Regional innovation patterns from an evolutionary perspective

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ABSTRACT

Regional innovation patterns from an evolutionary perspective. *Regional Studies*. Based on the conceptual notion and empirical verification that innovation follows differentiated spatial patterns, the paper analyses the conditions that enable changes in regional innovation patterns. Consistently with evolutionary theory, these changes are interpreted as path-dependent processes characterized by trajectories and paradigms, understood as learning processes. The novelty of the work rests on the adaptation of creation, diversification and upgrading pathways – generally used in the literature to explain changes in development paradigms – to the interpretation of changes in learning trajectories and paradigms, and on the empirical validation of this conceptual underpinning.

KEYWORDS

regional patterns of innovation; regional learning paradigm; regional learning trajectory; pathways

摘要

从演化视角看区域创新模式。*Regional Studies*. 本文根据创新跟随着差异化的空间脉络之概念与经验检证，分析让区域创新模式改变成为可能的条件。与演化理论一致的是，这些改变诠释为以轨迹与范式为特徵的路径依赖过程，并理解为学习的过程。本研究的新颖之处在于使解释发展范式改变的文献中被广泛使用的创新，多样化与升级途径，适应于学习轨迹与范式改变的诠释，以及此一概念基础的经验实证。

关键词

创新的区域模式; 区域学习范式; 区域学习轨迹; 途径

RÉSUMÉ

Modèles d'innovation régionaux sous une perspective évolutionnaire. *Regional Studies*. Sur la base de la notion conceptuelle et de la vérification empirique d'après laquelle l'innovation suit des tendances spatiales différenciées, la présente communication analyse les conditions qui permettent des changements dans des modèles d'innovation régionaux. En accord avec le théorie de l'évolution, ces changements sont interprétés comme des procédés tributaire du chemin suivi, caractérisés par des trajectoires et des paradigmes, interprétés comme des processus d'apprentissage. La nouveauté de l'ouvrage réside dans l'adaptation de la création, la diversification et la mise en œuvre des parcours – généralement utilisés dans les documents pour expliquer des variations dans des paradigmes de développement – pour l'interprétation des changements dans les trajectoires et paradigmes d'apprentissage, et dans la validation empirique de cette base conceptuelle.

MOTS-CLÉS

modèles d'innovation régionaux; paradigme d'apprentissage régional; trajectoire d'apprentissage régionale; parcours

ZUSAMMENFASSUNG

Regionale Innovationsmuster aus evolutionärer Perspektive. *Regional Studies*. In diesem Beitrag analysieren wir auf der Grundlage der konzeptuellen Vorstellung und empirischen Überprüfung, dass die Innovation differenzierten räumlichen Mustern folgt, die Bedingungen für Veränderungen in regionalen Innovationsmustern. In Übereinstimmung mit der

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evolutionären Theorie werden diese Veränderungen als pfadabhängige Prozesse interpretiert, die sich durch Verläufe und Paradigmen auszeichnen, welche als Lernprozesse aufgefasst werden. Das Neuartige an diesem Beitrag beruht auf einer Anpassung der Pfade der Erzeugung, Diversifizierung und Modernisierung – welche in der Literatur generell zur Erklärung von Veränderungen in den Entwicklungsparadigmen herangezogen werden – an die Interpretation von Veränderungen bei den Verläufen und Paradigmen des Lernens sowie auf einer empirischen Überprüfung dieser konzeptuellen Grundlage.

SCHLÜSSELWÖRTER
regionale Innovationsmuster; regionales Lernparadigma; regionaler Lernverlauf; Pfade

RESUMEN
Patrones de innovación regional desde una perspectiva evolutiva. *Regional Studies*. A partir de la noción conceptual y la verificación empírica de que la innovación sigue patrones espaciales diferenciados, en este artículo analizamos las condiciones que permiten cambios en los patrones de innovación regional. En coherencia con la teoría de la evolución, estos cambios se interpretan como procesos que dependen de rutas y se caracterizan por trayectorias y paradigmas, entendidos como procesos de aprendizaje. La novedad en este trabajo radica en la adaptación de las rutas de creación, diversificación y mejora – que en general en la bibliografía sirven para explicar los cambios en los paradigmas de desarrollo – a la interpretación de los cambios en las trayectorias y los paradigmas del aprendizaje, y en la validación empírica de este fundamento conceptual.

PALABRAS CLAVES
patrones regionales de innovación; paradigma del aprendizaje regional; trayectoria del aprendizaje regional; rutas

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INTRODUCTION

This work starts from the notion and the empirical observation that innovation occurs with variants in space, i.e., innovation follows differentiated spatial patterns (Asheim, Grillitsch, & Trippl, 2015; Capello & Lenzi, 2013).

Several contrasting territorial innovation approaches have been elaborated to highlight the territorial conditions under which innovation occurs in an area. Amongst the existing approaches, regional innovation systems (RIS) (Asheim et al., 2015; Cooke, 2001), learning regions (Hassink & Klaerding, 2012), *milieux innovateurs* (Aydalot, 1986; Camagni, 1991), and regional patterns of innovation (Capello & Lenzi, 2013) figure prominently. The common goal of these approaches is to account for the spatial heterogeneity of innovative activities (i.e., where innovative activities concentrate and why some regions are more innovative than others). Importantly, all these approaches stress (though with specific and varying interpretations in each of them) the relevance of the existence of a deep and rich web of local (and, to a certain extent, extra-regional) relations among local agents as a precondition for local learning and innovation, and, by extension, development.

If these approaches cleverly point out the conditions under which innovation occurs in a region, and therefore its innovation pattern, their achievements in explaining how these innovation patterns evolve over time are still limited (Asheim et al., 2015; Trippl, Grillitsch, & Isaksen, 2015). Consequently, an unexplored research avenue is the explanation of the determinants of the dynamics of such innovation patterns through the analysis of the system of relationships (internal and external to the region) supporting them (Hassink & Klaerding, 2012). In other words, how, when and why alternative and more complex innovation modes (deviating from existing practices) arise in a region, thanks to structural changes in the system of relationships that supports each innovation process, requires further investigation.

This paper aims to tackle this issue by offering a twofold contribution. First, building on a previous conceptual work of the authors', it proposes a conceptualization of the possible determinants of the evolution of innovation patterns in regions. Second, it identifies empirical regularities to examine this new conceptual approach, in the methodological spirit of 'appreciative theorizing', i.e., a theory that aims to capture the basics of what is actually going on (Nelson & Winter, 1982). By doing so, the paper provides insights into how regions can move towards more complex learning and innovation patterns. In detail, regional patterns (or modes) of innovation represent alternative spatial variants/combinations of context conditions and of specific modes of performing and linking the different phases of the innovation process. This framework has been now conceptually accepted and empirically proved (Capello & Lenzi, 2013, 2015) and presents the advantage of considering all types of innovations, from radical to imitative ones. Especially the latter are typical of peripheral or declining industrial areas, possibly dominated by branches of multinational corporations, and they have generally been left aside by previous regional innovation approaches (Asheim & Isaksen, 2002).[1] This paper will therefore apply the notion of regional patterns of innovation to explain the determinants of the structural dynamics of regional innovation processes, i.e., how, why and when regional innovation modes can transform, adapt and evolve over time, and it will afford an understanding of how more complex learning and innovation processes can emerge even in backward areas.

The paper is organized as follows. The following section introduces the framework of regional innovation patterns and comments on the dynamics of regional innovation patterns detected in European regions. The third section then elaborates on why the different innovation patterns and their dynamics can be conceived as learning paradigms and trajectories and identifies the possible and most suitable alternative evolutionary pathways to move towards a new learning paradigm and trajectory. Next, the fourth section proposes a way to examine empirically these evolutionary pathways in the context of a change in a region's learning trajectory (in the fifth section) as well as in the context of a change in a region's learning paradigm (in the sixth section). The final section puts forward concluding remarks and policy reflections.

THE DYNAMICS OF REGIONAL PATTERNS OF INNOVATION

The conceptual framework used in this paper is based on the notion of regional patterns of innovation. Regional patterns of innovation are defined according to the presence/absence of some context conditions that allow for the creation and/or the adoption of knowledge and innovation (Capello & Lenzi, 2013). They are obtained as different variants of the linear knowledge, invention, innovation model, 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).[2] Three main 'archetypal' innovation patterns have been conceptualized. In particular, a micro-founded approach drives the conceptualization of territorial patterns of innovation because certain territorial resources and conditions influence certain types of economic agents' strategies and behaviours (Capello & Lenzi, 2015). The main innovation patterns can be described as follows:

- *Science-based pattern*: in this pattern, knowledge is primarily created locally by firms, universities and research and development (R&D) centres, and exchanged and enriched not only by the local actors within the region but also outside it on the basis of interregional cooperation with selected external partners, as highlighted in most of the literature dealing with knowledge and innovation creation and diffusion (Jensen, Johnson, Lorenz, & Lundvall, 2007; Mack, 2014).
- *Creative application pattern*: in this pattern, knowledge is primarily sourced outside the region but applied for local innovation needs thanks to entrepreneurial creativity and collective learning processes (Foray, David, & Hall, 2009). Knowledge providers supporting the innovative activities of local firms are mostly located outside the region, and knowledge exchanges are nourished more by cognitive and sectoral proximity (i.e., shared cognitive maps) than by belonging to the same local community (Asheim & Isaksen, 2002).
- *Imitative innovation pattern*: in this pattern, innovation is primarily based on imitation processes, frequently dependent on relationships between local firms and dominant firms (typically multinationals), as described in the literature dealing with innovation diffusion (Pavlínek, 2002).[3]

Moreover, within each theoretical pattern characterized by a specific relational structure, two distinct processes of knowledge accumulation and knowledge acquisition for innovation discovery can be identified, depending on different cognitive bases. In particular:

- the science-based pattern can be divided into a basic and an applied science-based pattern, according to the basic versus applied nature of the scientific knowledge base;[4]
- the application pattern can be divided into a formal and an informal knowledge application pattern, according to the formal versus informal nature of the knowledge base;[5] and
- the imitative innovation pattern can be divided into an active and a passive imitation pattern, according to an active versus passive attitude towards imitation.[6]

The regional patterns of innovation framework shares with the RIS approach (Asheim & Isaksen, 2002) the idea that specific local and regional resources are important in firms' efforts to innovate, and therefore in forging firms' innovative behaviours. Without contradicting the existing literature, however, the concept of regional patterns of innovation introduces some novelties in framing and explaining regional innovation processes. In detail, it goes more in depth to identify the local elements that help firms to innovate by distinguishing between local preconditions explaining firms' capacity to create knowledge, to turn knowledge into innovation, to acquire knowledge and innovation from outside the region. By doing so, different possible patterns/modes of innovation are obtained. The typology of innovative regions proposed is based on the presence/absence of territorial conditions that support specific firms' behaviours and propensity to innovate with respect to others. In the regional innovation pattern approach, all types of innovative modes are taken into consideration. Even the imitative innovation approaches typical of peripheral areas and declining industrial regions are considered in the innovation pattern approach, for which the RIS approach (and the different typologies of RIS; Asheim et al., 2015) instead is considered a less fruitful analytical framework and policy approach (Asheim & Isaksen, 2002).

Moreover, the regional innovation pattern approach is in line with the distinction proposed by Jensen et al. (2007) between the science, technology and innovation (STI) and learning by doing-using-interacting (DUI) mode of innovation, yet with two differences and novelties. First, the innovation modes proposed by Jensen et al. neglect the possibility of innovation modes based on imitative processes, which are instead fully accommodated in the regional pattern of innovation approach. Second, the application pattern departs from the DUI model developed by Jensen et al., in that it considers the production of innovation based on both scientific and technological knowledge, as well as informal, tacit, craft-based knowledge produced *outside* the region.[7] Creative local firms/entrepreneurs source such external knowledge, bring it into the region, and revisit, exploit and turn it into innovation. Furthermore, the distinction between basic versus applied scientific knowledge, formal versus informal, active versus passive imitation, enriches previous classifications, namely the threefold distinction between analytic, synthetic and symbolic knowledge bases (Asheim et al., 2015). In particular, two different types of science-based (i.e., analytic) knowledge are considered: basic and applied scientific knowledge. Similarly, two types of application-based knowledge are considered, one based on the use of formalized, engineering (i.e., synthetic) knowledge and the other based on the use of informal, craft-based (i.e., symbolic) knowledge. Moreover, and not considered in the knowledge bases approach, we also distinguish between different types of imitative behaviours according to the degree of creativity and adaptation of the imitation process (active versus passive imitation).

Regional innovation patterns have been recently identified empirically in European regions for 2002–04 (Capello & Lenzi, 2013, 2016a) (Figure 1(a)). In this paper, the same exercise has been conducted for 2004–06 (Figure 1(b)), so that a comparative analysis is amenable.

The first impression stemming from Figure 1 is one of remarkable persistence, with some islands of change. Overall, 61 out of 262 regions (23%) have been able to change towards a more complex pattern of innovation; 28 did the opposite; while 173 maintained their innovation pattern (see Table A1 in Appendix A in the supplemental data online).

Unfortunately, persistence especially affects regions belonging to the less complex patterns; in fact, none of regions in the passive imitation group is able to escape from its innovative backwardness condition, with only one exception.

Generally, changes, if any, are incremental, and radical ones are unlikely. Regions usually move from the imitation patterns to the application ones and from the application patterns to the science-based ones, while there are no regions moving from the imitation patterns to the science-based ones. Most changes also occur in close proximity to the prevailing pattern; indeed, 80% of regions that change their innovation pattern (49 out of 61) move to the adjacent one (e.g., from the active imitation pattern to the informal application one, and so on), meaning that changes are gradual and not abrupt. Lastly, most turbulence occurs in the most complex patterns. Interestingly, Figure 1 as well as Table A1 in Appendix A in the supplemental data online consistently highlight an expansion of both science-based patterns, especially (in relative terms) of the basic science pattern (which almost doubles in terms of number of regions).

The next section proposes a conceptual interpretation of regional innovation patterns' dynamics and some alternative evolutionary pathways driving those dynamics.

REGIONAL PATTERNS OF INNOVATION AS REGIONAL LEARNING PARADIGMS AND TRAJECTORIES

The conceptual interpretation

The regional patterns of innovation framework presented in the previous section is fundamentally a structural (static) approach. Such an approach, however, can also be extended in a dynamic perspective so as to explain the conditions under which a new and more complex innovation pattern can emerge in an area. In a recent paper, an interpretation of the dynamics of regional patterns of innovation has been proposed. This interpretation builds on the idea that any dynamic and process of change of regional innovation patterns is shaped by the evolution of the specific context conditions and the technological/cognitive dimension defining them (Capello & Lenzi, 2016b).

Importantly, evolutionary economics (e.g., Dosi, 1982; Nelson & Winter, 1982), evolutionary regional economics (e.g., Aydalot, 1986; Camagni, 1991; Cerisola, 2016), and evolutionary economic geography (e.g., Asheim et al., 2015; Martin & Sunley, 2006; Simmie, 2012; Trippl et al., 2015) have repeatedly illustrated how the laws of dynamics of structural elements and of the cognitive dimension are characterized by path dependence. In this respect, two evol-utionary conceptual tools can be useful in the elaboration of the dynamic interpretation of regional innovation patterns.

First, evolutionary thinking highlights that learning, innovation and change are characterized by cumulative trajectory and paradigm patterns of evolution (Dosi, 1982). On elaborating this intuition in the context of regional pat-terns of innovation, it means that the dynamics of regional patterns of innovation can be interpreted in terms of ordered processes of change along and across specific tra-jectories and paradigms.

Following this approach, then, the conceptual 'archetypes' of regional innovation patterns can be interpreted as *regional learning paradigms*, in that they represent modes of innovation and knowledge accumulation stem-ming from the functional and relational characteristics of territories. By 'functional characteristics' we mean the knowledge-creating functions internal to and available in a region in the form of institutions/organizations (e.g., uni-versities, research centres and local firms) and all informal relationships that give rise to local collective-learning pro-cesses. By 'relational characteristics' we mean long-distance relationships that take place between local actors and selected extra-regional partners, in line with the *milieu innovateur* approach (Camagni, 1991) as well as the local preconditions for the existence and maintenance of such relationships. In short, regional learning paradigms represent regional systems of relationships (internal and external to the region) that shape the process supporting innovation, and therefore identify the way in which new knowledge is acquired and a learning process is developed. A change of regional learning paradigm therefore derives from a change of either its functional (internal) character-istics or its relational (external) characteristics, or both.

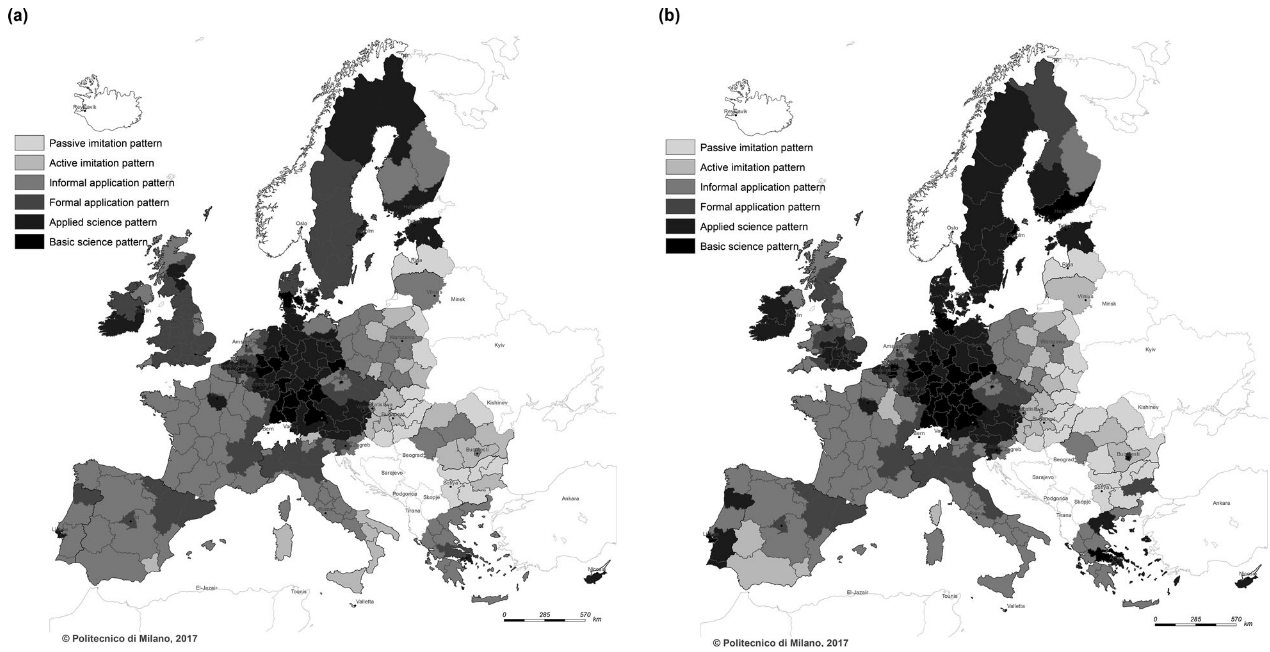

Figure 1. Regional patterns of innovation: (a) 2002–04; and (b) 2004–06.

By extension, the empirical regional innovation patterns can be interpreted as alternative *regional learning trajectories* within each specific paradigm, defined according to the type of knowledge (basic versus applied, formal versus informal, active versus passive) and the intensity of the type of innovation specific to each paradigm (either imitation, or application or invention) (Capello & Lenzi, 2016b).

A change of regional learning trajectory therefore derives from a change of the type of knowledge within each paradigm. In fact, within each paradigm, as time passes, the intensity of imitation/application/invention can increase along a trajectory, while keeping a similar quality of knowledge.

The second important conceptual tool deriving from evolutionary theory is the notion of path dependence. In fact, evolutionary theory explains how path dependence affects structural dynamics and therefore the possibility to move from one trajectory/paradigm to another, and how such moves can occur. As discussed for technological paradigms and trajectories by Dosi (1982), and more recently in a spatial perspective by Martin and Sunley (2006), Simmie (2012) and Henning, Stam, and Wenting (2013),[8] among others, path dependence can condition and set the boundaries of the direction and the alternative options in which change and evolution can be gradually channelled, i.e., how a new regional learning trajectory/paradigm can be initiated and develop over time.

The next section then elaborates on the pathways behind a change from one trajectory/paradigm to another by offering an explanation of when and under what conditions (i.e., through which channels and paths) a new learning trajectory/paradigm is able to emerge in a complex landscape of path-dependent developments of structural elements.

Local pathways of change

Changes of paradigms or trajectories can stem from two sources. The first is related to deliberate action, purposive design, intentional behaviour, strategic decision, 'mindful deviations' of knowledgeable economic agents, notably entrepreneurs (but also policy-makers), interpreted as the key endogenous drivers of novelty and, by extension, of new learning paradigms and trajectories (Simmie, 2012). Recent works in evolutionary economic geography have highlighted alternative intentional behaviours that trigger an endogenous switch and open the way to alternative local development (industrial) paths (e.g., Martin & Sunley, 2006; Simmie, 2012). These intentional behaviours identify possible paths through which agents' deviant actions can turn into a gradual transformation of current arrangements and structures (i.e., in a path-dependent manner) leading to the creation of new ones (Martin & Sunley, 2006; Simmie, 2012). For example, Martin and Sunley (2006) conceptualize five alternative options in regional economic evolution, i.e., indigenous creation, heterogeneity and diversity, transplantation, diversification into related activities, and upgrading. Importantly, these alternative options are conceived and applied to study the evolution of a regional economic system as a whole and, in particular, its industrial structure (Martin & Sunley, 2006).

However, on purely theoretical grounds, it is not possible to exclude that the emergence of a new trajectory/paradigm can be driven by a spontaneous, unconscious, unplanned and uncoordinated process (i.e., disembodied economic forces) which represents the second source of evolutionary change.

Both types of change represent abstract, stylized and conceptually different pathways that can be detected in regions when shifting from one trajectory/paradigm to another.[9] They apply to whatever type of paradigmatic change is faced, from imitative to applicative and from applicative to science-based paradigmatic shifts, with specificities, however, with respect to the context conditions (functional or relational) and the cognitive dimension that forge each paradigm/trajectory, as further detailed in the next sections.

In this paper, three main evolutionary pathways are expected to lead to a change of a regional learning trajectory/paradigm: namely creation, diversification and upgrading (Capello & Lenzi, 2016b). These pathways can emerge as the outcomes of unintentional events or of purposeful, mindful and intentional behaviours (i.e., strategic and economic decisions) of local economic agents. This last interpretation is consistent with the idea of 'strategic management of place' advanced by Audretsch (2015), which refers to the deliberate and purposeful efforts, or *strategies*, of places, i.e., of their local economic agents, to improve their place.

In the context of regional learning trajectories, creation represents a pathway 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 and integrated, as similarly described by 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. Diversification entails an expansion of the existing local research/industrial base through a branching process à la Frenken and Boschma based on related variety mechanisms (Frenken, van Oort, & Verbug, 2007). 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 (Henning et al., 2013). Lastly, upgrading refers to the rejuvenation, revitalization and enhancement of the existing local research/industrial base by means of a reorientation process leading to conversion to new activities so as to serve new purposes and to move upwards in the value chain (Martin & Sunley, 2006). 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 adding value and knowledge content to it.

In the case of regional learning paradigms, the pathways 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 relational dimensions.

Applied to the functional dimension, a creation pathway entails a better exploitation of both material and non-material local resources, including, for example, the formation of local human capital, as well as establishing scientific and technical organizations and infrastructures previously not available. A diversification pathway instead 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 an enlargement of the mix of the functions performed in a region so that it includes complementary and interrelated ones. Differently, upgrading involves a 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.

As regards the relational dimension of regional learning paradigms, creation means the generation, launching and revitalization of relationships outside the region. 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 those that exist. 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 (more complex and advanced) purposes.

The subsequent parts of the paper present an empirical analysis to highlight whether empirical regularities exist in the link between the above-mentioned pathways and the change in paradigms and trajectories envisaged in the second section.

METHODOLOGICAL ASPECTS

Two main premises have driven our empirical approach to understanding the role of the three alternative pathways in the change of regional learning trajectories and paradigms. Firstly, we start from the idea that the endowment of specific characteristics supporting the presence of a complex learning trajectory/paradigm in a region belonging to a less complex trajectory/paradigm indicates that that particular region is more likely to change its innovation trajectory/paradigm. Secondly, we contend that the presence of this endowment is not random, but achieved as the result of long-term intentional behaviours, actions and/or unintentional events that drive the region to cumulate the characteristics favouring that particular change. This approach is indeed consistent with the view that a change occurs when niche, deviant behaviours become dominant and prevailing at the regional level (Simmie, 2012).[10]

Based on this approach, it is possible to establish a link, i.e., to detect an empirical regularity, when there is a (statistically) significant association between a change in a region's learning trajectory and a greater endowment of those characteristics enabling a change in the region.

Technically, in order to establish such a link we conducted a series of statistical tests (i.e., t-tests) to compare the endowment of the preconditions for change in the group of regions that changed their learning trajectory/paradigm with respect to the group of regions that maintained it. T-tests in fact enable assessment of whether the average value of one variable (i.e., precondition for change) statistically differs between the group of regions that changed their learning trajectory/paradigm and the group of regions keeping their learning trajectory/paradigm. We chose this approach for two concomitant reasons. First, the number of observations (i.e., regions) displaying a change was limited, especially for some specific jumps (e.g., there were only three regions moving from the informal to the formal application trajectory; see also Table A1 in Appendix A in the supplemental data online). This condition prevented us from using regression techniques adequately and safely. Second, by means of *t*-tests we were able to identify structural characteristics common to regions experiencing a change and, thus, to establish an association between regional features enabling change and actual changes. We are aware that this approach does not enable the drawing of cause–effect conclusions as more advanced econometric techniques would do. Nonetheless, it affords preliminary insights into the phenomenon under consideration for a large number and variety of regions (i.e., 262 NUTS-2 regions of European Union). This is definitively a novel and original aspect of the paper that complements if not supersedes case-based and anecdotal evidence, largely framing and supporting the existing scientific debate in this field.

This approach, however, encounters substantial empirical challenges. First, it is necessary to exemplify how each pathway is linked to an endowment of specific characteristics favouring the move from one specific trajectory to another (e.g., from passive to active imitation, from informal to formal application, from basic to applied science) or from one specific paradigm to another (e.g., from imitation to application, from application to science based). Second, it is necessary to identify single indicators specific and exclusive to each specific jump and each pathway. Empirically speaking, this latter task is extremely complex. Therefore, our approach aimed primarily to distinguish the specificities of the change from one particular trajectory/paradigm to another, rather than to distinguish exactly among pathways. Nevertheless, an attempt was made to identify precise indicators to be linked to each single pathway in the context of each trajectory/paradigm jump, as detailed in the following sections. The precise definition and measurement of the selected indicators is available in Table A2 in Appendix A in the supplemental data online.

CREATION, DIVERSIFICATION, UPGRADING AND THE DYNAMICS OF REGIONAL LEARNING TRAJECTORIES

With regard to the empirical approach described in the previous section, the indicators, together with the results achieved in the case of changes in trajectories, are now presented (Table 1).

In the case of the move from the passive to the active imitation trajectory, all three types of pathway (creation, diversification and upgrading) are expected to generate preconditions that favour the introduction of some degree of novelty and adaptation in the imitation processes implemented in the region. Indicators should therefore capture such an effort. In the case of the creation pathway, a possible indicator of the capacity of an area to attract and create new activities is an indicator of penetration by foreign investments (regional foreign direct investment (FDI) penetration rate). The literature highlights the importance of FDI as a channel of knowledge and innovation transmission and as a trigger of creative imitation activities in laggard areas (Caragliu & Lenzi, 2013). In the case of the diversification pathway, an index of related variety in local economic sectors can be useful to grasp the expansion of local activities in proximate sectors, thus capturing the capacity to diversify local activities (Frenken et al., 2007). Finally, the upgrading pathway entails

Table 1. Creation, diversification, upgrading and regional learning trajectory dynamics: indicators.

Pathway	From basic to applied science trajectory	From applied to basic science trajectory	From informal to formal application trajectory	From passive to active imitation trajectory
Creation	Making the best use of existing excellence niches in applied sciences *Indicator: no GPT patents per capita*	Making the best use of existing excellence niches in basic sciences *Indicator: GPT patents per capita*	Making the best use of technological niches *Indicator: Patents per capita*	Attracting new economic (MNC) activities *Indicator: FDI penetration rate*
Diversification	Enlarging research activities toward basic science fields *Indicator: Continuity of the knowledge base*	Enlarging research activities toward basic science fields *Indicator: Originality of the knowledge base*	Enlarging local production towards technology-oriented modes of innovation/industries *Indicator: Technological diversification*	Enlarging local activities to related ones *Indicator: Related variety in local sectors*
Upgrading	Enriching the knowledge base in basic science fields *Indicator: Specificity of the knowledge base*	Enriching the knowledge base in basic science fields *Indicator: Generality of the knowledge base*	Formalizing the knowledge base *Indicator: Citations received per capita*	Redirecting local production to more complex goods *Indicator: GVA in (medium-) high-tech sectors*

Note: FDI, foreign direct investments; GPT, general-purpose technologies; GVA, gross value added; MNC, multinational corporation.

redirecting local activities to more complex productions, which can be captured by the share of gross value added (GVA) in (medium-) high-tech sectors generally associated with a greater knowledge content (Pavlínek, 2002).

The move from the informal to the formal application trajectory instead requires that the three pathways involve a change in the type of the externally sourced knowledge applied to local innovation needs, from informal to formal and technology-based knowledge. Accordingly, such a move can be linked to the exploitation of (new) technological niches in the case of the creation pathway, measurable through a standard indicator of technological activities such as patents (Hall, Jaffe, & Trajtenberg, 2001). A diversification pathway can be captured by the enlargement of local activities towards technology- and knowledge-based modes of production and innovation via a traditional indicator of technological diversification, namely, the opposite of the Herfindahl index computed on patents' technological classes (Frenken et al., 2007). Lastly, the upgrading pathway entails the formalization and improvement of the knowledge at the basis of local production and technological activities. The number of citations received per capita can capture the (technological and economic) importance of the patents (i.e., formal knowledge) produced locally (Hall et al., 2001) and, thus, can be a useful proxy for upgrading.

A shift from the applied to the basic science trajectory on the other hand entails a change in the predominant characteristics of the scientific knowledge base, namely from applied to basic science (see also endnote 4). The creation pathway can be grasped through the smarter utilization of (new or existing) excellence niches in basic sciences. In measurement terms, an indicator of the basicness of the local knowledge can be a useful proxy. The knowledge base's basicness is measured through the number of patents in general-purpose technologies (GPT) per capita, as suggested by some studies (Foray et al., 2009). A diversification pathway can be linked to the expansion of existing research activities towards basic science fields which require the mastery and recombination of different sources and pieces of scientific knowledge. A proxy for the diversification pathway can be the originality of the regional knowledge base resulting from the recombination of pieces of knowledge distributed across different technical fields (i.e., citations to different technologies) and associated with previously unexplored applications (Hall et al., 2001). The indicator of originality used is the opposite of the Herfindahl index computed on the technological classes of the citations made. Finally, upgrading is linked to the reorientation of the existing knowledge base towards basic science fields, leading to a more abstract and general knowledge base. The generality index (defined as the opposite of the Herfindahl index computed on the technological classes of the citations received) can be a useful indicator in this case, since more general knowledge has wider applications and a greater technological value (Hall et al., 2001).

The opposite move from basic to applied science[11] can be based on similar (albeit reversed) mechanisms. For example, creation can be linked to the exploitation of excellence niches in applied sciences, diversification to the expansion of local research activities into applied fields and upgrading to a reorientation of local research towards applied science fields. Empirically, suitable indicators can be the opposite of those used in the case of the move from the applied to the basic science trajectory.

As described in detail in the fourth section, the *t*-tests assessed whether regions changing their learning trajectory showed in a previous period a greater endowment of preconditions for change with respect to regions that maintained it. These tests were conducted in the two cases presenting a sufficient number of changes: the move from the informal to the formal application trajectory, and the change from the applied to the basic science trajectory. The results are reported in Table A3 in Appendix A in the supplemental data online, together with their statistical significance. Interestingly, the results suggest that whatever pathway considered, those regions moving from the informal to the formal learning trajectory show a statistically significant larger endowment of preconditions for change: a more formal and technical knowledge base (patents), a more diversified technological profile (technological diversification), and a more formalized knowledge base (citations received). Similarly, regions that moved from the applied to the basic science trajectory exhibit a more basic (GPT patents), original (originality) and general (generality) knowledge base.

Overall, therefore, findings support the view that, for both types of learning trajectories examined above, the proposed pathways of creation, diversification and upgrading prove to be positively and significantly associated with actual changes in regional learning trajectories. This conclusion has important implications. Without contradicting the existing literature emphasizing the importance of diversification, our results suggest that there can be plausible alternatives to diversification for regions willing and ready to change their innovation patterns and learning trajectory. While creation might be a highly risky (though highly rewarding) pathway, upgrading can be a viable and promising option if diversification is not feasible.

CREATION, DIVERSIFICATION, UPGRADING AND THE DYNAMICS OF REGIONAL LEARNING PARADIGMS

A similar reasoning to trajectories was applied to identify indicators for preconditions for change in the case of paradigmatic jumps, with the intention to suggest specific indicators not only for each type of move and each pathway but also for the functional and relational dimensions defining each paradigm (Table 2).

First consider the change from the imitation to the appli-cation paradigm. Regarding the functional dimension, all three pathways involve the generation of local preconditions useful for developing autonomous local innovation. Such a change, then, can be related to a better use of creative human capital resources in the case of creation. Suitable indicators in this case can be the share of managers and/or technicians on total employment, which can capture the

Table 2. Creation, diversification, upgrading and regional learning paradigm dynamics: indicators.

Pathway		From application to science-based paradigm	From imitation to application paradigm
Creation	Functional dimension	Making the best use of returnee scientists *Indicator: Inventor inflows on population*	Making the best use of creative human capital resources *Indicators: Managers and technicians (% on total employment)*
	Relational dimension	Making the best use of external technological relations *Indicator: Co-patents per capita*	Making the best use of technical excellence niches *Indicator: Entrepreneurial ability, risk perception and competitive attitude*
Diversification	Functional dimension	Expanding application-based activities to science-based ones *Indicator: R&D expenditure on GDP (%)*	Expanding the existing industrial activities to higher-level ones *Indicator: Top level occupations (location quotient on total employment)*
	Relational dimension	Expanding the ability to be part of a network *Indicator: Extra-regional citations made per capita*	Expanding local activities into application-based fields *Indicator: Entrepreneurial technological adoption*
Upgrading	Functional dimension	Reorienting the application-based activities to science-based ones *Indicator: Employment in high-tech sectors (%)*	Reorienting existing industrial activities to higher-level ones *Indicator: Trademarks and product designs per capita*
	Relational dimension	Reorienting local existing relationships to new science-based actors *Indicator: 5th Framework Program projects per capita*	Reorienting local entrepreneurship to creative activities *Indicator: Entrepreneurial product and process innovation*

Note: GDP, gross domestic product; R&D, research and development.

knowledge and capabilities embedded in specialized workers. These workers are indeed those most likely to adapt and improve the production processes leading to the introduction of innovation (Fagerberg & Shrolec, 2008). Differently, diversification entails an expansion of local production activities to more complex production functions. The extent and relevance of the latter can be measured by the share of the most value-added occupations in total employment (Capello & Lenzi, 2013). Lastly, upgrading refers to the reorientation of local activities to more complex ones. The degree of complexity of local activities can be associated with the number of issued trademarks and designs per capita because they indicate the capacity to make local activities more creative and internationally recognized (Mendonça, Pereira, & Godinho, 2004).

In terms of the relational dimension, all three pathways are expected to generate local preconditions to facilitate external relations that are weak in the imitation paradigm but fundamental in the application paradigm to source external knowledge to be applied for local innovation needs. The establishment and maintenance of such external relations dedicated to the scouting and sourcing of external knowledge is primarily an entrepreneurial task. Accordingly, creation can be associated with the exploitation of existing technological and production excellence niches pioneered by local enlightened entrepreneurs open to grasping opportunities and ready to take the risk of launching new businesses and face competitive pressure on (international) markets. Measures of entrepreneurial ability, risk perception and competitive attitude, made available by Szerb, Acs, Autio, Ortega-Argilés, and Komlosi (2013), are used as a proxy for creation. Along the same line of reasoning, diversification can be linked to the expansion of local activities into technology and applied fields, which may be led by entrepreneurs ready to deploy new technologies. The indicator of entrepreneurial technological adoption developed by Szerb et al. (2013) measures this aspect of entrepreneurship and is used as a proxy for diversification. Upgrading, instead, can be related to a reorientation of local entrepreneurial activities towards more creative applications, i.e., to the presence of innovative entrepreneurs inclined to introduce product and process innovations. The indicators of entrepreneurial product and process developed by Szerb et al. (2013) measure these characteristics of entrepreneurship and are used as proxies for upgrading.[12]

In the case of the shift from the application to the science-based paradigm, all three pathways involve the reinforcement of local preconditions useful for developing autonomous knowledge production activities, weak or inexistent in the application paradigm, when the functional dimension is taken into account. This change can be associated with the attraction of highly skilled human capital resources that can open new research and production fields, like, for example, returnee scientists in the case of the creation pathway. A useful proxy in this case, therefore, could be inventor inflows on population (Miguélez & Moreno, 2013). Moreover, this change can be linked to the expansion of local production and development activities to include also research activities in the case of the diversification pathway, which can be captured by the share of R&D expenditures on GDP (Vogel, 2015). Lastly, this change can involve the reorientation of local activities to science-based ones. The importance of science-based activities can be grasped by looking at the share of employment in high-tech sectors, which is generally concentrated in science-based sectors (Szerb et al., 2013).

In terms of the relational dimension, all three pathways are expected to favour local preconditions to enrich external relations. In the case of the creation pathway, new external relations can be created (or reinforced, if not fully exploited) by launching joint research and technological activities that can eventually lead to the opening of new fields of production and research activities. Empirically, the number of per capita co-patents with extra-regional partners can account for the possibility of using external knowledge to create new local activities, as suggested by the literature (Miguélez & Moreno, 2013). In the case of the diversification pathway, external relations can be expanded by reinforcing the presence in scientific and tech-nological networks, so as to become more visible, stable and central partners in existing (and new) scientific and techno-logical networks. The number of extra-regional citations made per capita can indicate the capacity to source external knowledge and be a recognized partner of a network (Miguélez & Moreno, 2013). Finally, external relations can be used to reinforce the local scientific knowledge base in the case of the upgrading pathway. The number of the 5th Framework Program (FP) projects per capita indicates the capacity to launch external relations that involve scientific collaborators and can thus work as a proxy for upgrading (Capello & Lenzi, 2013).

Overall, findings based on *t*-tests confirm the main conclusion deriving from the analysis of the dynamics of regional learning trajectories, i.e., the dynamics of regional learning paradigms can be associated with the proposed pathways of creation, diversification and upgrading (see Tables A4 and A5 in Appendix A in the supplemental data online). In fact, whatever the pathway and the specific move considered, those regions changing their learning paradigm show a statistically significant larger endowment of preconditions for change. In the case of the move from the imitation to the application paradigm, this entails a bet-ter endowment in terms of more complex occupations (share of managers and technicians), of job market expansion in top-level occupations (location quotient (LQ) of top occupations), and of creativity (designs and trademarks). Moreover, these regions have a higher propensity to create new entrepreneurial activities (entrepreneurial ability and risk perception) and face competition (entrepreneurial competitive attitude), to adopt new technologies (entrepreneurial technological adoption) and to introduce innovation (entrepreneurial product and process innovation).

Regions transiting from the application to the science-based paradigm exhibit greater highly skilled human capital attractiveness (inventor inflows on population), stronger knowledge creation activities (R&D on GDP), and a job market expansion in knowledge-intensive sectors (employment in the high-tech sector). Additionally, these regions present an enhanced propensity to engage in joint knowledge-creation activities (extra-regional co-patents), to source knowledge from outside (e.g., extra-regional citations made), and to enter research networks and exchange knowledge (FP projects).

These results reinforce the main conclusion deriving from the analysis of regional learning dynamics, namely that creation and upgrading can represent viable alternatives to diversification in order to achieve a change of the current paradigm (see also Table A6 in Appendix A in the supplemental data online). Moreover, these results highlight that changes along both the functional and the relational dimensions are significant for moving towards a more complex paradigm, testifying that these dynamics are complex and multidimensional evolutionary processes.

CONCLUSIONS

The empirical investigation of the dynamics of regional innovation patterns in Europe has interesting implications on how to have a region move towards a more complex learning trajectory and paradigm. The results achieved by this study do not contradict the diversification argument in the current academic debate and policy arena, and they are fully consistent with a place-based approach to regional innovation policies (Boschma, 2014).

More than this, however, they highlight and empirically testify that other pathways can be explored and exploited to achieve changes in current trajectories and paradigms. Upgrading and creation can be worthy alternatives to activate such evolutionary changes. Especially in areas with limited density of economic and innovative activities (and therefore limited scope for diversification), upgrading can be a valuable and still promising option, one definitely less risky than creation. An upgrading pathway (with respect to both trajectories and paradigms) has indeed been detected in some successful European regional cases (Caragliu & Lenzi, 2013).

Our results also emphasize the multidimensional nature of the evolutionary processes needed to make a region move towards a more complex learning paradigm. In particular, they suggest that diversification of economic/innovative activities can be a good option to pursue change (even if it is not the only one available), but it is 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. Theoretically speaking, the smart specialization strategy has rightly adopted this approach by emphasizing the role of connectivity. However, practically, the first action plans put in place by the regions highlighted that the identification of inter-regional links had been almost entirely ignored and inter-regional links between core and peripheral areas turned out to be very weak (Iacobucci & Guzzini, 2016). Moreover, by favouring scientific links between advanced and laggard areas, whatever the structure of local relationships and the mode of learning, the smart specialization strategy has implicitly induced lagging regions to jump to modes of knowledge exchange that do not reflect their predominant mode of learning and interacting (Capello & Kroll, 2016; Capello & Lenzi, 2016b).

These conclusions concern matters to be reflected upon in the next round of regional innovation policies.

DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

SUPPLEMENTAL DATA

Supplemental data for this article can be accessed at http://dx.doi.org.10.1080/00343404.2017.1296943

NOTES

1. Cooke (2001) acknowledges that RIS are rare.
2. Although the 'linear model of innovation' has been heavily criticized as unrealistic and rooted in the idea of a rational and orderly innovation process, in many cases scientific advances are still a major source of innovation, as the information and communication technology paradigm indicates. As recently argued by Balconi, Brusoni, and Orsenigo (2010), an alternative model of full complexity, where 'everything depends on everything else', does not help in conceptualizing and interpreting the systemic, dynamic and interactive nature of innovation. Additionally, self-reinforcing feedbacks from innovation to knowledge and from economic growth to innovation and knowledge play an important role in innovation processes. Finally, the impact of science on innovation does not merely reside in the creation of new opportunities to be exploited by firms; it also concerns the increasing productivity of, and returns to, R&D through the solution of technical problems, elimination of research directions that have proven wrong and the provision of new research technologies. We therefore strongly support the concept of a 'spatially diversified, phase-linear, multiple-solution model of innovation', in which the single patterns represent a linearization, or a partial block-linearization, of an innovation process where feedbacks, spatial interconnections and non-linearities play a prominent role.
3. The regional patterns of innovation framework adopts a relative conception of innovation: regions are innovative insofar as 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). In this respect, imitation can also represent innovations that are new to a region.
4. In the present context, basic scientific knowledge is produced through research activities and tends to have wider technological applications and commercial value, to be more original, recombinatorial and radical, and to be oriented to GPT such as biotechnology, information and communication technology, and nanotechnology. The opposite applies to the applied scientific knowledge. For a similar discussion, see Capello and Lenzi (2013).
5. In the present context, 'formal knowledge' refers to codified technological, engineering-based knowledge. On the other hand, 'informal knowledge' refers to knowledge that is uncodified, tacit, embedded in professional capabilities, and based on professional practices and experience. For a similar discussion, see Capello and Lenzi (2013).
6. In the present context, we distinguish among different types of imitative behaviours according to the degree of creativity and adaptation introduced in the imitation process (active versus passive imitation). For a similar discussion, see Capello and Lenzi (2016a).
7. Some authors argue that this type of knowledge is primarily exchanged through geographical proximity. Yet, there are several cases documented in the literature in which this type of knowledge is also exchanged at long distances through employees' mobility (Trippl et al., 2015).
8. For a thorough theoretical discussion of the notion of path dependence and its application in a spatial perspective, see, for example, Henning et al. (2013).
9. In other words, creation, diversification and upgrading are alternative mechanisms through which local agents' behaviours and events can lead to change in a region's learning trajectory/paradigm, i.e., through which a regional learning trajectory/paradigm can evolve into a new, more complex, one. Even if we cannot observe which specific agents (e.g., entrepreneurs or policy-makers) have been leading the process of change, we can still see the final aggregate outcome (at the regional level) of such deviating individual actions, and this is the focus of the paper. For a similar approach, see Schamp (2005).
10. Rather than observing and measuring directly the different pathways (an almost impossible task with secondary data), we propose an indirect approach. In fact, an endowment of preconditions for change (specific to each pathway and jump) is interpreted as a proxy for different behaviours and actions and/or events put in place by local actors in previous times. Therefore, in our empirical exercise we linked the outcome of longer-term and slow evolution processes and pathways to the presence and probability of a change. Hence, we could not establish and observe the exact starting point in time of such processes; this is, however, not of detriment to our reasoning. This also explains why the indicators of endowment have only a few time lags with the variable measuring the change in innovation patterns, even if structural long-term effects are the subject of analysis.
11. Such a change is not only conceptually conceivable but also empirically testified by several real cases. Cambridge (UK) perfectly fits this pathway. The region, in fact, has

moved from a pure basic science trajectory to a more applied one because of the increasing proliferation of research and technologies based on knowledge recombination, as also described by Martin and Sunley (2006).

12. In a recent paper, Capello and Lenzi (2016c) show how different regional entrepreneurial characteristics and innovation patterns combine to affect regional growth. While based on the same regional innovation pattern framework, the present work departs from the previous one in that the focus is on the dynamics and pathways of regional innovation patterns and not on economic dynamics (i.e., regional GDP per capita growth).

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