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PERSISTENCE AND EVOLUTION IN REGIONAL LEARNING PARADIGMS AND TRAJECTORIES. TOWARDS A DYNAMIC THEORY OF TERRITORIAL PATTERNS OF INNOVATION

R. CAPELLO, C. LENZI

Roberta Capello - Department of Architecture, Built Environment and Construction Engineering (ABC), Politecnico di Milano, Piazza Leonardo da Vinci 32, 20133 Milan, Italy. E-mail address is: roberta.capello@polimi.it. Telephone number is: +39 02 2399 2751.

Camilla Lenzi (corresponding author) - Department of Architecture, Built Environment and Construction Engineering (ABC), Politecnico di Milano, Piazza Leonardo da Vinci 32, 20133, Milan Italy. E-mail address is: camilla.lenzi@polimi.it. Telephone number is: +39 02 2399 2749.

Abstract

Based on the conceptual notion and the empirical verification that innovation follows differentiated spatial patterns, the paper analyses the conditions that enable regions to change their innovative patterns. Consistently with the evolutionary theory, these changes are interpreted as path-dependent processes characterized by trajectories and paradigms, understood as learning processes. Multiple sources of persistent path-dependence in a given learning trajectory and paradigm are identified. They pertain to both the technological and cognitive domains, as well as to the functional, institutional, social and relation systems prevailing in a region. To mitigate the risk of bottle-necks and long-run structural inefficiencies due to persistence, regions can initiate new paths by shifting to more advanced learning trajectories and paradigms. How, when, and why this shift is possible is the main topic of this paper, which finds an explanation in the evolutionary path-creation strategies that it highlights. Finally discussed are some possible alternative evolutions which require a dynamic matching of the functional and relation systems that characterize a regional learning paradigm.

JEL codes: O11, R11
Keywords: regional innovation pattern, regional learning paradigm, regional learning trajectory, persistent path-dependence, evolutionary path-creation strategies.

1. Introduction

This work starts from the notion and the empirical observation that innovation occurs with variants in space, i.e. that innovation follows differentiated spatial patterns stemming from the heterogeneous availability of a local knowledge base (cognitive inputs) and context conditions for knowledge creation and acquisition, the combination of which gives rise to what has been called a regional pattern of innovation (Capello, 2013).

This framework has been now conceptually accepted and empirically proved; what still has to be done is explain the determinants of the structural dynamics of such regional innovation modes. In other words, how, when, and why a region is able to shift from one innovation pattern to another requires further investigation, such as that presented in this paper.

The explanations of regional dynamics in innovation patterns have a robust conceptual background in evolutionary economics (Nelson and Winter, 1977; Dosi, 1982; David, 2007), evolutionary regional economics (Aydalot, 1986; Camagni, 1991; Calafati, 2009), and evolutionary economic geography (Martin and Sunaly, 2006; Martin, 2010; Simmie, 2011). As discussed in Section 2, regional innovation patterns are identified on the basis of different modes of performing the various phases of the innovation process (knowledge – invention – innovation) according to the presence/absence of certain context conditions. The evolution towards a new regional pattern of innovation is driven by an evolution of both the technological/cognitive dimension and the local context conditions. For this reason, the conceptual approach of this paper takes account of both evolutionary economic thought (Dosi, 1982; David 2007) and its spatial perspective (Martin, 2012,); and it puts the evolution of the context conditions at the centre of the regional innovation paradigmatic shifts (Aydalot, 1986; Camagni, 1991; Calafati, 2009; Camagni, 2015).

The merger between evolutionary economics, on the one hand, and evolutionary economic geography on the other, requires an approach reconciling persistence and creativity, continuity and interruption. On the one hand, in fact, innovation entails change and evolution; on the other, innovation manifests itself according to ordered (but dynamic) patterns. As more recently discussed by David (2007) and, from a spatial perspective, by Martin (2012), the essentials of this dilemma rely on the conceptualization of continuity in change, or, put in extreme terms, of the dichotomy between continuity and change. The famous paradox of 'the ship of Theseus' has been invoked by both authors in order better to convey the fundamental intuition at the basis of this (apparent) contrast. Over the course of its long voyage, this mythical vessel experienced many, incremental, changes; "each timber, plank, mast had to be replaced, one-by-one, so that when it returned not a single piece of the original structure remained. Nonetheless, the 'ship' had survived unchanged" (David, 2007, p. 101).

Almost by definition, in fact, the debate on the dilemma between continuity and change (and change within continuity or "rupture/filiation" *à la* Aydalot) lies at the heart of any reflection on economic evolution and innovation, and it has recently achieved new momentum in the regional economics and economic geography literature as well (Henning et al., 2013). However, especially as far as local settings are concerned, this discussion "is by no means 'done and dusted' or settled" (Martin, 2012, p. 1989).

This paper once more takes up the challenge of offering a reconciliatory perspective on this issue. Its aim is to make a conceptual contribution to this line of inquiry by endeavouring to advance the understanding and interpretation of the structural dynamics that enable regions to transform, adapt, and evolve their innovation patterns over time.

The remainder of the paper is organised as follows. The following section presents in more detail the conceptualization of innovation in space, i.e. the regional innovation patterns framework. Then, by building on key theoretical insights from evolutionary economics, evolutionary regional economics and evolutionary economic geography, and by linking to the ongoing debate in evolutionary economic geography on the nature, sources, characteristics of path-dependence in regional development, it elaborates on why the different innovation patterns can be conceived as learning paradigms and trajectories. Moreover, the paper argues that multiple sources and forms of path-dependence affect both regional learning paradigms and trajectories, and it emphasizes the advantages of persistence in a given learning paradigm and trajectory (Section 4). However, changes, though unlikely and rare, are necessary to avoid structural inefficiencies in the long run because also persistence may have a downside and imply possible bottle-necks. To mitigate this risk, regions can seek to initiate and create new paths by changing their current learning trajectory and paradigm, though still subject to evolutionary path-dependence (Section 5). Then, the paper suggests and comments on the possible and most suitable alternative evolutionary pathways towards a new learning paradigm (Section 6). Concluding remarks and policy suggestions are finally put forward (Section 7).

2. Regional patterns of innovation

Innovation may happen by following differentiated spatial ‘patterns’ linked to differentiated context conditions (particularly urban structure, accessibility, general development level, specialisation) and cognitive inputs (education, skills, R&D, entrepreneurship). The different components of the linear model of innovation – knowledge → invention → innovation – are broken down, separated, differently allocated in time and space and finally recomposed following a relational logic of inter-regional cooperation and exchange (Camagni, 2015). In this perspective, therefore, regional patterns of innovation represent different variants of a ‘spatially diversified, multiple-solution model of innovation’ (Capello, 2013, p. 137), a specific linearization, or a partial block-linearization, of an innovation process where feedbacks, spatial interconnections and non-linearities play a prominent role.

Conceptually speaking, each regional pattern of innovation represents a mode of knowledge creation and acquisition, and a type of learning process based on interregional cooperation among knowledge creators and on specific local preconditions (context conditions). Because each territorial pattern of innovation is the result of a combination of innovation phases on the basis of the presence/absence of territorial preconditions allowing a certain phase to take place, these context (structural) conditions become crucial and integral parts of each regional pattern of innovation, and its way of learning, and they characterize this concept as a structural one.

A previous study (Capello, 2013) has proposed three main 'archetypal' regional innovation patterns:

a) *a science-based pattern*, where preconditions for knowledge creation (e.g. the presence of universities, research centres, highly advanced human capital) and for converting knowledge into innovation (e.g., the presence of entrepreneurial spirit and creativity), guarantee the transformation of knowledge into innovation. This pattern is expected to be prominent in regions hosting highly innovative firms belonging to high added value and technology-intensive sectors and, given the complex nature of knowledge creation nowadays, tightly interrelated with other regions by international scientific networks. From the conceptual point of view, this advanced pattern is the one considered by most of the literature dealing with knowledge and innovation creation and diffusion (Malecki, 1980, Saxenian, 1994; Audretsch and Feldman, 1996; Mack, 2014);
b) *a creative application pattern* characterized by the presence of creative (small and medium) enterprises, mainly belonging to traditional or medium-tech sectors, curious enough to look for knowledge outside the region – given the scarcity of local knowledge – and creative enough to apply external knowledge to local innovation needs (Foray, 2009; EC, 2010; Licht, 2009). Knowledge providers supporting the innovative activities of local firms are mostly located outside the region, and knowledge exchanges are nourished more by cognitive (industrial) proximity (i.e. shared cognitive maps) than by belonging to the same local community;
c) *an imitative innovation pattern*, where firms in traditional sectors, or branches of multinational enterprises, in different sectors, seeking low labour-cost areas to locate their lower added-value functions, base their innovation capacity on imitation of already-existing innovations, albeit with differing degrees of adaptation. In several cases, regions reflecting this pattern are likely to be characterized by a higher presence of firms with few learning and innovative activities. This pattern is based on the findings of the literature dealing with innovation diffusion (Hägerstrand, 1967; Pavlínek 2002 and 2004; Varga and Schalk 2004).

Regional innovation patterns are not simply useful conceptual constructs; they also have empirical importance because they have been recently identified in European regions (Capello and Lenzi, 2013, 2015).[1] Interestingly, the empirical results show a larger variety of possible innovation patterns than conceptually envisaged, but they are still consistent with the theoretical notions presented above. Firstly, patterns vary in terms of the relational structure supporting knowledge creation and acquisition. In the science-based patterns, (scientific) knowledge is exchanged on a bilateral basis across regions; in the application-based patterns, instead, external relations are essential to access locally unavailable (formal or informal) knowledge; whilst in the imitation patterns external knowledge is acquired as embedded in innovations developed elsewhere and then replicated and, possibly, adapted locally. Moreover, within each theoretical pattern characterized by a specific relational structure, two distinct processes of knowledge accumulation and knowledge acquisition channels for innovation discovery can be identified, depending on different cognitive

[1] For further details on the variables used in the cluster analysis implemented to detect innovation patterns in European regions and the variables representing the key territorial features of the different groups of regions see Capello and Lenzi (2013).

bases. In this respect, two clusters can be associated with the first conceptual pattern, but they differ in terms of basic vs. applied scientific knowledge base; two clusters can be associated with the second pattern, but they differ in terms of formal vs. informal knowledge; two clusters can be associated with the third pattern, but they differ in terms of an active vs. passive attitude towards innovation. In short:

- the science-based pattern is divided between a basic and an applied science-based pattern;
- the creative application pattern is divided between a formal and an informal knowledge application-based pattern;
- the imitative innovation pattern is divided between an active an a passive imitation pattern.

Regional innovation patterns are inherently shaped by specific learning processes and structural dynamics. In order to determine the conditions under which a region is able to evolve its way of learning, key theoretical insights from evolutionary economics, evolutionary regional economics, and evolutionary economic geography can be of help. For this purpose, the next section elaborates on why and how regional innovation patterns can be interpreted as learning paradigms.

3. Regional innovation patterns and regional learning paradigms and trajectories

3.1. Learning paradigms and trajectories: the role of territory

Since the early contributions of evolutionary economics (Dosi, 1988; Nelson and Winter 1977, 1982; Rosenberg, 1976, 1982), learning has always been considered to be at the origins of innovations and improvements; and it has been viewed as a problem-solving process of incremental knowledge development and accumulation based on routines and coordinated actions among individuals. Learning thus consists of interaction and knowledge transfer among individuals, and it is intrinsically cumulative and dynamic: a process "developed on an element of continuity, on which knowledge rests and cumulates as time goes by" (Capello, 1999, p. 355). Hence, regional innovation patterns and learning processes are closely intertwined in two main respects. First, regional innovation patterns have a distinctive relational and interactive character (as discussed in Section 2); second, they are conceived and defined as alternative knowledge accumulation and creation processes based on different types of context conditions. Both arguments, therefore, clearly fit with an interpretation of regional innovation patterns as learning processes.

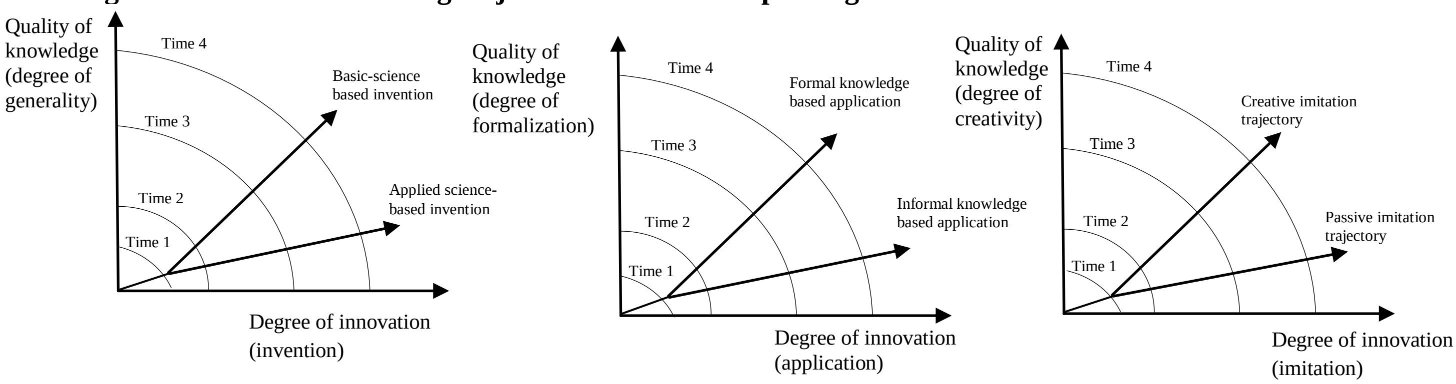
Specifically, this paper conceives regional patterns of innovation as *regional learning paradigms*, since they are defined by rules – shared by the entire local community of technological, institutional and economic actors – on how the functional, institutional, social and relational systems shape the process upon which one looks for process and product innovation, and therefore identify the way in which regions acquire new knowledge and develop a learning process. In short, regional learning paradigms represent models of innovation and knowledge accumulation stemming from the functional, institutional, social and relational characteristics of territories.

Accordingly, learning paradigms can be associated with the three 'archetypal' conceptual regional patterns of innovation outlined above, each entailing different modes of innovative search, and each

based on specific knowledge accumulation processes, on the one hand, and the context conditions supporting them on the other. The science-based learning paradigm is characterised by local knowledge, by the presence of knowledge creation functions and by an interregional cooperation spirit; the application-based learning paradigm is characterised by local knowledge and by a degree of entrepreneurial spirit and interregional cooperation; lastly, the imitative innovation learning paradigm is characterised by an imitative type of innovation, and by the capacity of the local area to attract innovative functions and activities in general.

Within each learning paradigm, alternative *learning trajectories* (modes of innovative search) can be identified. And they can be defined as alternative options in the performance space of each paradigm identified by the intensity of innovation (imitation, application or invention) and by the quality of knowledge (Figure 1). Within the science-based learning paradigm, two alternative learning trajectories emerge according to the degree of knowledge generality, basic scientific knowledge vs. applied scientific knowledge (Figure 1a). Within the creative application learning paradigm, two alternative learning trajectories are empirically distinguished according to different channels of knowledge acquisition, one based on formal external knowledge and the other on informal external knowledge (Figure 1b). And, finally, within the imitation learning paradigm, two alternative learning trajectories are envisaged, one based on a passive attitude, the other on an active attitude towards imitation (Figure 1c). Within each paradigm, as time passes, a regional system can increase the intensity of imitation / application / invention along a trajectory which does not imply an increase in the quality of knowledge.

Figure 1. Alternative learning trajectories within each paradigm



a) Science-based learning paradigm b) Application-based learning paradigm c) Imitative learning paradigm

Source: Authors' elaboration

The definition of trajectories and paradigms shares quite clear resemblances with, and admittedly is inspired by, Dosi's (1982) notions of technological paradigms and trajectories. Quite similarly, in fact, regional learning trajectories and paradigms are meant to explain 'patterned', 'ordered' innovation and change or, in the words of Dosi (1982, p. 152), "the pattern of 'normal' problem solving activity (i.e. 'progress')", i.e. the structural (and persistent) characteristics at the basis of innovation and change. The very nature of the underlying learning processes, in fact, can account for the relatively ordered and cumulative, in short path-dependent, nature of learning trajectories and paradigms. In this respect, both sets of concepts represent structural theoretical constructs.

Notwithstanding this basic (though important) similarity, the concepts of regional learning paradigm have important differences with respect to that of a technological paradigm. Consistently with earlier studies in evolutionary regional economics (Aydalot, 1986; Camagni, 1991; Calafati, 2009), the concepts of regional learning paradigms allow a step further to be taken with respect to the previous evolutionary economic perspective by separating out the functional, institutional, social, and relational elements that govern learning processes but are mixed up in the interpretation of evolutionary economic theory,[2] and by emphasizing the distinctive and active role played by the local context in learning processes (Capello, 1999; Capello and Faggian, 2005). In fact, regional learning paradigms share the idea that a territory is a system of localized competences and skills, socio-cultural relationships, values and representations that shape and condition the way in which regions learn and innovate. The interpretation of the characteristics and role of space applied in this definition of regional innovation paradigm differs from that elaborated and proposed in evolutionary economics. The latter simply emphasises the importance of Marshallian specialization externalities generated by the interaction and interdependence of co-localized firms, as well as the complementarities and interrelatedness arising in local labour and financial markets, in relationships with suppliers and customers, which reduce transaction and information costs as distance decreases (Dosi, 1982; Antonelli, 1994). In our approach, on the contrary, the territory participates in the knowledge-learning processes through codes, symbols, behavioural habits and competencies that are rooted in the local society, support local relationships, and represent the fuel of dynamic collective learning processes as well as the relational thickness which generates casual contacts conducive to new knowledge creation in a collective way (Camagni, 1999; Cusinato and Philippopoulos-Mihalopoulos, 2015). Hence, the attention shifts from technological space to socioeconomic and relational space, beyond a pure and simplistic geographic dimension. In this perspective, technical change and innovation are localized with reference to the socioeconomic and relational space in which they are rooted and from which they spring, rather than with reference to pure technological space. Because learning trajectories are embedded in specific paradigms, they also show this territorial dimension with respect to technological trajectories as generally conceived in evolutionary economics.

The role of the territorial conditions in shaping a learning paradigm has important consequences on the nature of a learning paradigm. With respect to a "technological paradigm" identified by technological and institutional rules governing the world economy in a period of time, a "learning paradigm" is identified by socioeconomic rules governing specific regional systems; in this sense, alternative regional learning paradigms co-exist in a certain period of time in different local realities, and none of them governs the entire world. But this also signifies that a paradigmatic jump assumes a relative connotation, since it means a localized novelty in the model of innovation and of knowledge accumulation *with respect to the past*, not with respect to a dominant paradigm present worldwide (Camagni, 2015).

In a structural concept like a learning paradigm, therefore, the context conditions play a fundamental role, and their evolutionary paths are components inherent to any dynamic and process of change. Adaptation and modification of the existing functional, institutional, social, and relational structures at the basis of local learning processes are the key driving forces behind a

[2] For an example on this specific point see Dosi (1982, p. 155) and Dosi and Orsenigo (1988, pp.19-20).

reorientation, transformation, or if not, upgrading of present learning and innovation modes. Indeed, jumping to a more advanced paradigm requires not simply changes in the cognitive and technological domain (i.e. of the learning trajectory) but also changes in a region's functional, institutional, social, and relational structures.[3] In this respect, regional learning trajectories and paradigms can be useful notions with which not only to capture and describe structural characteristics of regional innovation but also to understand their dynamics.

However, the explanation of such evolution is not simple, since it requires interpretation of the laws of dynamics of structural systems and calls for an effort to develop a reconciliatory perspective on the above-mentioned dilemma between continuity and persistence, on the one hand, and change and evolution on the other.

3.2. Persistence and evolution in learning trajectories and paradigms

At a certain moment in time (e.g. time 1 in Figure 1), the conditions enabling the shift to another trajectory may emerge, giving rise to an alternative innovative path characterised by another property of the innovation learning paradigm which was relatively less prominent in the previous trajectory. How, when, and why these conditions emerge can be explained with the help of evolutionary economic theory.

The evolutionary economic theory interprets innovation and change as path-dependent processes characterized by cumulative (learning) trajectories and paradigms because persistence in a given path and pattern can provide multiple advantages. The tendency to persistence has been deeply and richly explored and discussed in evolutionary economics, as originally highlighted by David (1985, 1994) and Arthur (1989, 1994). In this perspective, path-dependence is conceived as a legacy from the past,[4] and it accounts, generally, for a system's persistence in its structural characteristics, and more specifically, for the cumulative, incremental, ordered, patterned and coordinated features of innovation phenomena. The risk and uncertainty associated with innovation lead to behavioral routines of agents that prefer to follow well-defined technological paths exploiting economies of scale associated with incremental innovation. Moreover, bounded rationality characterizes economic agents that limit risks through routinized choices and cumulative self-reinforcing decision-making processes (Dosi, 1982, 1988; Nelson and Winter, 1982). Transferring this argument to the present context, path-dependence can account for the persistence of existing innovation patterns, and can thus be termed 'persistent path-dependence'.

By favouring continuity, persistent path-dependence may condition, if not hinder, the capacity to embrace change. Yet, in the long run, persistence and continuity can have a downside and engender bottle-necks and inefficiencies that make relatively radical, though unlikely and rare, changes necessary.

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[3] In other words, changes in a learning trajectory do not automatically lead to a change of paradigm unless they are matched by changes in a region's functional, institutional, social, and relational structures.

[4] In the literature, in general, path-dependence refers to complex processes unable to shake themselves free of their history (David, 2001).

Here long-term structural inefficiency should be understood in relative, strategic, and future-oriented terms (Sydow et al., 2009) and therefore not with respect to some best practices or more efficient alternatives realised elsewhere, but rather with respect to changed internal or external circumstances requiring new solutions to prevent a lock-in outcome. In fact, 'major discontinuities and revolutions in the existing scientific and techno-economic paradigm, increasingly pushed from advances in fundamental sciences and the (related) general purpose technologies' (Dosi, 1988, p.228), may be disruptive, make existing innovative search modes and learning processes inadequate, and require transformations within and of the learning trajectory and/or paradigm (Perez, 2010).

Importantly, the presence of multiple forms and sources of persistent path-dependence (Martin, 2010; Henning et al., 2013) not only makes transformations rare and obstructed by substantial barriers; it also conditions and sets the boundaries of the direction and the alternative options in which change can be gradually channelled, as similarly discussed for technological trajectories by Dosi (1982), and more recently in a spatial perspective by Martin and Sunley (2006), Martin (2010), Simmie (2012) and Henning et al. (2013).[5] In fact, as recent contributions in evolutionary economic geography suggest, path-dependence must be considered an enabling rather than constraining process focused not simply on continuity and eventual inertia but also on evolution, change, and new developmental path-creation. As such, it has a positive connotation and is the outcome of (limitedly) rational behaviors of socioeconomic agents creating a directional bias in the subsequent moves and development paths. In this respect, path-dependence can also represent a 'roadmap in which an established direction leads more easily one way than another and wholesale reversals are difficult' (Walker, 2000 p. 126 in Martin and Sunley, 2006 p. 398) and explain the changes that a structure can undertake (endogenously or exogenously) around a limited set of options by favoring some alternatives with respect to others (Henning et al., 2013). Hence, in the present context, path-dependence is meant to condition (but not to determine) the set of available options of evolution and new path-creation, i.e. of the new learning paradigm or trajectory to be initiated. It can therefore be termed 'evolutionary path-dependence'.[6]

This duality of path-dependence again points to the dilemma between continuity (i.e. persistence) and change (i.e. evolution) epitomized by the paradox of Theseus's ship mentioned in the introductory section, and it has recently been much debated in regional science and economic geography (Martin, 2010; Henning et al., 2013; Simmie, 2012). Strong defenders of both interpretations of path-dependence (especially in their most extreme versions) can be found in the scholarly community. Although a thorough theoretical discussion of the notion of path-dependence

[5] Several scholars have recently commented on the increasing popularity of the notion of path-dependence in the scientific arena, as supported by database searches in organization, management, economics and, more generally, social sciences journals (Vergne and Durand, 2010). A critical debate on its application for the analysis of the evolution of local economies is also in progress (Martin and Sunley, 2006; Martin, 2010; Henning et al., 2013).

[6] This notion of path-dependence is close to Martin (2012)'s notion of 'developmental path-dependence' and path-creation. In this respect, it is worth stressing that Martin (2010 and 2012) rejects the possibility that path-dependence can explain persistence and inertia, while he only retains the interpretation of path-dependence as a developmental concept. Moreover, he applies the notion of path-dependence to the evolution of local economies, whereas in the present context path-dependence is meant to account for the existence of current learning trajectories and paradigms and their possible alternative evolutionary paths.

and its application in a spatial perspective falls outside the scope of this paper and has already been the subject of in-depth analysis and reviews elsewhere (Martin, 2010; Henning et al., 2013; Simmie, 2012), in the present context it is worth stressing that these two perspectives are not necessarily conflicting and can even share a key feature. In fact, they both stress that innovation and development, and by extension change, are characterised by continuity. On the one hand, continuity implies gradual and incremental changes along the current path, in a conservative perspective. It therefore explains why, at a given point in time, a certain path (in the present context paradigm/trajectory) has become dominant and persists. On the other, continuity implies gradual and incremental changes among new alternative paths that may emerge, in an anticipatory and far-looking perspective. It therefore explains why, at any point in time, evolution will be channelled into certain paths (in the present context paradigm/trajectory) rather than others.

3.3. Incremental changes in learning trajectories and paradigms

As the evolutionary theory highlights, changes in regional learning trajectories and paradigms occur incrementally. The explanation provided for this statement is as follows. Differently from most technologies, which are frequently singular and/or non-decomposable systems and can be changed only as a whole (e.g. the famous QWERTY case discussed by David), regional economies, and their respective learning paradigms and trajectories, are composite entities made of multiple micro-level agents and institutions that incrementally vary and adapt over time without necessarily requiring changes in the other components. Micro-level incremental changes can cumulate and result in fundamental, radical changes in terms of structure, scope and function, but still exhibiting continuity and avoiding systems' failure (Martin, 2010). As a consequence, regional learning paradigms and trajectories can gradually evolve over time through changes affecting their lower-level components, even at different rates and intensities.[7] In turn, past macro-structures emerging from micro behaviours and interactions among micro-level components condition future micro behaviours, generating autocatalytic, self-reinforcing – in short, path-dependent – dynamics.

Evolution is therefore based on memory and selection, because a macro structure imparts instructions to micro components to develop the adaptive traits that best fit the (changing) environment. Furthermore, macro structures and their respective micro components co-evolve in a truly evolutionary fashion because selective adaptation to a changing environment implies a continuous re-shaping of lower-order dynamics and, in turn, of higher-level structures and properties and their downward influences (Martin and Sunley, 2012).[8] In short, the economic landscape is the outcome of path-dependent processes, and it is a major determinant shaping future ones (Martin and Sunley, 2006). As a consequence, this complex cumulative co-evolution can explain why we simultaneously observe continuity and persistence along a specific trajectory, and paradigm and change and evolution towards a new trajectory and paradigm, i.e. why new path-

[7] It is precisely the decomposable nature of regional learning paradigms and trajectories that can ensure their ongoing evolution without being trapped in persistent path-dependence outcomes (Castaldi and Dosi, 2006). Yet, as noted by Bassanini and Dosi (2001), the structure of the interaction among constituent parts has to be sufficiently 'strong' to impart a specific 'path-dependent' evolution to the aggregate system, and there is no *a priori* way to specify a threshold for the strength of these interactions so that path-dependent outcomes can be observed.

[8] For further details about the debate on the concept of emergence and its application in spatial analysis see Martin and Sunley (2012).

creation inherits the legacy of its own past and, ultimately, is evolutionary path-dependent. This perspective offers a reconciliatory view on, and explanation of, the much-debated dilemma between continuity/persistence and change/evolution.

Also in the present case, changes in learning trajectories (and paradigms) must be expected to occur incrementally (i.e. in an evolutionary path-dependent manner) in close proximity to the current ones still representing more advanced alternatives – as inferior ones would not constitute a real and rational choice (Sydow et al., 2009). Consequently, changes in the existing learning trajectory are likely to be more feasible within the same learning paradigm, i.e. within the frame of the same functional, institutional, social and relational structural conditions: for instance, a move from the applied to the basic science trajectory, from the informal to the formal application trajectory, and from the passive to the active learning trajectory (Figure 1). In this last case, however, also the opposite move from the basic to the applied science trajectory can be conceivable and considered as real and rational, because regions may want to avoid decreasing returns to R&D activities in terms of knowledge creation by diversifying research into new application fields in new industries (Camagni and Capello, 2013). By the same token, it is quite unrealistic to expect a direct move from the imitation paradigm to the science-based one. Especially changes of learning paradigms can be challenging, slow and long-lasting. In fact, following the definition of learning paradigms, paradigmatic jumps require not only a redirection of existing learning trajectories (i.e. to change knowledge creation and acquisition processes), but also a change in the structure of the local system (structural dynamics), in all its dimensions, by acting on existing functions and the relational, institutional and social systems. The rarity and difficulty of such changes, even when necessary because of modified (internal or external) circumstances, can be easily explained: both knowledge creation and acquisition processes and the structure of the local system are subject to multiple sources and forms of path-dependence (as more thoroughly discussed in the next sections).

Whilst the incremental process explains how these trajectories (and paradigms) develop over time, the discussion on, and the explanation of when and under what conditions (i.e. through which channels and pathways), a new learning trajectory/paradigm is able to emerge in a complex landscape of path-dependent developments of structural elements (which themselves may lead to a long term structural inefficiency) is still a matter of debate (Martin, 2012). The next sections of the paper offer a conceptual advance in this direction.

4. Persistent path-dependence along learning paradigms and trajectories

4.1. Persistence in learning trajectories

The original idea of path-dependence was introduced by David (1985, 1994) and Arthur (1989, 1994) in order to explain the persistence of a structure, by which they meant mostly a (suboptimal) technological standard. The literature in the field of innovation, organization, social and political sciences has diverse mechanisms and different forms of increasing returns, stemming from different sources and with an array of advantages as well as possible adverse effects. Importantly, the form and operation of these mechanisms has a clear spatial dimension, as also confirmed by Martin and

Sunley (2006), Martin (2010) and Simmie (2012). In fact, path-dependence can be considered a process and/or effect that stems from and is contingent on and embedded in places, i.e. path-dependence is "to a large extent 'place-dependent' " (Martin and Sunley, 2006, p. 409). This applies all the more to learning paradigms and trajectories, which, as explained in Section 3.1 are embedded in and shaped by socioeconomic milieux.

Following the definitions of regional learning paradigms and trajectories proposed in the previous section, the sources of persistent path-dependence (i.e. of the related increasing returns) can pertain to both the technological and cognitive domains, as well as to the functional, institutional, social and relation systems prevailing in a region. In particular, technological and cognitive domains shape the processes by which knowledge is accumulated in a region. They can therefore account for continuity and persistence in the current learning trajectory. Functional, institutional, social and relational domains, instead, influence the context (regional) conditions in which these processes take place. They can therefore account for continuity and persistence in the current learning paradigm.

As regards regional learning trajectories, sources of persistence stem from both technical and cognitive aspects, because each learning trajectory innovates in specific technologies according to the local industrial specialization and the prevailing, long-lasting modes of cooperation, whose relative importance may differ among trajectories (Table 1). In the literature, the increasing returns associated with the production and/or adoption of technologies were among the first mechanisms identified and denoted with (among others) the labels of 'complementary technical interrelatedness' and 'cognitive (learning) effects' (David, 1985; Arthur, 1994, Sydow et al., 2009).

Table 1. Sources of persistent path-dependence along a learning trajectory

Sources of persistent path-dependence	Advantages	Disadvantages
Complementary technical effects (production and/or adoption of innovation)	Network externalities and/or economies of scale and/or scope	Loss of alternative technical opportunities
Cognitive effects	Easier interaction thanks to common cognitive maps	Loss of alternative cognitive fields

Source: Authors' elaboration

Technical interrelatedness due to complementarities between different components of a technology and its use, economies of scale and network externalities among adopters, as well as quasi-irreversibility of initial (learning and adoption) investments (i.e. switching costs to alternative uses) are sources of technical persistence mentioned by the evolutionary theory (David, 1985). On the production side, set-up costs leading to a decrease in unit costs as output increases, learning effects within firms, coordination effects with suppliers and customers, as well as self-reinforcing expectations about preferences for one product over others are invoked (Arthur, 1989). These effects point to the economic advantages deriving from the exploitation of interrelations among components/economic agents and the saving of misfit costs caused by alternative solutions

deviating from the established and progressively dominant path. Following Sydow et al. (2009), these effects may be grouped under the label of 'complementary effects'. Specialization in knowledge and innovation domains exhibiting such properties makes it possible to enjoy the increasing returns effects depending on the existence of network and/or scale and/or scope economies, and it can turn into a source of stability and persistence in a given learning trajectory (and can thus explain its path-dependent and cumulative nature). In the basic science-based learning trajectory, for example, specialization in ICT fields, whose applications are largely characterised by complementary effects, is more likely to generate such effects than specialization in other scientific domains. Complementary effects, however, are not costless, because they may carry the risk that alternative technological opportunities are missed, as early highlighted by David (1985), for example, in the well-known case of the QWERTY keyboard.

The persistence along a certain learning trajectory gives rise to specialization in a given regional technological regime, supported by dedicated technology and research organizations, so that interactions and interrelatedness among firms become an additional source of path-dependence (Martin and Sunley, 2006). In fact, persistence takes place not simply because of cumulative self-reinforcing technological know-how, but also because of subsequent iterations of a specific action, repeated application of devices and more generally practices and routines, especially in relation to the use and/or production of a specific technology stemming from specific learning processes. An applied science-based invention trajectory requires cumulative knowledge about specific technologies, and long-lasting cooperation with other actors outside the region. A formal knowledge-based application trajectory relies for its knowledge exchange on formal cooperation among actors (firms). An informal knowledge-based application trajectory springs from informal cooperation behaviours and processes of collective learning deeply embedded in the local society. A creative imitative learning trajectory requires long-lasting cooperation among economic actors, e.g. among local firms and the multinational one, or among local firms and their international customers/suppliers. These repeated cooperation actions make it possible to achieve higher efficiency levels and to consolidate skills; and they may induce a preference for repetitive exploitative behaviours in a given technological path, rather than critical examination of existing ones and a search for fresh alternatives (Camagni, 1991). But especially these repeated actions participate in the construction of shared cognitive maps and world-views. Mimetic and isomorphic behaviours, processes of local collective learning and knowledge socialization, in fact, have been highlighted in the literature (Martin and Sunley, 2006) as powerful sources of advantages stemming from persistence, especially in spatial clusters (Grabher, 1993). As in Sydow et al. (2009), these cognitive mechanisms can be termed 'learning effects'. However, cognitive/learning effects are not only supportive of existing learning trajectories; they may also entail risks, such as crystallization of the existing knowledge base even if obsolete, and a decrease in the variety of (new opening) knowledge fields, approaches and solutions, thereby reducing the potential for knowledge exploration and re-combination (Table 1).

4.2. Persistence in learning paradigms

As regards learning paradigms, there are various mechanisms that generate persistence in the existing structures and reinforce and support existing systems. These mechanisms arise from the

nature itself of the existing local innovative modes. The science-based learning paradigm reflects a historic investment in research activities and in institutional codes and rules supporting scientific cooperation. The application-based learning paradigm is instead the result of the presence of social values like trust or a sense of belonging which support creativity, collective learning processes, and a capacity to collect knowledge outside the region and turn it into a source of knowledge useful for local innovative processes. The imitative innovation learning paradigm reflects the socio-institutional conditions of the local economy lacking "knowledge infrastructure" as well as creativity and collective learning processes.

In this framework, persistent path-dependence has several sources consisting in the different dimensions that forge the socioeconomic context of a learning paradigm, namely the functional, institutional, social and relational dimensions (Table 2). Specialization advantages due to the presence of specific knowledge creation functions represent a source of continuity, with the risk of sunk costs of physical or infrastructural capital that may generate inertia to change, and the costs of being tied to old, outdated (vintage) functions (Table 2) (Martin and Sunley, 2006; Grabher, 1993). Specialized R&D laboratories cumulate knowledge in well-defined technological fields, and they invest in technical equipment specific to certain technological fields. As a positive outcome, increasing returns due to a critical mass of knowledge in the fields emerge, but inertia inevitably arises at the same time because of sizeable costs of adjustment to a new technological field.

Table 2. Sources of persistent path-dependence along a learning paradigm

Sources of persistent path-dependence	Advantages	Disadvantages
Specialization effects (functional dimension)	Functional specialization advantages (economies)	Costs of old/ vintage functions
Coordination effects (institutional dimension)	Increasing returns thanks to well-known rules	Institutional hysteresis in old and outdated rules
Adaptive expectation effects (social dimension)	Lower transaction costs thanks to social capital and identity	Homophily and loss of variety
Common knowledge base (relational dimension)	(In)voluntary knowledge exchanges, trans-coding, risk sharing, risk reduction, within a consolidated relational network	Entropic death

Source: Authors' elaboration

Institutions, too, are an important source of persistent path-dependence. The idea that institutions are 'carriers of history' is indeed well established in the literature (North, 1990; David, 1994; Martin and Sunley, 2006; Sydow et al., 2009; Simmie, 2011). Not simply institutions are slow to change. More importantly, in fact, common and well-known institutions, by which are meant rules enacted by government (Simmie, 2011), make interaction among individuals easier and more efficient by coordinating behaviors and generating scale advantages and increasing returns; a simple example is that rules become more attractive, the higher the number of people following them (Sydow et al., 2009). Institutions guarantee the stability and predictability of the economic environment necessary for economic transactions and incorporate the outcomes of those economic behaviors, meaning that, as a consequence, they inherit the legacy of their own past (Martin and

Sunley, 2006). Coordination effects therefore arise as the benefits of adopting the same rules increase with the number of people willing to conform with them, leading to the replication and consolidation of behaviors and increasing the costs of getting rid off of well-attuned ones, eventually freezing the economy in old and outdated economic rules (e.g. rigid labor markets, intellectual property rights) – what in the literature is also called institutional hysteresis.

Similarly to formal institutions, also informal ones – norms, conventions, routines, traditions, social arrangements, cultural forms, historical ways of doing things that incur sanctions if not respected (Simmie, 2011) – are subject to persistent path-dependence, albeit through different channels. In fact, not only do such social rules provide coordination advantages as described above, but they also represent a way to align individuals' expectations and make them mutually consistent (David, 1994). For example, shared historical experiences, perception of a common past, interactive building of preferences and their adaptation in response to expectations, search for legitimacy and signaling are mechanisms that support the emergence of a dominant behavioral pattern and code (Sydow et al., 2009). Such mechanisms are likely to play an important role especially in the application-based learning paradigm, in which socially embedded relations are at the basis of the (collective) learning processes that characterize this learning paradigm; and they generate rules that at the same time punish opportunistic behaviors and reward reputation (Dei Ottati, 1987). The development and accumulation of social capital and the strengthening of local identity are the outcomes of such adaptive self-reinforcing mechanisms leading to lower transaction costs. By rewarding adaptation and conformity of behaviors, such adaptive expectation effects favor the creation of informal 'clubs' (if not even more structured institutions) and require a considerable investment by single individuals in terms of socialization, acculturation and acquaintance to common routines and practices. Not only is deviation from the adopted collective norms sanctioned, in different forms and with varying severity according to the infraction, but it becomes increasingly costly over time (David, 1994). All this may ultimately come at the cost of promoting excessive homophily, group thinking, mimetic and isomorphic behaviors, as well as reducing the diversity of and openness to alternative conducts.

Finally, an important element in a learning paradigm is cooperation among actors of different regions. A relational dimension is therefore of importance for the evolution of each paradigm. It operates through a variety of intra- as well as inter-industry relationships in the form of input-output linkages, agglomeration economies, and indirect (untraded) interdependencies. As argued by David (1994), the functioning and efficiency of such interactions frequently rely on the formation and existence of channels to filter, coordinate, trans-code and transmit the knowledge exchanged through such networks, and on specific often idiosyncratic codes whose development and learning represent an especially durable form of capital (Arrow, 1974). Once established, such codes allow the cumulative development of a common knowledge base, which is nourished and expanded through (in)voluntary knowledge exchanges and mechanisms of risk sharing and reduction (Camagni, 1991; Capello, 1999; Capello and Faggian, 2005). However, well functioning networks may entail the risk of entropic death, by which is meant an excessive inward orientation and over-embeddedness leading to the inability to screen for alternative external sources of knowledge to be integrated and recombined in search of novel solutions, especially necessary in a time of increasing

knowledge complexity and knowledge sources' spatial and cognitive dispersion (Breschi and Lenzi, 2015).

As discussed in Section 3, although rare, changes in a region's learning trajectory and paradigm are necessary to avoid structural inefficiencies in the long run, but they are still subject to evolutionary path-dependence and creation. The next section therefore highlights the mechanisms and strategies through which regional economies can avoid the emergence of the possible bottlenecks associated with their current learning trajectory and paradigm (i.e. the different sources of persistent path-dependence), and change them by initiating and creating new paths so to move towards and achieve more advanced trajectories and paradigms.

5. Evolutionary path-dependence in regional learning paradigms and trajectories

5.1. Regional strategies of evolutionary path-dependence and creation

Regional learning paradigms and trajectories are subject to persistent path-dependence leading to continuity. As argued in the previous sections, however, persistent path-dependence provides not only advantages favouring the current configuration and structure of regions but also costs (meant as constraints on change), possibly leading to entrapment in persistent path-dependent outcomes (Sydow et al., 2009). Avoiding this risk becomes very important in a long-term, strategic perspective. However, explaining how regions can engage in virtuous and successful strategies is a rather challenging theoretical task because it requires deep understanding of structural dynamics in regions and a conceptualization of how new trajectories and paradigms can arise in conditions of historical path-dependent evolution (Simmie, 2011).

Although it is not possible to exclude, on purely theoretical grounds, that this process is spontaneous, unconscious, unplanned and uncoordinated (i.e. exogenously driven by disembodied economic forces), there are theoretical and empirical reasons to contend that deliberate action, purposive design, intentional behaviour, strategic decision, 'mindful deviations' of knowledgeable economic agents, notably entrepreneurs (but even policy makers), are the key endogenous drivers of novelty and new path-creation, i.e. they are the sources of new learning paradigms and trajectories, as convincingly argued by Garud and Karnøe (2003) and Martin and Sunley (2012).

In fact, new transformative paths leading to new learning trajectories and paradigms are rarely triggered by exceptional breakthroughs, 'gales of creative destruction', or exogenous shocks; rather, and more frequently, they are initiated by economic agents building upon inherited resources available in a region (Simmie, 2011). Such resources and the initial conditions under which a new paradigm/trajectory can arise are determined by previous rounds of the historical evolution of the current paradigm/trajectory. More importantly, they shape and condition the potential and scope of mindful deviations of knowledgeable economic agents (Henning et al., 2013). As a consequence, change and evolution in learning paradigms and trajectories occur in a patterned, ordered manner and are characterised by continuity. This means not only that there is continuity and persistence in change but also that there is evolutionary path-dependence in learning paradigms and trajectories

dynamics. More importantly, evolutionary path-dependence in learning paradigms and trajectories can incrementally, cumulatively, path-dependently turn into new learning paradigms and trajectories, generating an *evolutionary path-creation*.

Mindful deviations are most likely to occur in niche environments that provide minority selection settings not subject to the operation of economic, technological, cognitive, institutional, relational forces and barriers stemming from history (Simmie, 2011). Niches offer space to incubate and experiment with novelties while guaranteeing some shelter from the unfolding of forces and tides supporting persistent path-dependence of existing paradigms and trajectories. The discovery and exploitation of niches is essentially an entrepreneurial action (Garud and Karnøe, 2003; Simmie, 2011) based on the cultivation of alternative/dormant technologies, the adoption of unconventional external practices, the redeployment/rejuvenation of knowledge, reminiscences, experiences and competences from previous, even failed or incomplete, experiments (Martin 2010). Such micro-level deviating behaviours can initiate a process of transformation, if not creation, that can produce at a more aggregate level different macro structures, i.e. paradigms and trajectories, from the originating ones. However, new paradigms and trajectories rarely arise in virgin environments; rather, they tend to emerge in complex landscapes of historical path-dependent developments which may hinder or even prevent their emergence (Simmie, 2011). Hence, such behaviours have to achieve and overcome existing barriers and sources of persistence and reach a critical mass if the new paradigm/trajectory, and all its components, is to establish itself and become dominant, meaning that sufficient agents must be prepared to switch to new alternatives. Reaching a critical mass (meant as a discontinuity point that imparts a radical shift away from the existing system, consistently with Witt (1997)) is therefore a prerequisite for the new learning paradigm/trajectory to gain full acceptance and to consolidate.

Possible strategies can be highlighted, namely **creation**, **diversification** and **upgrading:** they describe how such deviant behaviours can turn into a gradual transformation of current arrangements and structures (i.e. in an evolutionary path-dependent manner) leading to the creation of new ones (Martin and Sunley, 2006; Martin, 2010; Simmie, 2011). In this paper, the three main strategies highlighted in the literature are conceptualized within the context of regional learning paradigms and trajectories, in a way that seems suitable and able to fit the purpose of mitigating the risks of being entrapped in persistent path-dependent outcomes, and, if successfully implemented, of moving towards more advanced paradigms and trajectories. Differently from the case of persistent path-dependence, where the sources of dependence are shared – with different degrees of intensity – by alternative learning trajectories and paradigms, these mainly endogenous path-creation evolutionary strategies require specific adaptation in the context of each learning paradigm and trajectory, as the next sections explain in depth.

5.2. Evolutionary path-creation in regional learning trajectories

The key features of creation, diversification and upgrading strategies in the context of regional learning trajectories are summarised in Table 3.

By **creation** is meant a strategy based on the exploitation of knowledge niches which leads to the creation of a new industry. In this context, niches are underutilized (or new) knowledge and technological opportunities that can be recombined by borrowing, adapting, learning, experimenting, and integrating elements, fragments, components, arrangements, and solutions of existing (but adjacent, subdominant or dormant) technologies and fields, following the basic argument that variety is crucial for novelty, as similarly described by Martin (2010) and Simmie (2011). Such creative destruction can be initiated by leveraging on existing minority excellence niches and by appreciating and making the best use of such niches. The application domain of such niches differs according to the specific move considered from one learning trajectory to another. In particular (Table 3):

Table 3. Evolutionary path-creation in learning trajectories

Evolutionary path-creation in learning trajectories	From basic science to applied science-based trajectory	From applied to basic science-based trajectory	From informal to formal knowledge application-based trajectory	From passive to active imitative innovation trajectory
Creation	By appreciating and exploiting (making the best use of) existing excellence niches in applied sciences	By appreciating and exploiting (making the best use of) existing excellence niches in basic sciences	By appreciating and exploiting (making the best use of) technological niches and promoting/supporting them as best practices of innovation modes	By attracting a new MNC's activity By making the best use of excellence previously ignored
Diversification	By enlarging local production/research activities towards applied science fields	By enlarging local production/research activities towards basic science fields	By enlarging local production towards technology-oriented modes of innovation/industries	By linking MNC's activities to the local production system By enlarging local activities to related ones within the same industry
Upgrading	By enriching the knowledge base in applied science fields	By enriching the knowledge base in basic science fields	By formalizing the knowledge base	By enhancing MNCs' functions By redirecting local industry outcome to more complex goods

Source: Authors' elaboration

- the move from the applied to the basic science-based trajectory can be initiated by making full exploitation of existing excellence niches in basic sciences[9];
- by the same token, the move from the basic to the applied science-based trajectory can start by making the best use of minority basic research activities already in place. The well-

[9] As discussed in Section 3, also the move from the basic to the applied science-based trajectory within the science-based paradigm is conceivable and rational to avoid the diminishing returns associated with that pattern.

known case of Cambridge (UK) perfectly fits the implementation of this strategy. The region, in fact, has moved from a pure, basic science-based trajectory to a more applied one because of the increasing proliferation of research and technologies based on knowledge recombination, as also described by Martin (2010);;

- the move from the informal to the formal application-based trajectory within the application-based paradigm can be triggered by the full exploitation of technological niches and promoting/supporting them as best practices of innovation modes;
- differently, the move from the passive to the active imitative innovation trajectory within the imitation paradigm may be spurred by the exogenous attraction of a multinational corporation (MNC) operating in an industry new to the region, or also, endogenously, by the rediscovery and re-launching of previously ignored industrial activities of excellence.

Diversification is an alternative strategy that regions can embrace to advance their learning trajectory. The term denotes a process of layering of local activities, by which is meant the expansion of the existing local research/industrial base through a branching process *à la* Frenken and Boschma (2007) based on related variety mechanisms (Frenken et al., 2007).[10] Diversification therefore refers to a process through which new research/industrial activities arise in a region building upon the resources locally inherited, rather than disregarding existing ones, to embark on radically new ones (Henning et al., 2013). Although diversification may involve only small changes in the existing research/industrial base, it may cumulatively and incrementally lead to a substantial transformation of the fundamental nature of a regional learning trajectory.

Diversification can be pursued by building on the existing industrial production and scientific research activities and expanding them on the basis of a related variety principle. In detail (Table 3):

- the move from the applied to the basic science-based trajectory can be initiated by enlarging local production/research activities towards basic science fields;
- by the same token, a region in a basic science-based trajectory can incrementally enlarge its production/research towards applied scientific fields;
- the move from the informal to the formal application-based trajectory can be driven by an enlargement of local production towards more formalized, technology-oriented modes of innovation/industries;
- also, the move from the passive to the active imitative innovation trajectory may be undertaken by linking a MNC's activity to the local production system, or also, endogenously, by enlarging local activities to related ones within the same industry. An example of this latter strategy is the Kosice region in Slovakia described by Pástor et al. (2013). In this case, when the Iron Curtain fell, the formerly state-owned steel company spun off a family of small ICT entrepreneurial firms, gradually extending their competencies portfolios to include proximate business activities, including software development and

[10] Frenken and Boschma (2007) define branching as a process aimed at the generation of new routines needed for innovation by recombination and modification of existing ones, where the routine replication process (based on new firm creation, labour mobility, spin-offs) largely shows distinctive spatial patterns. Routine replication is mainly driven by related variety, meaning that replication primarily occurs in new but proximate cognitive fields in a given cognitive space.

testing, solutions for connected devices and mobile services, thus stimulating an active imitative attitude.

The last strategy considered is **upgrading**, by which is meant the rejuvenation, revitalization and enhancement of the existing local research/industrial base by means of a reorientation process leading to conversion to new activities. Through upgrading, existing structures and arrangements are adapted and reoriented so as to serve new purposes and to move upwards in the value chain. Differently from diversification, therefore, upgrading involves a substitution of current activities with new, more complex, upgraded ones. As in the previous cases, upgrading can be pursued by building on the existing industrial production and scientific research base and augmenting, adding value and knowledge content to it. Specifically for the case of learning trajectories (Table 3):

- the move from the applied to the basic science-based trajectory within the science-based paradigm can be initiated by introducing step-by-step research activities in basic science fields;
- by the same token, a region in the basic science-based trajectory can incrementally upgrade its production/research activities to applied scientific fields;
- the move from the informal to the formal application-based trajectory requires a process of formalization of the local knowledge base by raising awareness among local entrepreneurs of the importance of knowledge protection of new ideas and of formal knowledge exchange. Both processes can be the result of a cumulative destruction of social capital, trust, and sense of belonging that calls for formal cooperation;
- lastly, the move from the passive to the active imitative innovation trajectory may be undertaken by enhancing MNCs' functions at the local level or, possibly endogenously, by redirecting local production to more complex goods. This strategy can be of particular importance in regions specialized in traditional productions, as documented by the case of the dairy processing industry in Wales (Morgan, 2013). In this case, small producers have been able to increase their market shares and to thrive by using local assets and creativity to adapt existing technological and marketing innovations such as the design of new small-scale facilities, the creation and development of market niches, and the launch of new (more complex) dairy products.

5.3. Evolutionary path-creation in regional learning paradigms

Strategies to avoid persistent path-dependence and move to an evolutionary path-creation can be devised and applied also to changes in learning paradigms. In this case, the strategies must be applied to the context conditions that forge each paradigm, and in particular to the way in which the context conditions act on the knowledge creation and knowledge acquisition mechanisms. Two dimensions on which to apply the creation, diversification and upgrading strategies are the functional and the relational dimension. The former contains the context conditions that act on knowledge creation; the latter represents all context conditions (social, institutional and relational) that have an impact on knowledge acquisition and exchange.

The strategies applied to the functional dimension are represented in Table 4. Applied to the functional dimension, a **creation** strategy is identified as a strategy able to create new functions aimed at better exploitation of both material and immaterial local resources, including for example the formation of local human capital, as well as to establish scientific and technical organizations and infrastructures previously not available, also based on re-combinatorial processes as described above in the context of learning trajectories.

Specific cases can be highlighted according to the change in a learning paradigm:

- from the application-based to the science-based paradigm, creation can be the result of the opening of new research fields thanks to reverse brain drain and returnee scientists feeding and expanding the local knowledge base in unexplored research areas. In terms of local scientific and technical organizations and infrastructures, creation may require investing in the establishment of organizations dedicated to knowledge creation and transfer, such research universities and R&D laboratories;
- from the imitative-innovation to the application-based paradigm, creation can be achieved by exploiting underutilised human capital (e.g. through valorisation of underappreciated human capital resources in existing minority technical fields) or by investing in accessibility in order to improve local accessibility to markets, and in educational programs aimed at training local human capital suited to the requirements of local production. The experience of Győr (Hungary) represents a success story of the implementation of this strategy. Attracted by favorable wage levels, by geographical proximity to more central European markets, and more importantly by the local human capital and competencies underutilized after the fall of the Iron Curtain, MNCs and related FDIs, mostly in the automotive sector, flowed into the region. Over time, a new demand for upper level skills emerged, leading to the creation of dedicated degree programs at the local university, as well as to improvement of the region's physical infrastructure and accessibility so that it matched the new and increased business needs and volumes.

Table 4. Evolutionary path-creation of learning paradigms – functional dimension

Evolutionary path-creation in learning paradigms	From application-based to science-based paradigm	From imitative innovation to application-based paradigm
Creation	By making the best use of returnee scientists By investing in knowledge transfer activities and knowledge creation institutions	By exploiting underused human capital resources By investing in accessibility and educational programs oriented to local production specificities
Diversification	By enlarging the application-based activities to science-based functions (e.g. adding research functions to design activities)	By enlarging the existing industrial activities to higher-level functions (e.g. adding design functions to production activities)
Upgrading	By re-orienting the application-based activities to science-based functions	By re-orienting the existing industrial activities to higher-level ones

Source: Authors' elaboration

Diversification means an expansion of the existing set of local functions deriving from an enlargement of rules, procedures and values with respect to what exists, suggesting a change in the mix of the functions performed by a region and their consequent integration. In particular (Table 4):

- in the move from the application- to the science-based paradigm, diversification can take place through complementing and integrating the existing set of application-based activities with science-based ones, e.g. complementing design activities with research ones within local firms;
- in the move from the imitative learning paradigm to the application-based, diversification emerges through the enlargement of the existing industrial activities to higher-level functions, e.g. by transferring innovative activities from MNCs to local branches. The experience of Bratislava (Slovakia) fits this account quite well. In fact, MNCs and FDIs had a primary role in revitalization of the local automotive industry, and in sustaining the region's move from the imitation to the application paradigm precisely by supporting the transfer of innovation activities from MNCs' headquarters to their local plants (Šipikal and Bućek, 2013).

Upgrading of local functions is a strategy that involves reorientation of existing functions in terms of form and nature, suggesting a change in their main organization, arrangements, aim and scope, and leading to an advancement and increasing complexity of the local functional specialization. In particular, functional upgrading can take the form (Table 4):

- of re-orientation of existing application-based activities to science-based ones (e.g. by formalizing firms' basic research activities through the creation of internal labs) when moving from the application to the science-based paradigm or;
- of re-orientation of the existing industrial activities to higher-level ones (e.g. by transferring innovative activities from MNCs' local branches to local suppliers) when moving from the imitation to the application paradigm. This strategy has been successfully applied in the case of wine production in the province of Arezzo (Italy), as reported by Lenzi (2013). By attracting knowledge from outside (in the form of consultancies by external star oenologists), local firms, once the producers of budget wine, were able to improve the quality of the final product and increase the production value.

As regards the relational dimension of regional learning paradigms (Table 5), **creation** means the generation, launching and revitalization of relationships outside the region. In particular (Table 5):

- in the move from the application- to the science-based paradigm, returnee and expatriate scientists can provide linkages with researchers outside the region in fields not fully developed internally. The mobility of scientists is in fact an important channel for knowledge acquisition and social ties that facilitate the persistence of knowledge transfer even after formerly co-located individuals are separated (Agrawal et al., 2006). Indeed, the rapid growth of the Bangalore ICT industry has been largely driven by similar reverse brain drain dynamics (Bresnahan et al., 2001);

- in the move from the imitative learning paradigm to the application-based one, the leveraging of links with external sources of technical knowledge to be applied creatively and anew in specific excellence local production niches can initiate the creation process.

Diversification, instead, can be defined as the expansion of the existing web of relationships through the enlargement of rules, procedures and values with respect to what exists. Specifically:

- in the case of the move from the application- to the science-based paradigm, diversification can rely on complementing existing networks, from which knowledge is sourced for local innovation needs, with new ones in which scientific knowledge is exchanged on a bilateral basis, thus requiring increased awareness of network membership costs and benefits;
- on the other hand, the shift from the imitation to the application paradigm can be supported by branching processes (Frenken and Boschma, 2007) through entrepreneurial spin-offs transforming inter-regional vertical relations into horizontal ones, making it possible to source external knowledge to be applied for local production needs, and not simply to adapt (and creatively replicate) innovations developed outside the region. Moreover, strategically planned governmental interventions can sustain such processes and favour the connection between the industry and the application-based fields by introducing specific rules in their support. The above-mentioned example of Bratislava (Slovakia) testifies to both these mechanisms: the creation of spin-offs from the MNCs' branches, on the one hand, and intervention by the local government to provide favourable conditions on the other (Šipikal and Bućek, 2013).

Finally, the **upgrading** of relationships entails their reorientation in terms of form and nature, meaning that existing relations are expected to adapt to serve different purposes. In detail, upgrading can lead to (Table 5):

Table 5. Evolutionary path-creation in learning paradigms – relational dimension

Evolutionary path-creation in learning paradigms	From application-based to science-based paradigm	From imitative innovation to application-based paradigm
Creation	By making the best use of underdeveloped and underused scientific relations of returnee/expatriate scientists	By making the best use of excellence niches in technological fields creating connections with the local production fabric
Diversification	By enlarging institutional and social rules so as to support knowledge exchanges and to reinforce the ability to be part of a network (increased awareness of costs and benefits of membership)	By enlarging local activities through spinoffs from a MNC's activities transforming vertical relations into horizontal-interregional relations By introducing rules supporting the connection between the industry and the application-based fields

Upgrading	By reorienting local existing relationships to new science-based actors	By reorienting local entrepreneurship to creative activities

Source: Authors' elaboration

- a move from the application- to the science-based paradigm if existing ties are used to access external scientific and not simply technological applied knowledge, and if participation in networks is not simply passive and aimed to source knowledge from outside but also involves an active role as producer of scientific knowledge;
- a move from the imitation- to the application-based paradigm when local entrepreneurship improves and adds value and novelty to their activities by redirecting them towards more creative applications (e.g. the creation of new products if not markets) and not simply to continue to replicate, even if with some degree of originality, innovations conceived and realized outside the region. As commented above, the example of wine production in Arezzo province (Lenzi, 2013) fits this account very well.

6. Alternative paths towards a new learning paradigm: dynamic matching of evolutionary path-creation strategies

An important question arises from the previous discussion: does a change in the learning paradigm require evolutionary path-creation strategies in both knowledge creation and knowledge acquisition, or is it the case that an evolutionary path can take place under the push of only one of the two? This question allows us also to highlight what the possible and most suitable alternative evolutionary pathways towards a new learning paradigm are.

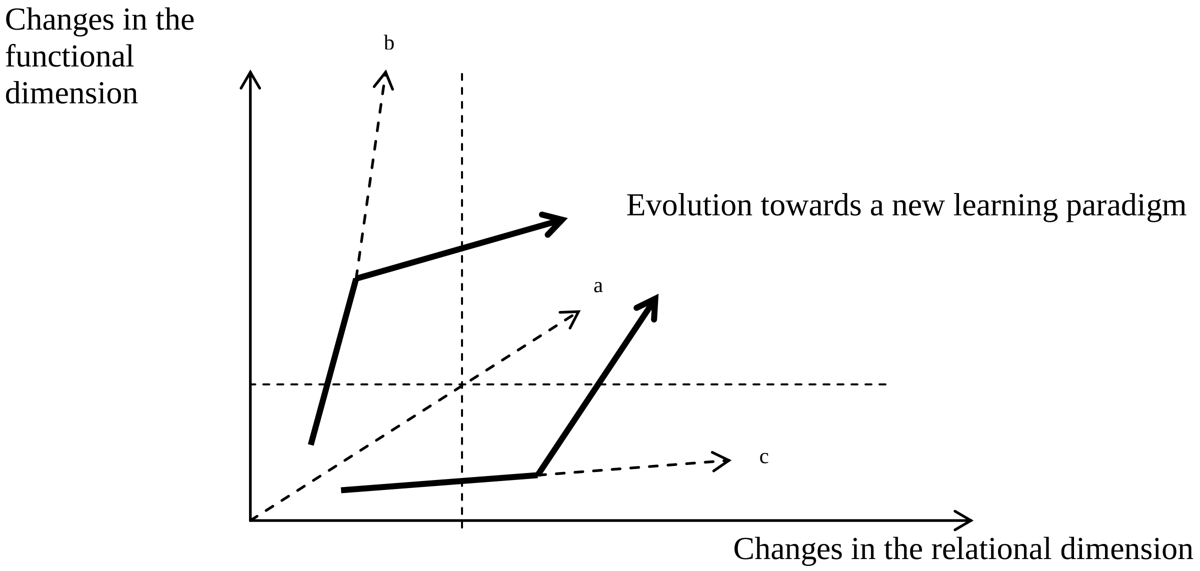
As discussed in the previous sections, in fact, a change of the learning paradigm requires a change of the functional and relation systems characterizing a region. Therefore, change of paradigm implies the harmonization, coordination, and synchronization of all these changes; in short, jumping to a new learning paradigm derives from the dynamic matching of all these dimensions, because changing a learning paradigm is a matter of structural dynamics.

Figure 2 illustrates this intuition by focusing on changes in a region's structural systems and, in particular, its functional and relational dimensions. The dashed 45° degree arrowed line represents a possible evolutionary path based on a balanced and congruent change in both the functional and relational dimensions (evolutionary path a in Figure 2). This path is the most promising one, and it is likely to support evolution towards a new learning paradigm because it involves symmetric changes and, thus, a dynamic matching of all structural elements in a region. This desirable evolutionary path is highly complex to implement since it requires that evolutionary strategies take place in both the functional and relational domains, in a harmonised and coordinated manner.

Different evolutionary paths can be conceived and pursued which do not require such a difficult task. One simple possibility is to leverage on the functional dimension (i.e. move along the vertical axis) with the expectation that changing the functional system will induce a change also in the

relational one (evolutionary path b in Figure 2). This strategy is possibly the most attractive one (with respect to operating on the relational dimension) because it is likely to produce the more immediate and more visible outcomes. An example of such strategies is the creation of new R&D laboratories or new advanced universities in areas where the capacity to create internal knowledge is very limited on the assumption that the creation of local knowledge will push the area to a science-based learning paradigm. The risk of failure of this evolutionary strategy resides exactly in the fact that the learning paradigm may not be able to evolve into the new one due to the lack of a balanced relational structure. In the example provided above, the new R&D laboratory or university remains isolated from the local context, without producing any knowledge spillovers in the area.

Figure 2. Possible evolutionary pathways towards a new learning paradigm



Source: Authors' elaboration

Alternatively, a region may choose to promote changes in the field of knowledge acquisition, i.e. in the relational dimension, again with the expectation that changing the relational system can induce a change also in the functional one (evolutionary path c in Figure 2). Changes in the relational dimension are very slow to take place compared to the changes in the functional one, and in general they are the result of spontaneous long-term processes of adaptation.[11] Once they become visible, a smart policy maker can intervene on the knowledge acquisition (functional) side, thus helping the regional system to move to the new path. Moreover, the probability of achieving a spontaneous evolution towards a new paradigm is higher following changes first in the relational dimension and then in the functional dimension (evolutionary path c in Figure 2) than in the opposite case (evolutionary path b in Figure 2); the relational changes are in fact likely to be so profound and deeply rooted in the regional socioeconomic structure as to drive a re-adaptation also of its functional dimension.

[11] Creating, diversifying and upgrading relations is possibly even more complex and time-consuming with respect to functions; on this issue, see also the discussion of persistent path-dependence in Section 4.

Jumps to new learning paradigms based on evolution in one single dimension are unlikely to occur; instead, it is more likely that changes in only one dimension will simply reinforce the existing paradigm. The best evolutionary strategy is to find a dynamic matching of the evolution in both dimensions. This remains the most promising, but also the most complex, evolutionary strategy that regions should put in place if they are to progress towards a more advanced learning paradigm.

7. Conclusions

The complexity of innovation policies at the regional level resides in the fact that the way in which regions innovate is a result of their learning processes embedded in their socioeconomic structure. Learning processes derive from the history of the local area, and they evolve in a persistent path-dependent manner based on continuity, on the one hand, and in an evolutionary path-creation manner on the other. For this reason, innovation policies should not be considered as sector policies, but rather as place-based innovative policies (Boschma, 2014; McCann and Ortéga-Argiles, 2014).

Evolutionary changes in both trajectories and paradigms are incremental; this message highlights the importance of a normative innovation policy conceived in light of the mode of innovation already present in the area. Moreover, changes in regional learning paradigms are the result of complex evolutionary strategies pursued on the functional and relational dimensions. There is a high risk that the functional dimension – which are easier and quicker to develop – may become the focus of innovation policies, neglecting the relational dimension, which instead requires a long-term strategy. This explains the failure of innovation policies mainly devoted to the creation of knowledge-generating functions.

The most successful and long-term rewarding strategy is the one that allows both dimensions to co-evolve. The dynamic matching of structural elements is at the same time the most successful but also the most difficult aim that an innovation policy should pursue at a local level. These considerations explain the high failure rate of innovation policies that have been developed in the past, as well as the complexity of making a regional system move to a different and more advanced learning paradigm.

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