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A concise history of the knowledge base literature: challenging questions for future research

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Abstract

This chapter aims to sketch a short history of the differentiated knowledge base (DKB) literature that has been initiated and pioneered by Bjorn Asheim. In its formative years, the DKB approach described three knowledge bases and explored the nature of knowledge sourcing and its geographical extent within each knowledge base. We identify seven claims proposed by DKB scholars concerning the geography of knowledge bases. Lately, DKB 1.0 has been challenged on several grounds. In recent years, a second generation of DKB literature, dubbed as DKB 2.0, has emerged, becoming more tightly connected to the evolutionary approach in economic geography. DKB 2.0 takes a combinatorial approach to innovation and links it to evolutionary concepts like related variety and proximity. Its prime focus is on identifying combinations between knowledge bases and, to an increasing extent, combinations within knowledge bases, and assessing whether these combinations enhance innovative performance. As DKB 2.0 is still in an embryonic stage, we identify promising avenues for future research, inspired by evolutionary thinking.

1. Introduction

The differentiated knowledge base (DKB) literature has been introduced in the field of economic geography in the mid 2000s by Bjorn Asheim and colleagues at Lund University (Asheim and Gertler 2005). It had its roots in the Innovation Studies literature, and more in particular the literature on Regional Innovation Systems that drew attention to the collective nature of learning and innovation in regional contexts and their institutional underpinnings (Cooke 2001; Asheim and Coenen 2005, 2006). In its formative years, the DKB literature shed light on the nature of knowledge sharing and its geographical extent which were claimed to vary between analytical, synthetic and symbolic knowledge bases (Manniche 2012; Martin 2012). We argue that the DKB literature has started to shift more recently to a more dynamic and combinational approach, linking it partly to evolutionary concepts like related variety and proximity (Asheim et al. 2011; Mattes 2012; Strambach and Klement 2012; Grillitsch and Trippl 2014; Grillitsch et al. 2016; Ingstrup et al., 2017; Klement and Strambach 2017).

The objective of this paper is to sketch a concise history of the DKB literature, to outline and review critically the main contributions so far, and to set out research challenges. We explore how the literature on Evolutionary Economic Geography (EEG) (Boschma and Frenken 2006; Martin and Sunley 2006) has contributed to the further development of the DKB view in economic geography more recently. We make explicit how the EEG literature on variety, relatedness and proximity, has become more tightly linked to the DKB literature (Asheim et al. 2011). We argue there is potential in the DKB approach to explore combinatory potentials of knowledge bases, their impact on regional development, and their dynamics over time.

The paper is structured as follows. Section 2 discusses the formative years of the DKB approach (dubbed as DKB 1.0) and outlines its strengths and weaknesses. The weaknesses may partly be attributed to the lack of a combinatorial and dynamic approach to DKB. Section 3 briefly introduces concepts like related variety and proximity developed in EEG as these have become applied more and more in the most recent literature on DKB to addresses these weaknesses. Section 4 discusses shortly the main features of an emerging new generation in the DKB literature (termed DKB 2.0), and it explores where and how DKB 2.0 and EEG may fruitfully meet in future research. Section 5 draws conclusions.

2. DKB 1.0

Bjorn Asheim has been a key initiator and promoter of the DKB concept. In the 2000s, Bjorn formed a group of talented, young scholars at CIRCLE of Lund University (Lars Coenen, Markus Grillitsch, Hogni Hansen, Roman Martin, Jerker Moodysson, Jan Vang, Elena Zukauskaite) who all worked on the DKB concept. The knowledge base concept was first developed and applied in a Nordic research project starting in 2001, coordinated by Lars Coenen (Asheim et al. 2017). From the mid 2000s onwards, the first pioneering publications (Asheim and Gertler 2005; Asheim and Coenen 2005, 2006) emerged to underline that

processes of learning and innovation differ between industries because their underlying knowledge base differs. The DKB approach was presented as a critical response to conceptualizations of knowledge that had been grasped in terms of high-tech (R&D-intensive) versus low-tech (R&D-extensive) (OECD 1996), tacit versus codified knowledge (Gertler 2003), and Science and Technology (STI) modes of learning and innovation versus Doing, Using and Interacting (DUI) (Lundvall and Johnson 1994). The DKB literature proposed a distributed view on knowledge bases that had the ambition to go beyond and transcend these conventional distinctions (Jensen et al. 2007; Manniche 2012).

A key source of inspiration was Laestadius (1998) who associated categories of analytical and synthetic knowledge to the Artistotelian notions of 'episteme' and 'teche' (Asheim and Gertler 2005). The DKB literature developed a broader vision of knowledge bases and added a third category of symbolic knowledge (Asheim et al. 2007), linking it to the notion of 'art' (Martin 2012). According to Asheim and Coenen (2005), the proposed knowledge bases (also known as the SAS taxonomy) had some resemblance with the seminal taxonomy proposed by Pavitt (1984) in which industries with synthetic knowledge bases were associated with Pavitt's categories of supplier-dominated and production-intensive industries, while industries with analytical knowledge corresponded closely to Pavitt's science-based industries.

From the beginning, the ambition of the DKB approach was to link the knowledge bases to geography. At this experimental stage, all kinds of claims were developed, many of them ambitious. DKB studies tended to follow a comparative case study approach to provide empirical evidence for some of these claims. For instance, Asheim and Coenen (2005) linked 5 clusters in the Nordic countries to a particular knowledge base, Coenen et al. (2006) compared the (analytical science-based) pharmaceutical bioregion of Scania and the (more synthetic knowledge based) agro-food bioregion in Saskatoon in Canada, and Martin and Moodysson (2013) made a comparison between (science-based) life sciences, the (engineering-based) food industry and the (arts-based) new media in the Scania region in Sweden. Another study typical of a DKB approach (Martin 2013) described how innovation networks in European regions differed between analytical, synthetic and symbolic industries, in terms of their structure and geographical configuration, the type of actors holding a strategic position, and the type of relations between actors.

The first claim in the DKB literature aimed to link the various knowledge bases to different types of regional innovation systems (Asheim 1998; Cooke 1998). In their seminal contribution, Asheim and Coenen (2005) proposed that the innovation process in industries is shaped by their underlying specific knowledge base. In 'a territorially embedded regional innovation system', the innovation process would build primarily on synthetic knowledge and geographically localised inter-firm learning processes. This would stand in contrast to 'a regionalised national innovation system' in which few links exist between local industry and the scientific knowledge infrastructure, and innovation is mainly based on analytic knowledge. This is different from 'a networked regional innovation system' in which advanced technologies are developed that often combine analytic and synthetic knowledge.

A second and more testable set of claims in the DKB literature concerned the structure of knowledge networks, in particular the nature of knowledge sourcing and its geographical extent within each knowledge base (Coenen et al. 2006; Moodysson 2008; Martin and Moodysson 2011, 2013; Broekel and Boschma 2011; Plum and Hassink 2011; Aslesen and Freel 2012; Martin 2012, 2013; Grillitsch and Trippl 2014; Herstad et al. 2014; van Tuijl and Carvalho, 2014; van Tuijl et al. 2016). Studies showed that the importance of geographical proximity for learning and innovation differs between knowledge bases (Martin and Moodysson 2013): it turned out to be especially important for symbolic and, to a lesser extent, synthetic knowledge, while analytical knowledge creation relied the least on local sources of knowledge. In analytical industries, linkages with organizations providing research, higher education and skilled labour were crucial, while innovation in synthetic industries was more driven by collaboration with suppliers and customers, often on a national scale. In symbolic industries, non-formalised knowledge sources tended to be more important, and therefore, the local milieu was considered crucial. As Martin (2013) put it, "... networks in analytical industries are not much constrained by geographical distance: knowledge is exchanged in a highly selective manner between research units and scientists in globally configured epistemic communities. Synthetic industries source knowledge within nationally or regionally configured networks between suppliers and customers, and within communities of practice. Symbolic industries rely on knowledge that is culturally defined and highly context specific, resulting in localized networks that are temporary and flexible in nature" (p. 1418).

A third claim of the DKB literature concerns the geographical distribution of the different knowledge bases and, indirectly, the tendency of knowledge bases to concentrate geographically. Linking occupation data to knowledge bases, Martin (2012) analyzed whether Swedish regions differ in the way they are specialized in a particular knowledge base. The study showed that regions differed with respect to specialization in the three knowledge bases. Few regions were dominated by more than one knowledge base, and specialization in synthetic knowledge was found in many regions, in contrast to the other knowledge bases.

This is closely connected to another DKB claim that industries drawing on different knowledge bases would show different degrees of spatial concentration. The DKB literature has been quite explicit on this matter, as in Asheim and Gertler (2005): " …. the innovation process in industries based on analytical forms of knowledge is no less spatially concentrated than those forms of innovative economic activity based on synthetic types of knowledge. Indeed, if anything, there is compelling evidence to suggest that the former may exhibit an even higher degree of geographical concentration than the latter …" (p. 298). This was considered a remarkable outcome given the greater prominence of codified knowledge in the innovation process in analytical industries that was supposed to travel more easily over large geographical distances. To Asheim and Gertler (2005), the highly uneven geography of innovation in analytically based industries could be attributed to highly localized knowledge spillovers, a specialized labor market offering very specific job career opportunities available only in just a few places, and the crucial importance of locations with a high quality of life. This tendency of analytical knowledge to concentrate geographically seemed to be inconsistent with the earlier finding that geographical distance is of less importance in

analytical industries. To reconcile both findings, the DKB view argued there are only a few of these innovation hubs in analytical industries worldwide that are strongly connected through knowledge exchange, especially through the mobility of scientists.

A fourth claim of the DKB literature, closely connected to the previous claims, is that knowledge bases concentrate in particular regions. Asheim, Coenen and Vang (2007) argued that creative industries drawing on symbolic knowledge would rely heavily on local buzz, and for that reason, are more inclined to thrive in large diversified cities. Local buzz is considered of crucial importance because of the one-off project-nature of production and collaboration, and the reliance on knowing people with the right skills and talents in creative industries. Large cities with a great diversity of knowledge and people would offer such an attractive setting. This is different from industries based on synthetic knowledge in which face-to-face communication, focusing on technical problem solving, bi-lateral knowledge exchange and customized solutions, rather than buzz, is considered of major importance. According to Asheim, Coenen and Vang (2007), synthetic knowledge-based industries could thrive in any agglomeration or cluster, irrespective of the urban-rural dimension, as long as there is spatial proximity to users and suppliers. For industries oriented on analytical knowledge, exchange of scientific knowledge, rather than buzz, was considered crucial, which could be organized through epistemic communities at a global scale. This required locations with excellent global connections and local proximity to leading universities and research organizations.

However, it is fair to say that the DKB literature has not investigated systematically the preferences of knowledge bases for certain locations on the urban-rural dimension. With respect to locational preferences, Asheim and Hansen (2009) made some ambitious claims connecting the DKB view to the creative class concept (Florida 2002). They argued that the residential locational preferences of the creative class in terms of Florida's distinction between people climate and business climate would differ between the three knowledge bases. Symbolic knowledge would be more closely connected to people's climate, while synthetic knowledge would be more focused on business climate, and analytical knowledge base would be somewhat in between these two positions. To build up their case, they referred to other studies that indicated that engineers tend to live in suburbs because they would be more conservative and family oriented, while artists and designers would have a stronger preference for city centres where the buzz is, and scientists would often live and work in larger city regions because of job opportunities (business climate) but also for reasons related to the people's climate. Linking occupational categories to each of the three knowledge bases in Sweden, Asheim and Hansen (2009) concluded that "... in regions where synthetic knowledge bases dominate, business climate scores tend to be higher that people climate scores, and that a people climate tends to be of greater importance than a business climate in regions that are dominated by the analytical and, especially, the symbolic knowledge bases" (p. 439).

Particularly relevant for our discussion later is that the DKB literature has also made some strong (and often rather bold) claims about the role of path dependency in the different knowledge bases. Past economic structures would have different impacts on the evolution of the three types of knowledge bases and what types of innovations (radical versus incremental

innovations) were likely to predominate. Asheim and Hansen (2009) hypothesised that regions more reliant on synthetic knowledge would display a more path-dependent evolution of their regional economies, and would be less inclined to depart from established trajectories. Asheim and Coenen (2005) argued that regions relying on synthetic knowledge bases would mainly produce incremental innovations because the innovation process is primarily based on the application of existing knowledge or new combinations of knowledge. Because of that, such regions would normally not have an ability to change technological trajectories, which posed a serious threat to their long-term development. According to Asheim and Hansen (2009), this would stand in contrast to the analytical and symbolic knowledge bases which were expected to rely less on established structures in regions. These two knowledge bases were more attracted to diversity in urban environments, and therefore more responsive to develop radical innovations, especially in industries based on analytical knowledge (Asheim and Coenen 2006). However, such statements have never been put to any systematic empirical tests. Moreover, it raises many questions. For instance, would this imply that radical innovations can only be made within a synthetic knowledge base by linking to other knowledge bases? We discuss this further in Section 4 where we discuss the rise of a combinatorial approach in the DKB literature.

Another claim of the DKB literature from its start is that the institutional tissue underpinning the different knowledge bases is different. The DKB literature has connected to the national and regional innovation system literature (Freeman 1987; Cooke 1998, 2001), the varieties of capitalism (Hall and Soskice 2001) and the national business system literatures (Whitley 1999) to discuss what types of institutions are characteristic for each knowledge base (Asheim and Coenen 2006; Zukauskaite 2013; Zukauskaite and Moodysson 2016). So-called coordinated market economies would be characterized by regulatory and institutional frameworks at the national and regional level that favour close user-producer interactions embedded in network governance structures that are more common in industries that draw primarily from synthetic knowledge bases (Asheim and Coenen 2006). This strong emphasis on interactive learning processes would promote the geographical concentration of firms in these industries and requires a common social and institutional context (Asheim and Gertler 2005). In contrast, liberal market economies would focus less on strong, long-term systemic relationships. They provided an institutional framework that favours more industries with an analytical knowledge base in which university-industry links, scientific labour mobility, academic entrepreneurs, incubators, short-term research projects and venture capital are encouraged that promote innovations (Asheim and Coenen 2006). In this institutional framework, the DKB literature has been less explicit on the specific features of the institutional texture that would support industries drawing on symbolic knowledge. In both liberal and coordinated market economies, such project-oriented industries could thrive, but the nature of projects would differ, as the institutional setting in coordinated economies would facilitate more long-term projects and a higher stability in team membership.

Martin, Moodysson and Zukauskaite (2011) explored the implications for regional innovation policy when a DKB approach is applied (Martin and Trippl, 2014). They have done so by looking at regional policy support programs targeting three industries in the Scania region in

Sweden. Data collection was based on structured interviews with firm representatives and in-depth interviews with policy representatives. One of the conclusions was that policies aimed at regional networking between academia and industry would be more appropriate for analytical industries (but with not too much of an intra-regional focus), but to a lesser extent for synthetic and symbolic industries. They concluded that policy initiatives should be fine-tuned to the needs of firms that result from being active in different knowledge bases.

In sum, the first generation of the DKB literature shed light on the different nature of learning and innovation between activities that are strongly shaped by their underlying knowledge base. From its very start, the DKB view connected to geographical issues and developed a number of (sometimes rather ambitious) claims linking types of knowledge bases to all kinds of spatial phenomena like: (1) types of regional innovation systems; (2) the geographical extent of knowledge sourcing; (3) the degree of spatial concentration; (4) preferences for particular regions; (5) the role of path dependence in the evolution of regions; (6) institutional underpinning at national and regional scale; and (7) the nature of regional innovation policy.

Despite valuable insights, the DKB literature has also met critique (e.g. Manniche et al. 2016). The most fundamental one comes down to a tendency to ascribe knowledge bases to certain professions (e.g. Asheim and Hansen 2009), entire industries (e.g. Martin 2012) and particular regions (e.g. Asheim and Coenen 2005). This has been shown as highly problematic as activities in practice draw upon more than one knowledge base. The proponents of the DKB view acknowledged this problem from the very start, as, for instance, in Asheim and Gertler (2005): "… it makes sense to conceive of individual industrial sectors being arrayed along a continuum between purely analytical and synthetic industries, with many— such as the automotive industry—occupying an intermediate position along this spectrum" (p. 47). Having said that, their main interest remained focused, till very recently, on whether entities (occupations, industries, regions) are dominated by a certain knowledge base from which, subsequently, all previously mentioned claims are derived. We refer to this as DKB 1.0.

A second main critique on DKB 1.0 is its static approach to knowledge bases, and its poor understanding of the role of history. Broadly speaking, DKB 1.0 aimed to map the configuration of knowledge networks, being contingent on the dominant knowledge base in place (Manniche et al. 2016), and focused on knowledge bases as a given resource tied to specific industries and regions (Ingstrup et el. 2017). A third main critique is that some claims set out earlier were descriptive rather than explanatory (Manniche et al. 2016), and some claims (especially the most ambitious ones) have not been tested empirically in a systematic way (Herstad, Aslesen and Ebersberger 2014; Grillitsch, Martin and Srholec 2016).

In Section 4, we will argue DKB 1.0 is very different from recent developments in the DKB literature that take a combinatorial approach and incorporate evolutionary concepts like variety, relatedness and related variety (e.g. Asheim et al. 2011; Fitjar and Timmermans 2017). There is a clear shift of attention to a combinatorial approach in which organizations, industries and regions rely on combinations of different knowledge bases, and that is also what makes them more likely to prosper (Strambach and Klement 2012; Grillitsch and Trippl

2014; Tödtling and Grillitsch 2015; Grillitsch et al. 2016; Ingstrup et al., 2017). There is also a tendency to employ a wider range of mixed methods, including quantitative studies that allow for more systemic testing, as compared to the DKB 1.0 literature that clearly favored a comparative case study approach. We refer to this second generation of DKB studies as DKB 2.0. Here, we clearly depart from Manniche et al (2016) that refers to the emergence stage of the DKB view as 'Combinatorial Knowledge Base typology 1.0'. In these formative days, however, we argue that only lip service was paid to the relevance of combinations of knowledge bases, and that this was not investigated empirically.

As DKB 2.0 incorporates concepts of Evolutionary Economic Geography (EEG) to develop a more dynamic and combinatorial approach, we shortly introduce the EEG literature on variety, related variety and relatedness in Section 3. We will use that as input to outline some features of the emerging DKB 2.0 and to explore further links with EEG for future research.

3. EEG and relatedness

This section focuses briefly on notions of related variety and relatedness developed in EEG (Boschma and Frenken 2006). These notions basically explained how processes of knowledge creation and diffusion are subject to path dependency (Martin and Sunley 2006). These processes are perceived to be imperfect, as actors have no full access nor a perfect ability to respond to external information. Therefore, actors tend to search locally in cognitive terms (cognitive proximity) and geographical terms (geographical proximity), and are also more likely to exchange knowledge and collaborate in R&D with other actors in these same two dimensions. This makes that actors are more likely to be successful in terms of diversification when they build on related capabilities within the same organization (Breschi et al. 2003), when they are located in regions with related externalities (Frenken et al. 2007), and when they share related capabilities with agents in their networks (Boschma and Frenken 2010).

This connects closely to the Schumpeterian view of innovations as emerging from new combinations (Fleming 2001). This implies that variety within regions conditions the scope for innovation, following Jacobs (1969). EEG argues that many technologies, products, industries and professions cannot be meaningfully combined. New combinations often stem from related activities that share similar capabilities. On the one hand, relatedness refers to similarities between activities in the cognitive dimension, and thus opportunities for interactive learning. On the other hand, relatedness includes complementarities, that is, the need to bring together different activities and combine them to produce new knowledge and innovations (Breschi et al. 2003; Broekel and Brachert 2015).

Frenken et al. (2007) has argued that variety must be related in regions to produce knowledge spillovers and to generate combinations across activities. Frenken and Boschma (2007) applied the relatedness concept to regional diversification and branching. Hidalgo et al. (2007) constructed a product space in which related products are positioned in a network, and found strong and robust evidence that countries develop new export products related to

existing products. Neffke et al. (2011) found evidence of capabilities providing opportunities for diversification at the regional scale: regions were more likely to diversify into new industries related to existing local industries. Since then, a large body of studies has confirmed the importance of regional branching (see for an overview, Boschma 2017) in the case of new industries (e.g. Essletzbichler 2015), new technologies (e.g. Rigby 2015; Tanner 2016) and new professions (e.g. Muneepeerakul et al. 2013).

4. DKB 2.0 and EEG

This section explores where EEG meets the most recent DKB literature. We argue that the DKB literature has evolved recently in the direction of an evolutionary approach to knowledge bases, as it has addressed, at least to some extent, some of the critiques formulated in Section 2. We outline the essence of what we dub DKB 2.0, and we discuss how DKB 2.0 could be strengthened further, and in which directions promising research avenues lay ahead.

First of all, what DKB 1.0 has in common with the EEG literature on relatedness is a search for commonalities and differences between activities in terms of knowledge and innovation. The relatedness literature is interested in exploring which pieces of knowledge can and which cannot be effectively combined, as captured by concepts like relatedness, cognitive proximity and related variety (Frenken et al. 2007; Quatraro 2010, 2016). It focuses on which pieces of knowledge provide learning opportunities (similarity) and complementary resources (complementarity) (Breschi et al. 2003), and assesses which combinations of knowledge enhance spillovers, regional growth and regional diversification (Boschma 2017). This focus is different from DKB 1.0 that had an interest to describe more in detail what features of knowledge are characteristic for each knowledge base, and which industries could be grouped together in that respect. Despite the fact that DKB 1.0 drew attention to cross-sectoral knowledge linkages (e.g. Coenen et al. 2006), DKB 1.0 did not investigate whether industries that belonged to the same knowledge base provided similar and complementary resources for learning and innovation. In that sense, DKB 1.0 was a-combinatorial, as it was not primarily interested to examine combinations within each knowledge base or between knowledge bases, and their economic effects. In contrast, DKB 2.0 is combinatorial, as its prime focus is on combinations between knowledge bases and, to an increasing extent, combinations within knowledge bases, and whether these provide learning opportunities and enhance the innovative performance of firms, industries and regions.

The most simple combinatory approach in DKB 2.0 has been the identification of mixtures of the three knowledge bases leading to novel combinations and innovation (Moodysson et al. 2008; Manniche 2012; Hoyssa 2014). A classic example is the evolution of the automobile industry which has been traditionally been dominated by synthetic knowledge (engineering) and symbolic knowledge (design of cars), but is shifting increasingly to analytical knowledge, as illustrated by computer-led mechanization (robotics) and the development of the self-driving car (sensor-based safety systems, communication systems, high-resolution mapping). This latter development has led to the belief that Silicon Valley might take over and dominate

the future car industry. A typical study following such a combinatory approach is Martin and Trippl (2015) who observed that the ICT cluster in Scania in Sweden was built on the combination of analytical, synthetic and symbolic knowledge bases in the region. Grillitsch, Martin and Srholec (2016) did the first systematic study to explore which combinations of knowledge bases within the firm and the region are most conducive to innovative performance of firms. One of the main conclusions was that firms tended to benefit most from locations with a mixture of all three knowledge bases.

However, DKB 2.0 provides a much richer exploration of more possible knowledge combinations than just between the three pre-defined knowledge bases (Hoyssa 2014). Here, there is a clear link to be made with the evolutionary literature on variety, relatedness and related variety (Martin 2012) that could take up a range of questions like: does related variety within each knowledge base have an impact on knowledge creation and innovation, can unrelated variety be associated with combinations between knowledge bases, does related variety transcend boundaries of knowledge bases, and when the latter happens, would that have a positive economic effect, as it would enable crossovers between related activities in different knowledge bases? This could also bring a further sharpening of the recombinatory approach (Strambach and Klement 2012) in which cumulative knowledge is often simply equated with knowledge creation within one knowledge base while recombinatory knowledge is associated with combinations of different knowledge bases. This opens up a whole new research agenda for DKB 2.0 to determine how much related and unrelated variety exists within each knowledge base, which combinations are made between both related and unrelated pieces of knowledge within and between knowledge bases, and what the economic effects of such combinations would be in terms of innovation, employment and productivity.

A number of recent papers are starting to address these questions. Grillitsch, Martin and Srholec (2016) did a study on the impact of variety within each knowledge base on the innovative performance of firms and regions. Their findings indicate that variety within each knowledge base was only positive for analytical knowledge, but not for synthetic and symbolic knowledge. Other papers are starting to explore the importance and economic significance of (related) variety within one knowledge base. In doing so, they deepen our understanding of the particular composition of knowledge in a knowledge base which was clearly not the focus of DKB 1.0. Doing a study on the symbolic knowledge base, Lazzeretti et al. (2017) investigated the whole sector of all creative industries, and found that related variety within creative industries had a positive effect on employment growth. Klement and Strambach (2017) took an explicit combinatory approach on the symbolic knowledge base to examine the role of the various variety dimensions for innovation in one particular creative industry (the music sector) in urban regions in North America and Europe. Based on information of users taken from social media platforms, they found that neither variety nor specialization in music types in an urban region will promote innovation in the music industry. What mattered for the combination of new symbolic knowledge (but not so much for its creation) was a certain degree of relatedness between combinable elements locally available in this knowledge base, as proxied by ranges of related music genres.

Instead of looking at (related) variety within one knowledge base, Fitjar and Timmermans (2017) explored the extent to which related variety crosses boundaries between the three knowledge bases. Their study on Norway is an important one, as it shows that industries are related to other industries in regions both within the same KB and across different KB, They did not, however, assess the economic effects of relatedness within and across KB. Sedita et al. (2017) demonstrated in a recent study on Italy that the positive effect of related variety on employment growth is stronger in regions with a large share of synthetic and symbolic (but not analytical) KB industries. In addition, they found an interaction effect between related variety and the share of symbolic KB industries, suggesting that symbolic industries in particular are dependent on the regional presence of related industries.

What is still missing in the DKB 2.0 literature here is an explicit focus on regional diversification. A combined approach on (related) variety and knowledge bases will provide new insights to the new path development literature. Fitjar and Timmermans (2017) has been the first to develop hypotheses in this direction but did not (yet) test for those. As they put it, "regions with relatedness ties mainly across industries with the same knowledge base could still suffer from lock-in and limited opportunities for new path development, while other regions with less relatedness can nonetheless manage to link industries with different knowledge bases. Conversely, …. the region does not necessarily benefit from having a balanced mix of different knowledge bases if these are not related" (Fitjar and Timmermans 2017, p. 17). Following this line of thought, one could think of assessing potentials of regions to develop new paths alongside the two dimensions of relatedness and KB, comparing regions in terms of: (1) related variety within the same KB; (2) related variety across KB; (3) unrelated variety within the same KB; (4) unrelated variety across KB.

Second, where DKB 2.0 and the evolutionary approach come together is a shared research interest in dynamic processes of change and transformation. As mentioned before, DKB 1.0 was static, as its main focus was on the configuration of knowledge networks, being contingent on the knowledge base in place (Manniche et al. 2016). As explained in Section 2, DKB 1.0 had a very poor understanding of the role of history and path dependence. DKB 2.0 is clearly challenging this static view of DKB 1.0 and its focus on knowledge bases as a given resource tied to specific industries and regions (Ingstrup et el. 2017).

Broadly speaking, this dynamic combinatorial perspective in DKB 2.0 has been taken on board in two types of studies so far. The first type of studies focuses on innovation projects or innovation events (Strambach and Klement 2012; Manniche et al. 2016; Davids and Frenken 2017). For instance, Moodysson, Coenen and Asheim (2008) analyzed innovation projects in the Medicon Valley life-science cluster in Sweden and showed that these projects consisted of mixtures of analytical and synthetic modes of knowledge creation, but that different stages of innovation also required a different dominant knowledge base, leading to dynamics in the knowledge network relations. The second type studies builds on the cluster life cycle literature (Menzel and Fornahl 2010), showing that the reliance of clusters on one or two dominant knowledge bases shifts over time (Martin 2012). Martin and Trippl (2015) looked at the evolution of the ICT cluster in Scania and found that the emergence of this Swedish

cluster in the 1980s was enabled by a strong analytical and synthetic knowledge base in the region, followed by a new growth trajectory that required combination with new symbolic knowledge in media and design. Ingstrup et al. (2017) showed in the case of a design cluster in Denmark that it evolved from a cluster with a dominant synthetic knowledge base in the 1860s-1940s, a symbolic knowledge base in the 1950s-1990s to a cluster adopting an analytical knowledge base in the 2000s. Isaksen and Trippl (2016) is another kind of study in this context that explored how new analytical or new synthetic path of developments unfolded in peripheral regions, which they perceive as exogenous events of new path development.

What still need to be developed further in DKB 2.0 is a stronger conceptualization of the role of history. These studies take on board the role of dynamics and changing combinations of KB over time, and in that sense they clearly belong to DKB 2.0. However, some of these studies still stick to associate a particular period of time with a dominant knowledge base, and in that sense, they are still part of the first generation of DKB 1.0. Relevant questions that require further attention in DKB 2.0 to make it a truly historical approach are, for instance: is each shift implying a radical break with the past, how did clusters manage to evolve from one knowledge base to another, and did clusters build on pre-existing structures (variety, relatedness, knowledge bases, institutions, et cetera) to make these shifts? Such a take on DKB would bring it more closely to an evolutionary approach on regional diversification that is interested in the role of path dependence in particular spatial settings, and the role of pre-existing structures in shaping new growth paths in regions.

Third, a promising research avenue is to link more tightly the EEG literature on proximity to the KB literature. Broadly speaking, DKB 1.0 primarily focused on the role of geographical proximity (and to some extent institutional proximity) which was perceived to vary between the three knowledge types. In EEG, the related variety and relatedness concepts focused on the role of cognitive and geographical proximity in processes of learning, innovation and diversification. In addition, EEG has focused on other types of proximity that enable the formation of new combinations (Boschma and Frenken 2010; Hansen 2014). Because actors have different capabilities, they prefer to interact and collaborate not only with those that have similar knowledge (cognitive proximity) and are located in the same place (geographical proximity), but also with whom they share norms and values (institutional proximity), social ties (social proximity) or organizational boundaries (organizational proximity).

Mattes (2012) was the first paper that connected the proximity framework to the KB literature, claiming that the various types of proximity are important to a greater or lesser extent depending on the underlying type of knowledge base. In that sense, it can be seen as an extension of DKB 1.0 including more proximity dimensions than just geographical proximity, but it also takes a combinatory approach typical for DKB 2.0, although still in a static way. Davids and Frenken (2017) adopted a proximity approach to KB, but added a dynamic perspective to it, looking at different stages of new product development in science-based industries. They distinguished between three stages of new product development (research, development and marketing), each of which is associated with a prevailing knowledge base that is used and produced (analytical, synthetic and symbolic, respectively). The paper claims

this has implications for the relative importance of proximity types over time, as the development process of new products passes from one stage to the next.

Finally, we think DKB 2.0 could be more explicit on the role of institutions at the macro and micro level, despite the fact that DKB 1.0 took on board the role of institutions, and more recent papers account for the role of institutional proximity (Mattes 2012; Davids and Frenken 2017). First of all, the DKB literature has been heavily influenced by the institutional system literature but empirical studies still have to make more explicit how institutions are linked to particular knowledge bases. For instance, does the organizational and geographical structure of each knowledge base look the same no matter where, or do these aspects of the same knowledge base look very differently in different institutional contexts? The Varieties of Capitalism literature may be a source of inspiration here (Hall and Soskice 2001; Boschma and Capone 2015), but also the literature on social capital. To my knowledge, this has not been tested yet. Second, there is a need to make the institutional perspective more dynamic and more in line with DKB 2.0. One potential way to go forward is to explore how the expanding literature on institutional entrepreneurship (Battilana et al. 2009) can be connected to the KB approach. For instance, could one expect institutional entrepreneurship to be more important in one of the three knowledge bases, and what role are they expected to play in making new combinations within and between different knowledge bases?

5. Conclusions

This objective of this chapter was to sketch a short history of the DKB literature that has been initiated and pioneered by Bjorn Asheim and a group of young scholars at Lund University since the early 2000s. We proposed to split the DKB literature in two parts: (1) DKB 1.0 during its formative years; and (2) DKB 2.0 that is still experimental and emerging.

The first generation labelled as DKB 1.0 focused on the nature of learning and innovation within activities (industries, regions) that is shaped by their underlying knowledge base. DKB 1.0 described what features of knowledge are characteristic for each knowledge base, and which industries have those in common. DKB 1.0 connected the three KB's to many geographical phenomena, such as how each knowledge base affects the spatial extent of knowledge sourcing. We summarized these in seven claims. DKB 1.0 has been criticized for ascribing knowledge bases to specific professions, industries and regions, as, in reality, these tend to draw upon more than one knowledge base. DKB 1.0 was not primarily interested in studying combinations within each knowledge base or combinations between knowledge bases, and their economic effects. Moreover, it developed a static view on knowledge bases, merely mapping their knowledge networks, and it had a very poor understanding of history.

We argued that a second generation of the KB literature, dubbed as DKB 2.0, has emerged in more recent years, which is also more closely connected to an evolutionary approach in economic geography. DKB 2.0 takes a combinatorial approach to innovation and links it to evolutionary concepts like variety, relatedness and related variety. DKB 2.0 is combinatorial, as its prime focus is on identifying combinations between knowledge bases and, to an

increasing extent, combinations within knowledge bases, and assessing whether these various combinations provide learning opportunities and enhance the innovative performance of firms, industries and regions. DKB 2.0 employs a wider range of mixed methods, including quantitative studies that allow for more systemic testing, as compared to DKB 1.0 that favored a comparative case study approach. Studies in DKB 2.0 have started to investigate which combinations between knowledge bases are most productive in economic and innovative terms. Using concepts like variety, relatedness and related variety, studies make an attempt to assess which combinations within and between knowledge bases enhance the performance of firms, industries and regions. Some of these studies focus on the importance of related variety within one knowledge base and the extent to which related variety transcends the boundaries between knowledge bases. This promises a much richer exploration of possible knowledge combinations than just between the three pre-defined knowledge bases.

Because DKB 2.0 is still unfolding, we identified a number of promising research avenues inspired by evolutionary thinking. Clearly, what is still found missing in DKB 2.0 is an explicit focus on regional diversification. We believe a combined approach on (related) variety and knowledge bases is likely to generate new insights to the literature on new path development. Secondly, DKB 2.0 is also meant to be dynamic. Studies are starting to show, for instance, that the reliance of firms or clusters on dominant knowledge bases may shift over time, possibly leading to dynamics in the structure of their knowledge networks. However, this literature is still embryonic, and lacks a strong conceptualization of history, as it has not yet taken up the question of whether pre-existing structures (variety, relatedness, knowledge bases, institutions, et cetera) enable them to make these shifts and develop new growth paths in regions. Thirdly, another promising research avenue is to link more tightly the proximity literature to the study of KB. Studies have started to make strong claims about the varying importance of forms of proximity depending on the underlying type of knowledge bases, but empirical studies are lacking so far. Finally, we propose to study the role of institutions in knowledge base dynamics more systematically at both the macro and micro level.

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