region can do more than continue or perish; it can also renew itself (Martin and Sunley, 2010).

4.3 Method of analysis and measurement

The stock of discussed empirical literature on regional path dependence comprises both quantitative and qualitative studies. As always, different methodologies provide comparative strengths in uncovering the specific mechanisms of regional path dependence. Whereas qualitative analysis excels in aligning theory to practice and advancing the conceptual

discussion, quantitative analysis may focus on testing hypotheses derived from existing theory. Many empirical studies of regional path dependence find illustrative evidence of such tendencies in the behaviour of agents, most often based on the statements of interviewees. For example, the study on path dependence in the Leipzig media cluster by Bathelt and Boggs (2003) offers qualitative evidence based on historical accounts and interviews with local entrepreneurs and industry experts. Forbes and Kirsch (2011, p. 590) argue that understanding emerging industries more fully will require scholars, collectively speaking, 'to work with qualitative and historical data to a greater extent than they have in the recent past'.

Other studies increasingly favour a quantitative approach, using different techniques. For example, Sunley and Martin (2007) examine path dependence in sectoral patenting activities in city regions in the UK. They use descriptive statistics to illustrate divergent paths in regional patenting, both generally and by industry. Furthermore, Essletzbichler and Winther (1999) use quantitative analysis to find path dependence in the regional technological development of the Danish food-processing industry. Stam and Martin (2012) find evidence of sequential development paths in the local industrial base that led to the success of the Cambridge high tech region in the 1990s.

Importantly, aside from efforts to ascertain the importance of inherited conditions on present behaviour, path dependence studies also address the increased likelihood of conformity to an established development path vis-à-vis other options. As such, a historical description of regional development can be viewed as evidence for a path dependence process only when the data show that the path does not only build upon itself but also does so in favour of other alternatives. Boschma and Wenting (2007) use survival analysis techniques to examine the emergence of the British automobile industry. They conclude that the local emergence of new industries from related industries, i.e., path creation through successive paths, is more likely than chance events. Based on this study, one could argue for a place-dependent perspective on path creation (see also Hassink, 2005). Moreover, Neffke *et al*. (2011) also show that new industries are more likely to emerge in regions where related activities are already present. Their study suggests that the existing regional industry structure conditions (but does not determine) the future development path of the regional economy.

Efforts to obtain and analyse rich historical data of both a quantitative and qualitative nature seem inevitable in studies of regional path dependence. Indeed, studies vary widely in terms of theoretical approach, concept definitions, and methodology. However, we find that a major predicament for path dependence researchers is dealing with the difficulties in comparing research results because of differences in metrics, definitions, and areas of application. We therefore find it hard to describe the empirical literature on path dependence as a cumulative effort. This feature is most likely common to any emerging literature. In the concluding section, we offer some suggestions on how to move the literature on regional path dependence forward.

5. Conclusions and avenues for future research

Path dependence offers a broad framework for the study of important aspects in regional economic renewal, transformation and decline. In our discussion of the literature, we have found that the range of empirical applications around the concept of path dependence is expanding. We distinguished between three common themes in economic geography path dependence studies: regional lock-in, disruptive events and regional path dependence, and path creation as a branching process. Studies focusing on regional lock-in explain the lack of change in a regional industrial structure as a consequence of path dependence, inhibiting diversion from the historically dominant path. Studies that address regional path creation often invoke the concept of path creation to describe a situation in which a region is de-locked from a previously locked-in state. Most of these studies focus on the external, shock-induced

'break' with the past through the development of a new path that replaced the old, declining path. Finally, studies of path dependence as a branching process explain changes in regional industrial structure and new path creation as the consequence of new combinations that are based on and limited by the existing regional industrial structure. This last perspective invokes an evolutionary approach and considers new path creation as an endogenous process.

We also identified three common difficulties in operationalising path dependence: (a) selecting the level of analysis and identifying the sources of path dependence and how these are related, (b) defining new regional paths, and (c) choosing methodology and how to compare studies that use different methodologies. So far, empirical studies on regional path dependence seem to favour analysis of one particular industry in one particular region, describing its initial growth, decline, replacement or renewal. Some exceptions are the studies on all or many of the industries in a region (e.g., Neffke *et al*., 2011) or country (e.g., Rigby and Essletzbichler, 1997), entrepreneurship as a source of regional path dependence (e.g., Staber, 2005), and the formation of inter-firm networks in clusters (e.g., Meyer-Stamer, 1998). Although this work has laid bare some of the different sources of path dependence at various levels, we believe that future research might benefit from gathering more comprehensive evidence on how different sources on different levels interact to create regional path dependence.

Because of the major differences in operationalisations, it is hard to compare results of different studies. By invoking path dependence concepts for a variety of levels of analysis and process and using different definitions and assumptions on regional paths, lock-in and spatial dimensions, path dependence studies tend to be 'stand-alone' cases of evidence rather than a research field in which knowledge about a particular phenomenon is accumulated. In the formative stage of any new research field, such a plethora of empirical work and methodologies is vital to exploring the validity of concepts and the range of their applications. There are a few topics that need more attention if the regional path dependence research is to move beyond this formative stage.

5.1 The self-reinforcing mechanisms or sources of path dependence

Many of the qualitative and single-case studies in the literature have successfully distinguished between the different sources of path dependence and discussed the most relevant spatial scale. However, the full palette of mechanisms working on different levels in regions has yet to be theoretically systematised and empirically investigated. An insightful and concrete discussion about the different mechanisms at work on the regional level, perhaps in the spirit of the discussion in Sydow *et al*. (2009), is, in our view, at the top of the regional research agenda. In fact, the explanatory power of path dependence mechanisms in generally shaping the development of regions is what could make a path dependence study go beyond a historical account of a region's development.

Additionally, we contend that regional path dependence studies are primarily concerned with regional structural change rather than regional economic growth per se. Path dependence seems to condition the variety of regional industrial structures in two seemingly contrasting ways. First, path dependence limits opportunities for change by promoting the growth of one industry over others, leading to the relative decline of other existing industries and limiting opportunities and resources for the emergence of new industries. In other words, a decline in regional adaptability is viewed as a direct consequence of continuous adaptation to a major industry (Grabher, 1993). However, path dependent reinforcement mechanisms cannot only be seen as inevitable causes of future decline but also as forces conditioning future variation and renewal. Second, path dependence therefore shapes opportunities for change through related diversification. In other words, existing technological or industrial paths are not only roads to regional lock-in but also trajectories along which new paths may be developed.

This perspective aligns path dependence studies with the recent development of evolutionary approaches in economic geography. Amongst others, Martin (2010) and Martin and Sunley (2006) rebel against a canonical negative 'lock-in' interpretation of the path dependence model and favour a more evolutionary account that stresses continuous change and the establishment of new paths. The "evolutionary touch" is therefore especially evident in empirical studies that investigate how regions alter their signatures through endogenous change in which new paths build upon existing, related paths. Branching has a clear spatial dimension in that it manifests itself through knowledge transfer mechanisms that tend to be spatially bounded (such as firm diversification, labour mobility and spinoff generation).[12] MacKinnon *et al*. (2009) reminds us that the path dependence concept is not privileged to evolutionary economic geography only but also has a long tradition in institutional analysis. However, these approaches need not to be separated, even if the evolutionary economic geography might so far have had a tendency to under-emphasise the role of institutions in shaping regional path dependency.

At first glance, it might seem odd that path dependence can be thought of as a source of continuous incremental renewal in some regions and a source of lock-in in others. Indeed, several empirical studies present external and disruptive change as the main "way out" for declining and locked-in regions. Therefore, the key question still remains: Why are some regions able to maintain a degree of economic flexibility despite the fact that they have adapted to a particular set of industries, while other regions are not? A major future challenge for path dependence research is to collect more coherent empirical evidence to ascertain the extent to which endogenous change is either stifled or invigorated by local conditions. This is especially true in regard to assessing which types of regional environments, specialised regions or regions characterised by related variety or large varied cities, are more conducive to which sort of 'lock-out' of established development paths.

5.2 Re-combination, agency and regional path dependence

Another important issue concerns the role of agency in the creation of paths, in contrast to the sometimes assumed non-purposive initiation of path dependence (Vergne and Durand, 2010). Which regional conditions enable path creation? Sydow *et al*. (2010) already initiated such a discussion by their study of the Berlin-Brandenburg optics cluster. Complimentary research remains vital to establish whether their findings are consistent over time and across industries as well as robust to varying spatial conditions. This research could also use insights from Austrian economics, in which the study of agency, entrepreneurship and institutions has become more spatially sensitive (see Stam and Lambooy 2012). Future research should also seek to specify which types of entrepreneurship reinforce regional structures and thus path dependence (cf. Staber, 2005) and which types reflect mindful deviation from regional structures, potentially resulting in path creation.

It is also of vital importance to investigate the role of elements of 'paths not taken' (see Cowan and Foray 2002; Schneiberg, 2007) in future re-combinations and regional growth. Indeed, the discussion of Schneiberg (2007) points at a weak spot in current regional path dependence studies; what happens to the remains of the paths that are not taken (one could think of skills, technologies, institutions, etc., that are peripheral to the taken paths). Which ones disappear? Which ones survive and provide inputs for future combinations? As for new regional paths, we also regard the connection to pervasive technology or paradigm shifts to be a promising area of future research. Overall, these are fascinating questions coming from a part of path dependence theory that has so far received little attention.

5.3 The economic impact of path dependence

So far, the regional path dependence literature addresses regional transformation and seems less explicitly concerned with its quantitative economic impact. In empirical studies, there is

surprisingly little encompassing evidence of the importance of industrial transformation processes for regional long-term growth (in terms of employment, income, value added, patents or other regional performance indicators). A considerable challenge for future path dependence research is not only to prove or disprove path-dependent development but also to determine its economic impact (cf. Boschma, 2004). Path dependence, broadly defined, may have both negative and positive effects on regional economic performance. On the one hand, path dependence may contribute to economic performance, as regional institutions and investments are adapted to enable the growth of a particular dominant industry. On the other hand, path dependence may eventually contribute to economic decline, as economies of specialisation give rise to inertia even when new environmental conditions require adaptability. As the region's dominant industry declines, it takes regional income and employment down with it. Such a story fits the evolution of many old industrial regions well. The fact that old industrial regions are the main source of empirical evidence for regional path dependence (e.g., Grabher, 1993; Bathelt and Boggs, 2003) shows that many scholars are interested in the economic relevance of the path dependence model.

The discussion in this paper notes that, although the field of research on regional path dependence and its empirical applications has grown considerably over the last decade, many research gaps must still be filled to establish a more mature body of literature. We do think it is necessary to study regional path dependence on different levels of analysis, investigate its various sources, and employ different methodologies. However, we also believe that commonalities in concepts and operationalisations of path dependence should be increasingly recognised to improve our understanding of uneven regional development.

NOTES

[1] The numbers shown here are not an attempt to fully explore the growth of the path dependence literature per discipline. The division of articles per discipline is based on the Web of Science's categorization of the journal. Since some journals are present in multiple categories, the results we report here offer a first indication of the relative shares per discipline in the path dependence literature. Furthermore, a drawback is that the Web of Science database might not include all publications or have a bias towards more recent publications.

[2] Because of the eventual importance of small events on the larger economic structure, Bassanini and Dosi (2001) have noted that path dependence is weak in the short-run but strong on the long-run.

[3] Ergodic means that outcomes are not dependent on the sequence of events and as such they are non-path dependent. See the discussion in Hirsch and Gillespie (2001, p. 71).

[4] More generally, path dependence can thus be used to explain why a pattern or outcome is surprisingly stable and becomes 'locked-in'. As such, path dependence is also used to address the reinforcing process towards a particular stable state, without necessarily referring to a (theoretical) optimal alternative.

[5] This sequence is discussed in Sydow *et al.* (2009). We thank one of the referees for making us aware of this discussion.

[6] At least in general terms, such a view on regional change is largely consistent with the canonical versions of path dependence. Note that the term "establishment of a new regional path" does not necessarily reflect intentionality by individual agents in the process (which we denote the "creation" of a new regional path).

[7] Despite the encompassing literature on techno-economic paradigms, long waves, technology shifts and industrial revolutions, it is debated if these grand shifts exist at all and especially which causalities give rise to them (see Rosenberg and Frischtak, 1983).

[8] In this respect, North (1990) has emphasised that economic activities do not start from scratch, but have a memory with cognitive and institutional aspects.

[9] Similar results have been found by Klepper (2002) for the US automobile industry, Cantner *et al.* (2006) for the German automobile industry, Audia et al. (2006) for US instrument manufacturers, and Wenting (2008) for the global fashion design industry.

[10] In organisation research, the analysis of path-dependent behaviour is becoming increasingly popular (see, for example, Beckman and Burton, 2008). However, as Sydow *et al*. (2009, p. 689) point out, here 'a clear specification [of path dependence]' is usually missing. This means, at the same time, that no indicators are available that allow for examining whether or not the organisational phenomena in question are actually path dependent.'

[11] David (1994) recognises the applicability of the path dependence model to institutional evolution, and describes institutions as the "carriers of history".

[12] See Boschma and Frenken (2009) and Neffke *et al*. (2011) for a discussion on spatially bounded knowledge transfer mechanisms giving rise to related diversification in regional industrial structures.

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