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REGULAR ARTICLE

The dynamics of regional learning paradigms and trajectories

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Abstract While the literature is rich with studies on the identification of alternative types of learning processes that might exist in the real world, the identification of the determinants of the structural changes in regional learning processes is still an underexplored research field in regional innovation theories. This paper proposes the concept of regional learning paradigms and trajectories to study how alternative and more advanced learning processes arise in a region, and highlights the evolutionary path-creation strategies enabling a paradigmatic jump. By taking into consideration also learning modes typical of peripheral or declining industrial areas, generally left aside in previous theories, this new conceptual approach allows us to understand how more complex learning and innovation processes can emerge in all types of regions. From these reflections, spontaneous processes or policy recommendations to catch-up in the innovation ladder are highlighted for each type of region.

Keywords Regional learning paradigm · Regional learning trajectory · Evolutionary path-creation strategies

JEL classification O11 · R11

1 Introduction

This work starts from the notion and the empirical observation that innovation occurs with variants in space. In the past thirty years, a rich literature has consistently demonstrated the

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heterogeneity of innovation episodes in space (Glaeser and Gottlieb 2009). Several (as well as competing) territorial innovation theories have been elaborated to identify territorial preconditions supporting innovation and to interpret the link between regional innovation and economic performance (Crevoisier and Jeannerat 2009). In this respect, regional innovation systems (RIS) (Cooke 2001; Asheim et al. 2011), learning regions (Morgan 1997), milieux innovateurs (Aydalot 1986; Camagni 1991) and the social filter theory (Rodríguez-Pose 1999; Crescenzi and Rodríguez-Pose 2009; Rodríguez-Pose and Crescenzi 2008) look promising.[1] The common aim of these theories is to highlight the conditions under which innovation occurs in an area. Central to these theories (though with specific and varying interpretations in each of them) is the role played by the existence of a deep and rich web of local relations among local agents as a precondition for local learning and innovation, and, by extension, development (Moulaert and Sekia 2003; Hassink and Klaerding 2012; Hansen 2014). In particular, in the case of learning regions, the accent is put on the institutional proximity among agents that supports learning processes; in the case of RIS, the interaction between sub-systems governing the demand and supply side of the innovation process is what sustains learning processes in an area. In the case of the milieux innovateurs theory, relational proximity among local agents guarantees a socialization of learning processes; the latter, coupled with long-distance relationships with selected partners that allow the avoidance of decreasing returns in knowledge accumulation, explains the continuous innovation processes in an area. The social-filter theory puts much emphasis on the socio-economic conditions as drivers of innovation in regions and as explanatory elements of its effectiveness on economic performance.

Notwithstanding their merits, the regional innovation theories mentioned above do not explain the determinants of the dynamics of learning processes. Their main aim, in fact, is to account for the spatial heterogeneity of innovative activities (i.e. where do innovative activities concentrate and why some regions are more innovative than others) and not how, when and why alternative learning modes can emerge in a region (Asheim et al. 2016). Some of the existing theories identify alternative types of learning processes that might exist in the real world. For example, Jensen et al. (2007) put forward the distinction between STI innovation mode and DUI innovation mode. Asheim (2007) and several of his collegues (Asheim et al. 2011; Halkier et al. 2010; Manniche 2012) conceptually propose and empirically apply the partition into analytical, synthetic and symbolic knowledge. Asheim (2012), also, posits a link between the analytical knowledge base and the STI innovation mode à la Jensen et al. (2007) and the synthetic and symbolic knowledge bases and the DUI innovation mode à la Jensen et al. (2007). Cooke and De Laurentis (2010) highlight two modes of inter-sectoral linkages upon which knowledge flows and learning can be based, cumulative (i.e. based on intrasectoral networks) and combinatorial (based on extras-sectoral networks). However, despite their achievements in highlighting the determinants of (alternative) learning modes, these contributions do not explain how new learning modes can emerge in a region (i.e. the changes from one learning mode to another) nor do they link such changes to differentiated systems of relationships, internal and external to the region, supporting them.

As a consequence, a research avenue that still remains underexplored is the explanation of the determinants of the dynamics (i.e. change vs. persistence) of such learning processes and their supporting system of relationships (internal and external to the

[1] For a review, see Moulaert and Sekia (2003).

region) (Hassink and Klaerding 2012). In other words, how, when, and why alternative and more advanced learning processes (deviating from existing practices) arise in a region, thanks to structural changes in the system of relationships that supports each learning process, requires further investigation.[2]

This paper aims to tackle this issue by offering a conceptualization of how learning processes can evolve and progress in regions, leaving to future reflections the explanation of why and when such structural changes can occur. Therefore, the paper aims at providing insights on how advances can be made in regions so as to move towards more complex learning and innovation processes and to catch-up in the innovation ladder (Lee and Malerba 2017). In this perspective, the study of the evolution towards more advanced learning paradigms requires a relative concept of innovation: regions have to be considered as innovative if local firms are able to do something new with respect to their past, and not with respect to a dominant paradigm present worldwide (Camagni 2015). This definition of innovation carries also an important consequence. All types of innovations have to be taken into consideration and analyzed, from radical to imitative approaches; the latter are typical of peripheral or declining industrial areas, possibly dominated by branch plant activities of multinational corporations, and are generally left aside in previous regional innovation studies (Asheim and Isaksen 2002; Isaksen 2015).[3] The approach presented in this work allows us to understand how more complex learning and innovation processes can emerge even in backward regions.

The paper addresses the issues above by suggesting a way to typify different learning processes and to interpret the structural dynamics at the basis of the transformation, adaptation, and evolution of regional learning and innovation over time and therefore of the system of territorial relationships behind learning processes. An issue such as this finds its natural theoretical substrate in theories of change, including evolutionary economics (Nelson and Winter 1977, 1982; Dosi 1982; David 2007; Perez 2010), evolutionary regional economics (Aydalot 1986; Camagni 1991; Calafati 2009), and evolutionary economic geography (Martin and Sunley 2006; Martin 2010; Simmie 2012). Evolutionary economics offers a framework to analyze learning and innovation structural dynamics, applied to the evolution of technologies. Evolutionary regional economics and evolutionary economic geography offer a framework to analyze the dynamics of a territorial entity. The merger and blending of these streams of research represents the backbone of the conceptualization effort developed in this paper and allows us to interpret structural dynamics not in the field of pure technological domains, but in learning modes embedded in regional systems. In particular, the paper will draw on the concept of regional learning paradigms and trajectories already introduced in a

[2] We acknowledge that learning and innovation processes are centered in firms and economic agents and each single economic agent in a region can show different innovative behaviors. However, we agree with other authors that there is a necessity of overcoming methodological individualism so to give full recognition of the role of territory: "if individual firms and individual people undertake collective activities, facilitated by (and creators of) trust and local social capital; and if significant cognitive synergies, readily apparent in the local *milieu,* result from their various interactions; and finally if these actions and these processes draw additional vitality from cooperation with local public administrations; then it appears justifiable to go beyond methodological individualism - which regards only single firms as operating and competing - arguing the logical validity of a 'collective' concept such as that of *territory*, and to affirm that territories compete among themselves, using the creation of collective strategies as their instrument." (Camagni 2002, p. 2406). For a similar approach, see Schamp 2005; Audretsch 2015).

[3] Cooke (2001) himself acknowledges that regional innovation systems are rare.

previous work (Capello and Lenzi 2016) in order to explain the persistence of innovative behaviors in regions. If, in the previous work, persistence in learning processes was analyzed and interpreted, in this study the aim is to examine how breaks in innovative path dependence can take place in regions and give rise to an evolutionary path-creation, so as to highlight how new learning and innovation modes can emerge. Strategies enabling a paradigmatic jump are the final goal of such a study.

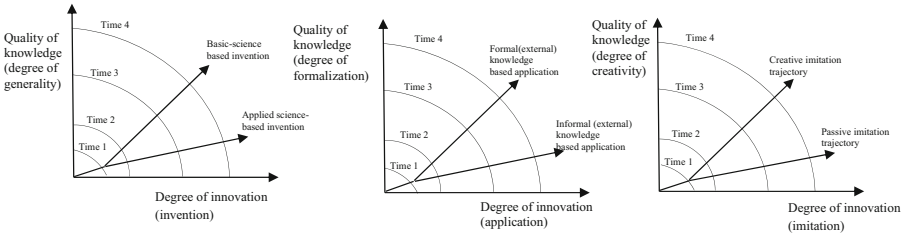
The remainder of the paper unfolds as follows. The following section proposes a definition of regional learning paradigms and trajectories. Then, it explains why learning paradigms and trajectories can exhibit both persistence and change (Section 3). Next, the paper highlights the strategies that lead to a change in a region's current learning trajectory and paradigm (Section 4). Then, the paper suggests and comments on the possible and most suitable alternative evolutionary pathways towards a new learning paradigm (Section 5). Concluding remarks and policy suggestions are finally put forward (Section 6).

2 Regional learning paradigms and trajectories

The concept of *regional learning paradigms* is defined in this work as regional systems of relationships (internal and external to the region) that, based on rules shared by the local community of technological, institutional and economic actors, shape the process upon which one looks for innovation, and therefore identify the way in which new knowledge is acquired in regions and a learning process developed. In short, regional learning paradigms represent models of innovation and knowledge accumulation stemming from the functional and relational characteristics of territories (Capello and Lenzi 2016). In line with the milieux innovateurs theory, these two terms represent the ways in which knowledge can cumulate in space: the functional characteristics represent the knowledge creating functions present in the region, in the form of institutions (universities, research centres, local firms). Relational characteristics refer to intra-regional relationships, as well as the external long-distance relationships that take place between local actors and selected partners.

Regional learning paradigms can be associated with three 'archetypes' of what have been previously called regional innovation patterns (Capello 2013; Capello and Lenzi 2013). The latter are defined as different variants of the linear knowledge-invention-innovation logical chain, once the different stages are broken down, separated, differently allocated in time and space, and finally recomposed following a relational logic of interregional cooperation and exchange (Camagni 2015). Each regional learning paradigm / pattern can entail different modes of innovative search, each based on specific knowledge accumulation processes stemming from local relations, on the one hand, and selected external networks supporting them, on the other (Fig. 1). In particular:

- in a *science-based learning paradigm*, knowledge is created by local functions like universities, R&D centers and local large firms, and their local relationships, enriched by cooperation with selected external partners;
- in a *creative application learning paradigm*, entrepreneurial creativity and collective learning allow sourcing external knowledge and its application to local innovation needs;



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

Source: Authors' elaboration

Fig. 1 Alternative learning trajectories within each paradigm

– in an *imitative innovation paradigm*, relationships between local firms and dominant firms (typically multinationals) allow adopting of innovations new for the area.

Within each paradigm, alternative learning trajectories can be defined according to the quality of knowledge and the intensity of the type of innovation specific to each paradigm (either invention, or application or imitation) (Fig. 1).[4] In particular[5]:

– the science-based learning paradigm can generate two alternative learning trajectories according to the degree of knowledge generality, namely, basic scientific knowledge vs. applied scientific knowledge (Fig. 1a). Therefore, the difference between the two types of trajectories lies in the type of knowledge produced: basic scientific knowledge tends to have wider technological applications and commercial value, to be more original, recombinatorial and radical, and to be oriented to general purpose technologies such as biotechnology, ICT, nanotechnology. The opposite applies to applied scientific knowledge;
– the creative application learning paradigm can give rise two alternative learning trajectories according to different types of knowledge namely, formal vs. informal external knowledge (Fig. 1b): formal knowledge refers to codified technological, engineering-based knowledge, while informal knowledge refers to knowledge that is uncodified, tacit, embedded in professional capabilities, based on professional practices and experience;
– the imitation learning paradigm can produce two alternative learning trajectories, one based on a passive and the other on an active attitude towards imitation (Fig. 1c). In this case, we distinguish between different types of imitative behaviors according to the degree of creativity and adaptation introduced in the imitation process (active versus passive imitation).

Within each paradigm, as time passes, in a regional system, the intensity of imitation / application / invention can increase along a trajectory, while keeping a similar quality of knowledge, or along a new one, characterized by a higher quality of knowledge.

[4] The conceptual typology of regions used in this paper has been also empirically proved for 262 NUTS2 regions of the EU (Capello and Lenzi 2013).
[5] For a more in-depth discussion on the different types of trajectories, see Capello and Lenzi (2013).

Similarly to Dosi's notions of technological paradigms and trajectories, regional learning trajectories and paradigms represent structural theoretical constructs. The very nature of the underlying learning processes can explain the patterned, ordered, cumulative, path-dependent, i.e. structural and persistent, characteristics at the basis of innovation and change. Yet, with respect to a technological paradigm identified by technological and institutional rules governing the world economy in any period, a regional learning paradigm is identified by socioeconomic rules governing specific regional entities, consistently with earlier studies in evolutionary regional economics (Aydalot 1986; Camagni 1991; Calafati 2009).

The concept of regional learning paradigms separates out the functional and relational characteristics (previously defined as in Capello and Lenzi 2016) that govern learning processes, mixed up in the interpretation of evolutionary economic theory.[6] The local context in fact plays a distinctive and active role in learning processes beyond the importance of Marshallian specialization externalities already emphasized in evolutionary economics (Dosi 1982; Antonelli 1994). In evolutionary regional economics, in fact, the territory represents a system of localized competences and skills, codes, symbols, behavioral habits, values and representations, rooted in the local society and supporting local relationships, that shape and condition the way in which learning and innovation happen in regions (Camagni 1991; Capello 1999; Capello and Faggian 2005; Cusinato and Philippopoulos-Mihalopoulos 2015).

Adaptation and modification of the existing functional and relational structures at the basis of local learning processes are therefore the key driving forces behind a 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 but also changes in a region's functional and relational structures.[7] In this respect, regional learning trajectories and paradigms can be useful notions with which not only to capture structural characteristics of regional innovation and learning 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, as discussed in the next section.

3 Persistence and evolution in regional learning trajectories and paradigms

Conceptualizing the determinants of the possible evolution and progress of learning processes in regions requires understanding the contrast and interplay between change and persistence in regional learning processes and in the system of relationships (internal and external to the region) supporting them. In the literature, such debate has largely revolved around the concept of path dependence, interpreted either as favoring persistence in evolutionary economic theory (David 1985, 1994; Arthur 1989, 1994) or as enabling and channelling change in evolutionary economic geography (Martin and Sunley 2006; Martin 2010; Henning et al. 2013).

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

Evolutionary economic theory has long studied the tendency to persistence (David 1985, 1994; Arthur 1989, 1994). In this perspective, path-dependence is conceived as a legacy from the past,[8] 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. By transferring this argument to the present context, path-dependence can account for the persistence of existing regional learning paradigms and trajectories, and can thus be termed 'persistent path-dependence'. The risks of such form of path dependence, and its implications for regional renewal and innovation policy design, are widely discussed in Capello and Lenzi (2016).

By favoring 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. 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 realized elsewhere, but rather with respect to changed internal or external circumstances requiring new solutions to prevent a lock-in outcome (Dosi 1988).

Importantly, the presence of multiple forms and sources of persistent path-dependence (Martin 2010; Henning et al. 2013; Capello and Lenzi 2016) 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 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).[9] 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 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 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'.[10]

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

[9] 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 science 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).

[10] 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, 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.

Regional scientists and economic geographers have recently debated this duality of path-dependence (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. Yet, in our opinion, these two alternative perspectives are not conflicting, since they stress that innovation and development, and by extension change, are characterized by continuity. What makes the difference is the perspective taken in the analysis. In a retrospective view, continuity implies gradual and incremental changes along the current path; it therefore explains why, at a given point in time, a certain path (in the present context paradigm/trajectory) has become dominant and persists. In an anticipatory and forward-looking perspective, by contrast, continuity implies gradual and incremental changes among new alternative paths that may emerge. It therefore explains why, at any point in time, evolution will be channelled into certain new paths (in the present context paradigm/trajectory) rather than others and why new path-creation, by inheriting the legacy of its own past, is ultimately evolutionary path-dependent. While the retrospective approach is the one elaborated and discussed in Capello and Lenzi (2016), the anticipatory and forward-looking perspective instead is the focus of the present paper.

Therefore, also in the case of regional learning paradigms and trajectories, changes 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 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 (Fig. 1). In this last case, however, also the opposite move from the basic to the applied science trajectory is conceivable and may be considered as real and rational, in order 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). Similarly, 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 functional and relational 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 can be subject to multiple sources and forms of persistent path-dependence (Henning et al. 2013).

The incremental process explains how these trajectories (and paradigms) develop over time; however, the discussion on, and the explanation of, 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 section of the paper proposes a conceptual advance in this direction.

4 Evolutionary path-dependence in regional learning paradigms and trajectories

4.1 Regional strategies of evolutionary path-dependence and creation

Explaining how virtuous and successful strategies can take off and develop in a regional economy 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 2012).

Although it is not possible to exclude the possibility, 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 behavior, 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 2012). 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). By extension, change and evolution in learning paradigms and trajectories also occur in a patterned, ordered manner and are characterized by continuity and evolutionary path-dependence. Relevantly, evolutionary path-dependence implies that the evolution of learning paradigms and trajectories can incrementally, cumulatively, path-dependently turn into *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 2012). 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 2012) 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 behaviors 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 that may hinder or even prevent their emergence

(Simmie 2012). Hence, such behaviors 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, consistent 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 behaviors 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 2012). 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.

4.2 Evolutionary path-creation in regional learning trajectories

The key features of creation, diversification and upgrading strategies in the context of regional learning trajectories are summarized in Table 1.

By **creation** is meant a strategy based on the exploitation of knowledge niches that 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 (2012). 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 1):

- 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;
- 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-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 described by Martin (2010)[11];

[11] As discussed in Section 3, 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 trajectory.

Table 1 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 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 to advance a region's 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).[12] 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 1):

- 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 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 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

[12] 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, labor mobility, spin-offs) largely shows distinctive spatial patterns. Routine replication is mainly driven by related variety, meaning that replication primarly occurs in new but proximate cognitive fields in a given cognitive space.

of a reorientation process leading to the 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 1):

- 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.

4.3 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, i.e. the functional and the relational dimensions. The former contains the context conditions that act on knowledge creation; the latter represents all relationships (within and outside the region) that have an impact on knowledge acquisition and exchange.

The strategies applied to the functional dimension are represented in Table 2. 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 non-material local resources, including, for example, the formation of local human capital, as well as to establish scientific and technical organizations and infrastructures previously not

Table 2 Evolutionary path-creation in 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

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 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 as research universities and R&D laboratories;
- from the imitative-innovation to the application-based paradigm, creation can be achieved by exploiting underutilized human capital (e.g. through valorization 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, flew 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.

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 2):

- 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 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 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 2):

- 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 3), **creation** means the generation, launching and revitalization of relationships, especially outside the region that may provide 'external energy' for change (Trippl et al. 2015). In particular:

- 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);

Table 3 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

– 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 favor 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 favorable 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 3):

- 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.

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

From the reflections presented above, spontaneous local processes and policy recommendations to catch-up on the innovation ladder can be highlighted. As discussed in the previous section, a change of the learning paradigm requires a change of the functional and relational systems characterizing a region. Therefore, a paradigmatic jump implies the harmonization, coordination, and synchronization of changes in both dimensions; in short, progressing to a new learning paradigm derives from the dynamic matching of the two dimensions.

Figure 2 illustrates this intuition by focusing on changes in a region's 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 Fig. 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 be

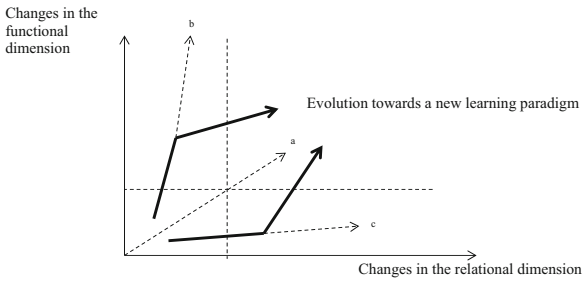


Fig. 2 Possible evolutionary pathways towards a new learning paradigm

implemented since it requires that evolutionary strategies take place in both the functional and relational domains, in a harmonized and coordinated manner.

Spontaneous long-term processes of adaptation are likely to make the system move along line c of Fig. 2. In fact, new selected, long-term relationships can induce spontaneous changes in learning paradigms while creating a disequilibrium between the external relationships and the local functional system. The latter may be then pushed towards a structural change in order to adapt to the new external forces; a smart policy maker can intervene on the functional side, helping the progress of regional system to the new paradigm.

Alternatively, normative interventions can be tempted to stimulate a paradigmatic change by leveraging on the functional dimension (i.e. a 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 Fig. 2). This strategy is possibly the most attractive one because it is likely to produce immediate and 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 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.

The best evolutionary strategy, therefore, is to find a dynamic matching of the evolution in both dimensions. This remains the most promising, but also the most complex, evolutionary strategy to be put in place to make progress in regions towards a more advanced learning paradigm.

6 Conclusions

The complexity of innovation policies at the regional level resides in the fact that the way in which innovation occurs in regions is a result of the learning processes embedded in regional 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 Ortega-Argilés 2014; Capello and Kroll 2016; Caragliu and Del Bo 2018).

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 learning 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 is 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.

In the academic and policy arenas, the hype has been put on the role of diversification of economic (industrial) activities as the principal path to be followed to achieve structural changes, in line with the smart specialization strategy and the place-based approach to regional innovation policies (Boschma 2014). However, diversification opportunities can be limited in less advanced areas, whereas constraints and inertia that may divert and suppress the emergence of alternatives are weaker, thus favoring creation strategies (Trippl et al. 2015; Simmie 2012). Moreover, upgrading can be a valuable and still promising option, one definitely less risky than creation, especially in less advanced contexts.

Additionally, evolutionary changes of regional learning processes show a multidimensional nature. In particular, even when diversification of economic/innovative activities can be the best option to pursue change (even if it is not the only one available), it might be not enough if it is an isolated action. In fact, a change of learning paradigm requires a change of the functional and relational dimensions characterizing a region at the same time. By emphasizing the role of connectivity, the smart specialization strategy has rightly adopted this approach; practically, however, the identification of inter-regional links has been nearly ignored and inter-regional links between core and peripheral areas turned out to be very weak (Iacobucci and Guzzini 2016; Bachtler and Begg 2018). Moreover, the proposal of reinforcing scientific links between advanced and laggard areas can be appropriate, depending on the structure of local relationships and learning mode, while it can be insufficient or misplaced for lagging regions characterized by a different predominant way of learning and interacting (Capello and Lenzi 2016). In fact, the most successful and long-term rewarding strategy is the one that allows the functional and relational 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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