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The dynamics of regional learning paradigms and trajectories: an empirical investigation

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Abstract
Based on the conceptual notion and the empirical verification that innovation follows differentiated spatial patterns, the paper analyses the conditions that enable regions to change their innovative patterns. Consistently with the evolutionary theory, these changes are interpreted as path-dependent processes characterized by trajectories and paradigms, understood as learning processes. Creation, diversification and upgrading strategies are proposed as to shift to more advanced learning trajectories and paradigms. Empirical evidence on European regions supports the relevance of these strategies to advance towards more complex learning and innovation processes and to catch-up in the innovation ladder.

JEL codes: O11, R11
Keywords: regional patterns of innovation, regional learning paradigm, regional learning trajectory, strategies.

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1. 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 (Crescenzi and Rodríguez-Pose, 2011; Capello, 2013; Asheim et al., 2011 and 2015).

Several and contrasting territorial innovation theories have been elaborated to highlight the territorial conditions under which innovation occurs in an area and to interpret the link between regional innovation and economic performance (see for reviews Moulaert and Sekia, 2003; Crevoisier and Jeannerat, 2009). Amongst the existing approaches, regional innovation systems (RIS) (Cooke, 2001; Asheim et al. 2011, 2015), learning regions (Morgan, 1997; Asheim, 2012), milieux innovateurs (Aydalot, 1986; Camagni, 1991; Crevoisier. 2004), the social filter theory (Rodríguez-Pose, 1999; Crescenzi and Rodríguez-Pose, 2009; Rodríguez-Pose and Crescenzi, 2008; Crescenzi and Rodríguez-Pose, 2011), regional patterns of innovation (Capello, 2013, Capello and Lenzi, 2013) figure prominently.[1] The common goal of these theories 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 are). Importantly, all these theories 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 theories cleverly point out the conditions under which innovation occurs in a region, and therefore its innovation pattern, they do not propose any reflection on how these innovation patterns evolve over time, i.e. they are unable to explain the determinants of the dynamics of regional innovation patterns (Asheim et al., 2015; Trippl et al., 2015). Consequently, an unexplored research avenue is the explanation of the determinants of the dynamics (i.e. change vs. persistence) of such innovation patterns, through the analysis of the system of relationships (internal and external to the region) supporting them (Hassink and Klaerding, 2012). In other words, how, when, and why alternative and more advanced 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.[2]

This paper aims to tackle this issue by offering a twofold contribution. First, building on a previous conceptual work of the authors (Capello and Lenzi, 2015c), it proposes a conceptualization of the possible determinants of evolution and progress of innovation patterns in regions; second, it identifies empirical regularities to support this new conceptual approach, in the methodological spirit of 'appreciative theorizing', i.e. a theory that aims to capture the basics of what actually is going on (Nelson and Winter, 1982; Nelson, 2008). By doing so, the paper provides insights on how advances can be made in regions so to move towards more complex learning and innovation patterns and to catch-up in the innovation ladder (Lee and Malerba, 2015). This empirical step forward is important for developing sound policy interventions to move regions to more advanced modes of innovation. This perspective demands a relative concept of innovation: regions are innovative as far as local firms are able to do something new with respect to their past, and not with respect to a dominant paradigm

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

[2] We acknowledge that learning and innovation processes are centred in firms and economic agents within each region have a large variety of innovative attitudes. Yet, this paper focuses on the regional outcome and consequences which emerge from learning and innovation (and their change) in firms (for a similar discussion, see Schamp, 2005).

present worldwide (Camagni, 2015). The regional patterns of innovation framework particularly suits this requirement as it fully ascribes such a relative approach to regional innovation. Regional patterns of innovation, in fact, represent different spatial combinations stemming from the heterogeneous availability of a local knowledge base (cognitive inputs) and context conditions for knowledge creation and acquisition (Capello, 2013). This framework has been now conceptually accepted and empirically proved (Capello and Lenzi, 2013, 2015a) and presents the advantage of considering all types of innovations, from radical to imitative approaches. Especially 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; Radosevic, 2002; Trippl, 2010).[3] This paper therefore will 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 allow to understand how more complex learning and innovation processes can emerge even in backward areas.

The remainder of the paper is organised 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 (Section 2). Then, by building on theoretical insights from evolutionary economics, evolutionary regional economics and evolutionary economic geography, it 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 strategies to move towards a new learning paradigm and trajectory (Section 3). Next, the paper proposes a way to measure empirically the preconditions enabling the implementation of these evolutionary strategies in the context of a change in a region's learning trajectory and offers empirical evidence about how such preconditions are associated to actual changes detected in European regions (Section 4). Similarly, the following section extends this discussion to the context of a change in a region's learning paradigm and offers empirical evidence about how such preconditions are associated to actual changes detected and impact on the probability of such changes in the case of European regions (Section 5). Concluding remarks are finally put forward (Section 6).

2. The dynamics of regional patterns of innovation

The conceptual framework used in this paper is based on the notion of regional patterns of innovation. Such a framework accounts for the specific characteristics of the knowledge and innovation creation processes in a region and stems from the strong belief that regions innovate following differentiated patterns, i.e. according to the presence/absence of some context conditions that allow for the creation and/or the adoption of knowledge and innovation. Regional patterns of innovation, in fact, represent combinations of context conditions and of specific modes of performing and linking the different phases of the innovation process (Capello, 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). Three main 'archetypal' innovation patterns have been conceptualized (Capello, 2013), each of them reflecting a specific body of literature on knowledge and innovation in space. In particular, a micro-founded approach drives the

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

conceptualization of territorial patterns of innovation because certain territorial resources and conditions influence certain types of firms' strategies and behaviors (Capello and Lenzi, 2015a). The main innovation patterns can be described as follows:

a) *a science-based pattern*, where knowledge is created by local actors and functions like universities, R&D centres and large firms, and their local relationships, enriched by interregional cooperation with selected partner, as highlighted in most of literature dealing with knowledge and innovation creation and diffusion (Audretsch and Feldman, 1996; Jensen et al., 2007; Mack, 2014);
b) *a creative application pattern* where entrepreneurial creativity and collective learning allow to source external knowledge and apply it for local innovation needs (Foray, 2009; EC, 2010; Licht, 2009). Knowledge providers supporting the innovative activities of local firms are mostly located outside the region, and knowledge exchanges are nourished more by cognitive and sectoral proximity (i.e. shared cognitive maps) than by belonging to the same local community (Asheim and Isaksen, 2002);
c) *an imitative innovation pattern*, where relationships between local firms and dominant firms (typically multinationals) allow to adopt an innovation new for the area as described in the literature dealing with innovation diffusion (Hägerstrand, 1952; Pavlínek 2002, 2004; Varga and Schalk 2004).

Moreover, within each theoretical pattern characterized by a specific relational structure[4], two distinct processes of knowledge accumulation and knowledge acquisition channels for innovation discovery can be identified, depending on different cognitive bases. In this respect, two clusters can be associated with the first conceptual pattern, differing in terms of basic vs. applied scientific knowledge base. Two clusters can be associated with the second pattern, differing in terms of formal vs. informal knowledge. Two clusters can be associated with the third pattern, differing in terms of an active vs. passive attitude towards innovation. In short:

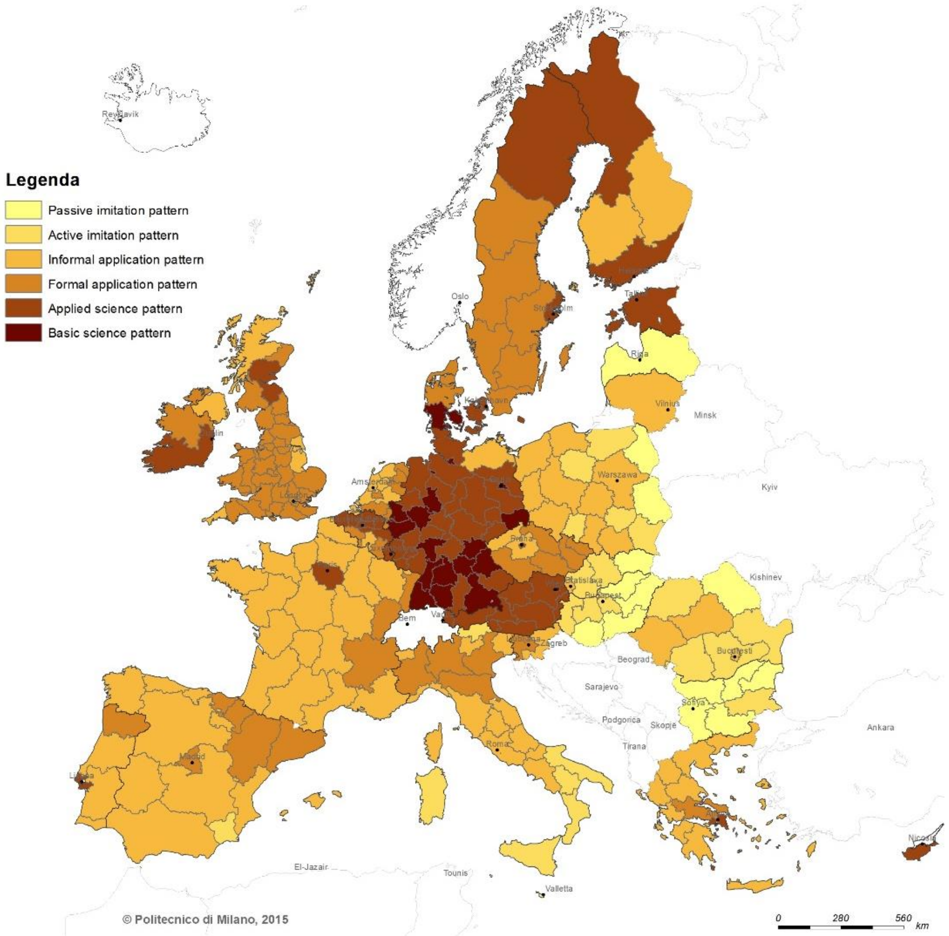
- the science-based pattern is divided between a basic and an applied science-based pattern;
- the creative application pattern is divided between a formal and an informal knowledge application-based pattern;
- the imitative innovation pattern is divided between an active an a passive imitation pattern.

Regional innovation patterns have been recently identified empirically in European regions for the period 2002-2004 (Capello and Lenzi, 2013, 2015b) (Map 1). In this paper, the same exercise has been conducted for the period 2004-2006 (Map 2), so that a comparative analysis over time is available.[5]

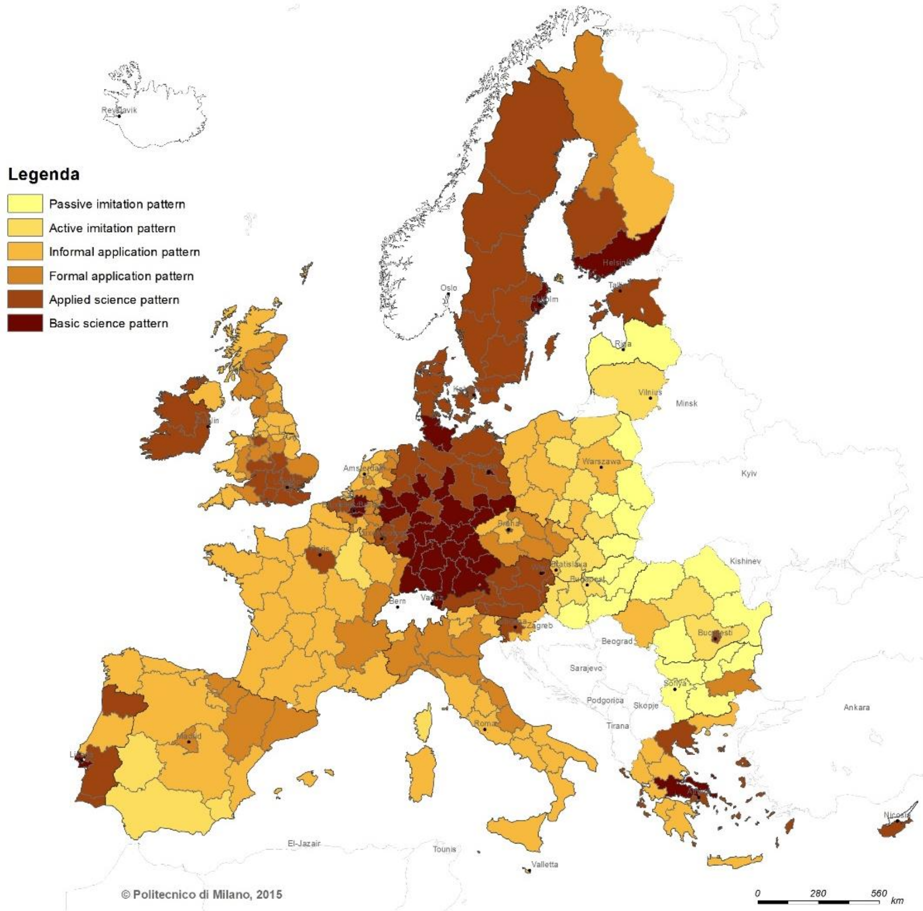
[4] Regional innovation patterns vary in terms of the relational structure supporting knowledge creation and acquisition. In the science-based patterns, (scientific) knowledge is exchanged on a bilateral basis across regions; in the application-based patterns, instead, external relations are essential to access locally unavailable (formal or informal) knowledge; whilst in the imitation patterns external knowledge is acquired as embedded in innovations developed elsewhere and then replicated and, possibly, adapted locally.

[5] For further details on the variables used in the cluster analysis implemented to detect innovation patterns in European regions and the variables representing the key territorial features of the different groups of regions see Capello and Lenzi (2013, 2015b).

Map 1. Regional patterns of innovation, 2002-2004



Map 2. Regional patterns of innovation, 2004-2006



From a dynamic point of view, the first impression stemming from Maps 1 and 2 is one of remarkable persistence over time, with some islands of change. To better understand these patterns of persistence vs. change, Table 1 reports the distribution of European regions across regional patterns of innovation in the period 2002-2004 and 2004-2006. The main diagonal indicates regions that did not experience change, top off-diagonal cells represent regions that advanced their innovation patterns (in bold) while bottom off-diagonal cells are occupied by regions that downgraded their innovation patterns (in italics). Overall, 61 regions out of 262 (23%) have been able to change towards a more advanced pattern of innovation, 28 instead fell behind while 173 maintained their innovation pattern. This persistence is also confirmed by the highly significance and relatively high value of the association statistics reported at the bottom of Table 1.

Unfortunately, persistence especially affects regions belonging to less advanced patterns; in fact, none of regions in the passive imitation group is able to escape from their innovative backwardness condition, with only one exception. Consistently, the relative majority of regions falling behind in their innovation patterns is in the active imitation pattern with almost 23% of regions moving backward in the passive imitation group, whereas this percentage ranges from 5% (in the case of basic science pattern) to 15% at maximum (in the case of the formal application pattern).

Generally, changes, if any, are incremental and radical changes 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 patterns. Most of changes also occurs in the 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 progresses along the innovation ladder are gradual and not abrupt.

Lastly, most turbulence occurs in the most advanced patterns. Interestingly, Maps 1 and 2 as well as Table 1 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). From a geographical distribution point of view, this expansion is primarily concentrated in more central and northern European regions, leaving aside both the Southern and the Eastern parts of the Union, in which instead persistence prevail. It is not possible to exclude, on purely conceptual grounds, that this expansion is somewhat related to the policy efforts aimed to promote research-based and formal knowledge based innovation activities undertaken in recent years as to achieve the EU policy goals (chiefly, the well-known the target of 3% R&D expenditures on GDP put forward in Lisbon). Such interventions, in fact, may have found a fertile ground especially in those innovation patterns (such as the formal application one or the applied science one) that are based on these cognitive inputs.

This very interesting empirical evidence reveals once more the urgency to explore more in depth the determinants of the dynamics (i.e. change vs. persistence) of such innovation processes (Asheim et al., 2015) and the system of relationships (internal and external to the region) supporting them (Hassink and Klaerding, 2012). In other words, there is need of explaining how, when, and why a shift towards alternative and more advanced innovation processes (deviating from existing practices) arise in a region. To fill this gap, the next section proposes a conceptual interpretation of regional innovation patterns' dynamics and some alternative evolutionary strategies to trigger these dynamics.

Table 1. The dynamics of regional patterns of innovation

	2004-2006						
2002-2004	**Passive imitation**	**Active imitation**	**Informal application**	**Formal application**	**Applied science**	**Basic science**	**N. of regions**
Passive imitation	14	-	**1**	-	-	-	15
Active imitation	*5*	10	**6**	**1**	-	-	22
Informal application	-	*8*	66	**3**	**10**	-	87
Formal application	-	-	*10*	34	**22**	**1**	67
Applied science	-	-	-	*4*	30	**17**	51
Basic science	-	-	-	-	*1*	19	20
N. of regions	19	18	83	42	63	37	262
Pearson chi2 =565.84***							
Likelihood ratio =428.24***							
Kendall's tau-b=0.80***							

Notes: *** = p<0.01. Italics for changes of innovation pattern that imply a downgrade; bold for changes of that imply a progression.

3. Regional patterns of innovation as regional learning paradigms and trajectories

3.1. The conceptual interpretation

The regional patterns of innovation framework presented in the previous section is fundamentally a structural (static) approach. Such an approach, however, is not simply useful to capture and describe structural characteristics of regional innovation but can also be extended to understand their dynamics. In a companion paper (Capello and Lenzi, 2015c), we recently proposed an interpretation of the dynamics of regional patterns of innovation through the explaination of the conditions under which a new and more advanced innovation pattern can emerge in an area.

This interpretation builds on the idea that any dynamic and process of change of regional innovation patters will be shaped by the evolution of the context conditions specific and the technological/cognitive dimension defining them. However, the explanation of such evolution is not simple. In fact, evolutionary economics (see among others: Nelson and Winter, 1977, 1982; Dosi, 1982; Arthur, 1989, 1994; David, 1985, 2007), evolutionary regional economics (see among others: Aydalot, 1986; Camagni, 1991; Calafati, 2009), and evolutionary economic geography (see among others: Martin and Sunley, 2006; Martin, 2010; Simmie, 2012; Isaksen, 2015; Asheim et al., 2011 and 2015; Boschma, 2015; Trippl et al., 2015), have repeatedly illustrated how the laws of dynamics of structural elements and cognitive dimension are characterized by path-dependence.

Evolutionary thinking, however, provides important conceptual tools to reply to this challenge, in two main respects.

First, it highlights that learning, innovation and change are characterized by cumulative trajectory and paradigm patterns of evolution (Dosi 1982, 1988). By elaborating this intuition in the context of regional patterns 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 trajectories and paradigms.

Following this approach, then, we proposed to interpret the conceptual 'archetypes' of regional innovation patterns as r*egional learning paradigms*, since they represent regional systems of relationships (internal and external to the region) that, based on rules shared by the entire local community of technological, institutional and economic actors, shape the process upon which one looks for innovation, and therefore identify the way in which regions acquire new knowledge and develop a learning process. In short, regional learning paradigms represent modes of innovation and knowledge accumulation stemming from the functional and relational characteristics of territories: the functional characteristics represent the knowledge creating functions internal to and available in a region, in the form of institutions (universities, research centres, local firms) and of all informal relationships that give rise to local collective learning processes. Relational characteristics highlight the external long-distance relationships that take place between local actors and selected partners, in line with the milieu innovateur theory (Camagni, 1991; Crevoisier, 2004). A change of regional learning paradigm therefore derives from a change of either its functional (internal) characteristics, or its relational (external) characteristics or both.

By extension, we proposed to interpret the empirical regional innovation patterns as alternative *regional learning trajectories* within each specific paradigm, defined according to the quality of knowledge and the intensity of the type of innovation specific of each paradigm (either imitation, or application or invention) (Capello and Lenzi, 2015).[6]. In particular:

- 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;
- the creative application learning paradigm can give rise two alternative learning trajectories according to different types of knowledge sourced, namely formal vs. informal external knowledge;
- the imitation learning paradigm can produce two alternative learning trajectories, one based on a passive and the other on an active attitude towards imitation.

A change of regional learning trajectory therefore derives from a change of the quality 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.

[6] The concept of regional innovation patterns fit an interpretation in terms of learning processes for two main reasons. First, learning is at the origins of innovations and improvements, as highlighted in the early contributions of evolutionary economics (Dosi, 1988; Nelson and Winter 1977, 1982; Rosenberg, 1976, 1982). Indeed, regional patterns of innovation are conceived and defined as alternative knowledge accumulation and creation processes based on different types of context conditions. Second, it is a problem-solving process of incremental knowledge development and accumulation based on routines and coordinated actions among individuals, consisting of interaction and knowledge transfer among individuals, in a cumulative and dynamic fashion (Capello, 1999). Indeed, as discussed above, regional innovation patterns have a distinctive relational and interactive character.

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. In fact, path-dependence can condition and set the boundaries of the direction and the alternative options in which change and evolution can be gradually channelled as discussed for technological paradigms and 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)[7], among others.

Indeed, recent contributions in evolutionary economic geography suggest that 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. In this perspective, 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) i.e., how a new regional learning trajectory/paradigm can be initiated. Hence, path-dependence can be interpreted and termed 'evolutionary path-dependence'.[8]

In short, evolutionary path-dependence explains how new trajectories (and paradigms) can develop over time. The next section then adds to this by offering an explanation of when and under what conditions (i.e. through which channels and pathways) a new learning trajectory/paradigm is able to emerge in a complex landscape of path-dependent developments of structural elements.

3.2. Local preconditions for change: alternative strategies

On purely theoretical grounds, it is not possible to exclude that the emergence of a new trajectory/paradigm is a spontaneous, unconscious, unplanned and uncoordinated process (i.e. exogenously driven by disembodied economic forces). Yet, there are theoretical and empirical reasons to contend that deliberate action, purposive design, intentional behaviour, strategic decision, 'mindful deviations' of knowledgeable economic agents, notably entrepreneurs (but even policy makers), are the key endogenous drivers of novelty and of new learning paradigms and trajectories, (Garud and Karnøe, 2003; Martin and Sunley, 2012). In particular, recent works in evolutionary economic geography have proposed some strategies to explain local (industrial) development (see among others: Martin and Sunley, 2006; Martin, 2010; Simmie, 2012; Isaksen, 2015; Asheim et al., 2011 and 2015; Boschma, 2015; Trippl et al., 2015). These stratgies describe how agents' deviant behaviours can turn into a gradual transformation of current arrangements and structures (i.e. in an

[7] Several scholars have recently commented on the increasing popularity of the notion of path-dependence in the scientific arena, as supported by database searches in organization, management, economics and, more generally, social sciences journals (Vergne and Durand, 2010). A thorough theoretical discussion of the notion of path-dependence and its application in a spatial perspective, however, falls outside the scope of this paper. A critical debate on its use for the analysis of the evolution of local economies is also in progress and has already been the subject of in-depth analysis and reviews elsewhere (Martin and Sunley, 2006; Martin, 2010; Henning et al., 2013; Simmie, 2012).

[8] This notion of path-dependence is close to Martin (2012)'s notion of 'developmental path-dependence' and path-creation. In this respect, it is worth stressing that Martin (2010 and 2012) 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 regional pattern of innovation and their possible alternative evolutionary paths.

evolutionary path-dependent manner) leading to the creation of new ones (Martin and Sunley, 2006; Martin, 2010; Simmie, 2012).

By elaborating on these contributions and adapting them to the context of regional learning paradigms and trajectories evolution, three main strategies are expected to lead to a change of a regional learning trajectory/paradigm: namely **creation**, **diversification** and **upgrading** (Capello and Lenzi, 2015c). These strategies represent abstract, stylized and conceptually different pathways that can be detected in regions when shifting from one trajectory/paradigm to another. The three strategies apply to whatever type of paradigmatic change is faced, from imitative to application and from application to science based paradigmatic shift, with specificities however with respect to the context conditions (functional or relational) that forge each paradigm, as further detailed in the next sections.

In the context of regional learning trajectories, **creation** represents a strategy based on the exploitation of knowledge niches, which leads to the creation of a new industry. In this context, niches are (underutilized or new) knowledge and technological opportunities that can be recombined and integrated, 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. **Diversification** can be pursued by expanding 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).[9] 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). Lastly, **upgrading** can be pursued through 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 and Sunley, 2006; Isaksen, 2015). 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.

In the case of regional learning paradigm, 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, in short to both the functional and relational dimensions, as discussed in section 3.1.

Applied to the functional dimension, a **creation** strategy entails a better exploitation of both material and immaterial local resources, including for example the formation of local human capital, as well as to establish scientific and technical organizations and infrastructures previously not available, also based on re-combinatorial processes as described above in the context of learning trajectories. A **diversification** strategy 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 a change in the mix of the functions performed by a region and their consequent integration. Differently,

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

upgrading of local functions 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 what exists. 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 strategies mentioned above and the change in paradigms and trajectories envisaged in Section 2.

4. Measuring alternative strategies for the dynamics of regional learning trajectories

4.1. Indicators

The measurement of creation, diversification and upgrading strategies in the context of learning trajectories requires two main steps. First, exemplifying how each strategy can be applied in the case of 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); second, identifying single indicators specific and exclusive for each specific jump and each strategy.

Conceptually speaking, in fact, creation, diversification and upgrading represent separate strategies of change. Empirically speaking, however, identifying single indicators specific and exclusive of each strategy is extremely complex. Therefore, our approach primarily aims to distinguish the specificities of the change from one particular trajectory to another rather than to distinguish exactly the actual strategy implemented to achieve such a change. Nevertheless, an attempt has been made to identify precise indicators to be linked to each single strategy in the context of each trajectory jump (Table 3).[10] The way in which a regularity is observed is through the link between a paradigmatic jump and a high presence of preconditions for change in a region. The precise definition and measurement of the selected variables is available in Appendix A.

In the case of the move from the passive to the active imitation trajectory, this change can be triggered by the attraction of new economic activities (creation), or their enlargement to new related ones (diversification), or their reorientation to the production of more complex goods (upgrading). Empirically, a possible indicator of the capacity of an area to attract new activities is an indicator of penetration of foreign investments (regional FDI penetration rate) (Pavlínek, 2002). On the other hand, an index of related variety in local sectors can be useful to grasp the expansion of local activities in proximate sectors (Frenken et al., 2007). Finally, the share of GVA in (medium-) high tech sectors

[10] Albeit catching the core intuition of each strategy, we cannot exclude some degree of overlap among the selected indicators.

can provide information about the reorientation of local activities towards more complex productions of greater knowledge and technological intensity (Pavitt, 1984).

The change from the informal to the formal application trajectory could be activated by the exploiting of (new) technological niches (creation), or by the enlargement of local activities towards technology- and knowledge-based modes of production and innovation (diversification), or by formalizing the knowledge at the basis of local production and technological activities (upgrading). A standard indicator of technological activities are patents (Dettori et al., 2012); therefore patents per capita can be used as an indicator of the creation strategy. A traditional indicator of technological diversification (namely, the opposite of the Herfinadal index computed on patents' technological classes) can instead be used to account for the expansion of local activities in technology-based industries (Frenken et al., 2007). On the other hand, the number citations received per capita can be applied to explain the (technological and economic) relevance of the formal knowledge produced locally (Hall et al., 2001).

A shift from the applied to the basic science trajectory can be initiated, for example, through a smarter utilization of (new or existing) excellence niches in basic sciences (creation), through the expansion of existing research activities towards basic science fields (diversification) or through the reorientation of existing knowledge base towards basic science fields (upgrading). In measurement terms, an indicator of the basicness of the local knowledge can be the number of patents in general purpose technologies (GPT) per capita, as claimed by some studies (Foray et al., 2009). For what concerns the diversification strategy, an useful indicator can be that of originality of the knowledge base which is the opposite of the Herfindal index computed on the technological classes of the citations made (Hall et al., 2001). Originality indicates the extent to which the knowledge produced in a region recombines pieces of knowledge distributed across different technical fields and is associated to previously unexplored applications. Differently, the generality index (defined as the opposite of the Herfindal index computed on the technological classes of the citations received, Hall et al. (2001)) can account for an upgrading strategy. Knowledge that is more general has wider applications and a greater technological value.

The opposite move from the basic to the applied science[11] can be based on similar (albeit reversed) mechanisms. For example, creation can be driven by the exploitation of excellence niches in applied sciences, diversification by the expansion of local research activities into applied fields and upgrading by a reorientation of local research towards basic science fields. Empirically, these strategies can be measured by using the opposite of the indicators used to explain the move from the applied to the basic science trajectory. In particular, the per capita number of patents not in GPT can accounts for creation. The enlargement of the knowledge base not in GPT (i.e., opposite of the Herfindal index on the citations made not in GPT) can proxy diversification, and increasing the knowledge base not in GPT (i.e., opposite of the Herfindal index on the citations received not in GPT) can measure upgrading.

[11] Such a change is not only conceptually conceivable as discussed above but also empirically testified by several real cases. Cambridge (UK) perfectly fits the implementation of this strategy. 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 (2010).

Table 2. Measuring the strategies for regional learning trajectory dynamics

Strategy	From basic to applied science trajectory	From applied to basic science trajectory	From informal to formal knowledge trajectory	From passive to active imitation
Creation	Making the best use of existing excellence niches in applied sciences *Indicator: SPT 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*

4.2. Results

In order to understand the relevance of each strategy for the dynamics of regional learning trajectories, a series of statistical tests have been conducted. In particular, we performed t-tests comparing the relative average endowment of the preconditions to implement each strategy, measured as detailed in Section 4.1 and Table 2, in the group of regions that changed their learning trajectory with respect to the group of regions that maintained it. Based on Table 1 (which reports the actual number of regions changing their learning trajectory in the period 2002-2006), these tests have been conducted only in two cases: the move from the informal to the formal application trajectory and the change from the applied to the basic science trajectory. Results are reported in Table 3, together with their statistical significance.

Interestingly, results suggest that the progress from the informal to the formal application trajectory is most likely in regions following at least one of the above-mentioned strategies, i.e. creation, diversification or upgrading. In fact, the regions that experienced a change show a larger knowledge base (e.g. patents per capita), a more diversified technological profile (e.g. technological diversification), and a more formalized knowledge base (e.g. citations received per capita).

A similar conclusion can be drawn also in the case of the move from the applied to the basic science trajectory. In fact, regions that experienced such a change exhibit a more basic (e.g. GPT patents per capita), original (e.g. originality), and general (e.g. generality) knowledge base. Overall, therefore, findings support the view that the proposed strategies actually find real application and are associated to the dynamics of regional learning trajectories.

Table 3. Regional learning trajectory dynamics: the role of different strategies

Change from the:	Change = 1	Change = 0	Average value	p-value
Informal to the formal application trajectory	N=3	N=74	N=77	
Creation- Patents per capita (2002-2004)	0.050	0.036	0.037	< 0.05
Diversification - Technological diversification (2002-2004)	0.922	0.882	0.884	< 0.01
Upgrading - Citations received per capita (2002-2004)	0.024	0.013	0.014	< 0.05
Applied to basic science trajectory	N=17	N=34	N=51	
Creation - GPT patents pc (2002-2004)	0.190	0.111	0.138	< 0.05
Diversification - Originality (2002-2004)	0.928	0.911	0.917	< 0.10
Upgrading - Generality (2002-2004)	0.908	0.878	0.888	< 0.05

5. Measuring alternative strategies for regional learning paradigms dynamics

5.1. Indicators

The measurement of creation, diversification and upgrading strategies in the context of learning paradigms entails the same difficulties described in the case of regional learning trajectories (see Section 4.1). In this case, an additional effort has been made to suggest specific indicators for each type of move, each strategy and for both the functional and relational dimensions defining each paradigm.

Let us first consider the change from the imitation to the application paradigm. Regarding the functional dimension, this change could be stimulated by a better use of creative human capital resources (creation), or by an expansion of local production activities to more advanced functions and production activities (diversification), or a reorientation of local activities to more advanced ones (upgrading). Suitable indicators to measure the preconditions enabling the creation strategy can be the share of managers and/or technicians on total employment, which can capture the knowledge and capabilities embedded in specialized worker. These workers are indeed those most likely to adapt and improve the production processes leading to the introduction of innovation (Fagerberg et al., 2007; Fagerberg and Shrolec, 2008; Capello and Lenzi, 2015b). Following a similar logic, the diversification strategy can be measured by looking at the share of the most advanced occupations on total employment (and not only at managers and technicians) (Capello and Lenzi, 2013). Finally, the number of issued trademarks and designs per capita can be a proxy of the upgrading strategy as they

indicate the capacity to make local activities more creative and internationally recognized (Mendonça et al., 2004).

In terms of the relational dimension, all strategies aim to generate local preconditions to facilitate external relations. Creation can be enabled by the exploitation of existing technological and production excellence niches pioneered by local enlightened entrepreneurs open to catch opportunities and prone to take the risk of launching new businesses and to face (international) markets' competitive pressure (Acs et al., 2014; Szerb et al., 2013). Diversification can be eased by the expansion of local activities into technology and applied fields, which may be led by entrepreneurs prompt to deploy new technologies (Acs et al., 2014; Szerb et al., 2013). Upgrading, instead, can be encouraged by a reorientation of local entrepreneurial activities towards more creative applications, i.e., by the presence of innovative entrepreneurs inclined to introduce product and process innovations (Acs et al., 2014; Szerb et al., 2013).

Let us then examine the shift from the application to the science-based paradigm. Concerning the functional dimension, this change can be activated by attracting highly skilled human capital resources that can open new research and production fields, as for example returnee scientists (creation); or by expanding production and development activities to include also research activities (diversification); or by reorienting local activities to science-based ones. In terms of measurement, useful proxies of these processes could be inventor inflows on population for creation (Breshnan et al.; 2001; Kerr, 2008; Miguelez and Moreno, 2013), R&D expenditures on GDP for diversification (Colombelli et al., 2013) and (share of) employment in high tech sectors for upgrading (Vivarelli, 2014).

In terms of the relational dimension, all strategies aim to favor local conditions to enrich external relations. For example, new external relations can created (or reinforced if not fully exploited) by launching joint research and technological activities that can eventually lead to opening new fields of production and research activities (creation). Moreover, external relations can be expanded by reinforcing the presence in scientific and technological networks, so to become more visible, stable and central partners in existing (and new) scientific and technological networks (diversification). Also, external relations can be used to reinforce the local scientific knowledge base (upgrading). Empirically, the number per capita of co-patents with extra-regional partners can account for the possibility to use external knowledge to create new local activities (creation) (Miguelez and Moreno, 2013). Similarly, 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 (diversification) (Miguelez and Moreno, 2013). Lastly, the number (funding) of FP per capita indicates the capacity to launch external relations that involve scientific collaborators (upgrading) (Colombelli et al., 2013).

Table 4. Measuring the strategies for regional learning trajectory dynamics

Strategies		From application-based to science-based paradigm	From imitative innovation to application-based paradigm
Creation	Functional dimension	Making the best use of returnees 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 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 functions *Indicator: R&D expenditure on GDP (%)*	Expanding the existing industrial activities to higher-level ones *Indicator: Top level occupations (LQ on total employment)*
	Relational dimension	Expanding 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 functions *Indicator: Employment in high-tech sectors (%)*	Reorienting existing industrial activities to higher-level ones *Indicator: Trademarks and product design per capita*
	Relational dimension	Reorienting local existing relationships to new science-based actors *Indicator: 5th FP funding/projects per capita*	Reorienting local entrepreneurship to creative activities *Indicator: Entrepreneurial product and process innovation*

5.2. Results

In order to understand the relevance of each strategy for the dynamics of regional paradigm trajectories, the empirical strategy applied is similar to that described in Section 4.2. A series of t-tests have been conducted to compare the relative average endowment of the preconditions to implement each strategy, measured as detailed in Section 5.1 and Table 4, in the group of regions that changed their learning paradigm with respect to the group of regions that maintained it. Results reported are in Table 5, together with their statistical significance.

Findings indicate that regions moving from the imitation to the application paradigm are better endowed in terms of more advanced occupations (e.g. share of managers and technicians), show a job market concentration in top-level occupations (e.g. LQ of top occupations), a greater creativity (e.g. designs and trademarks per capita). Moreover, these regions have a higher propensity to create new entrepreneurial activities (e.g. entrepreneurial ability and risk perception) and face competition (entrepreneurial competitive attitude), to adopt innovation and new technologies (e.g. entrepreneurial

technological adoption) and to introduce innovation (e.g. entrepreneurial product and process innovation).

Table 5. Moving from the imitation to the application paradigm: the role of different strategies

Functional dimension	Change = 1 (N=8)	Change = 0 (N = 29)	Average value (N = 37)	p-value
Creation - Share of managers (%) (2002-4)	3.17	2.15	2.37	< 0.05
Creation - Share of technicians (%) (2002-4)	3.56	2.77	2.95	< 0.01
Diversification - LQ top occupations (2002-4)	0.962	0.727	0.778	< 0.01
Upgrading - Trademarks per capita (2002-4)	0.014	0.03	0.06	< 0.10
Upgrading - Designs per capita (2002-4)	0.083	0.021	0.037	< 0.10
Relational dimension				
Creation - Entrepreneurial ability (2002-11)	21.635	18.001	18.787	< 0.10
Creation - Entrepreneurial risk perception (2002-11)	3.423	2.736	2.908	< 0.05
Creation - Entrepreneurial competitive attitude (2002-11)	17.369	10.182	11.734	< 0.01
Diversification - Entrepreneurial technological adoption (2002-11)	13.755	8.369	9.534	< 0.01
Upgrading - Entrepreneurial product innovation (2002-11)	3.783	2.561	2.825	< 0.01
Upgrading - Entrepreneurial process innovation (2002-11)	0.365	0.259	0.282	< 0.05

Similar comments can be made also for regions progressing from the application to the science-based paradigm. Indeed, these regions exhibit greater highly skilled human capital attractiveness (e.g. inventor inflows on population), wider knowledge creation activities (e.g. R&D on GDP), a job market concentration in knowledge intensive sectors (e.g. employment in high tech sector). Additionally, these regions present an enhanced propensity to engage in joint knowledge creation activities (e.g. extra-regional co-patents per capita), to source knowledge from outside (e.g. extra-regional citations made per capita) and to enter into research network and exchange knowledge (e.g. FP projects and funding per capita). As for regional learning trajectories, therefore, it is possible to conclude that the dynamics of regional learning paradigms can be associated to the proposed strategies of creation, diversification and upgrading.

Table 6. Moving from the application to the science-based paradigm: the role of different strategies

Functional dimension	Change = 1 (N=33)	Change = 0 (N=121)	Average value (N=154)	p-value
Creation - Inventor inflows on population (2002-2004)	10.41	4.33	5.63	< 0.01
Diversification - R&D on GDP (%) (2002-2004)	1.85	1.13	1.28	< 0.01
Upgrading - Employment in high-tech (%) (2002-2004)	4.52	3.75	3.92	< 0.05
Relational dimension				
Creation - Co-patents per capita (2002-2004)	196.947	112.745	130.790	< 0.01
Diversification - Extra-regional citations made per capita (2002-2004)	71.740	40.092	46.874	< 0.01
Upgrading - FP funding per capita (1998-2001)	27430.82	17787.67	19854.06	< 0.01
Upgrading - FP projects per capita (1998-2001)	0.181	0.118	0.131	< 0.01

5.3. Which strategy does pay off the most?

The empirical evidence discussed so far indicates a positive association between regional preconditions (specific of each strategy) for change and actual change of a regional learning trajectory / paradigm. These results suggest that all strategies seem to deliver the desired outcome but do not tell us which strategy pays off the most in terms of probability of change. To explore this issue, we performed a series of logit regressions to highlight the impact of the variables accounting for each strategy on the probability of trajectory/paradigm change. Based on Table 1, this analysis could be conducted only for the case of the move from the application to the science-based paradigm, as the other moves do not present a sufficient number of cases to apply econometric tools. In each regression[12], we controlled for a common set of variables accounting for a region's chief economic and territorial characteristics, namely: GDP per capita in 2002, dummy for regions with the capital city, dummy variables for regional urban structure, country dummies (see Annex A for additional details on these variables). In particular, we chose to report odds ratios (rather than coefficients) as odds ratios allow meaningful and scale-free comparisons of the impact of 1% increase in each variable on the odds ratio to observe a change.

Results of these estimations are reported in Table 7. By looking at the functional dimension, it seems that the probability of change is significantly associated to diversification and upgrading strategies, suggesting that existing policies aimed at enhancing R&D activities and high tech sectors can be suitable and fruitful in an application context. Regarding the relational dimension, on the other hand, the probability of change is associated to creation and diversification strategies that involve relationships closer to the development and commercialization stage rather than to the research stage, suggesting that existing policies based on basic research do not seem to be significantly appropriate in an application context.

[12] The variables accounting for the different strategies have been inserted in turn in the regressions because we wanted to isolate the effect of the single strategy, which are not entirely one independent from the other.

More generally, the magnitude and significance of the estimated odds ratios seem to support the prominence of the diversification with respect to the others both in the case of the relational and the functional dimensions, supporting the current emphasis and popularity of the diversification argument in both the academic debate (Boschma, 2015) and the policy arena (Boschma, 2014; McCann and Ortega-Argilés, 2014).

Table 7. Probability of moving from the application to the science-based paradigm

Dependent variable: change from the application to the science-based learning paradigm = 1				
Functional dimension	**Odds ratio**	**Chi^2**	**Pseudo r^2**	**Pseudo-likelihood**
Creation - Inventor inflows on population (2002-2004)	1.024	23.71***	0.34	-52.84
Diversification - R&D on GDP (%) (2002-2004)	2.325***	23.27***	0.40	-47.68
Upgrading - Employment in high-tech (%) (2002-2004)	1.311*	21.16**	0.36	-51.39
Relational dimension				
Creation - Co-patents pc (2002-2004)	1.005**	25.88***	0.37	-50.84
Diversification - Extra-regional citations made pc (2002-2004)	1.018*	20.60**	0.39	-48.52
Upgrading - FP funding pc (1998-2001)	1	20.97**	0.33	-53.57
Upgrading - FP projects pc (1998-2001)	0.275	20.98**	0.33	-53.67

Notes: *** = p<0.01., ** = p<0.05, * = p<0.10.
Control variables include GDP per capita in 2002, dummy for regions with the capital city, dummy variables for regional urban structure, country dummies.

6. Conclusions

The investigation of dynamics of regional innovation processes reveals that changes are rare and, if any, they are incremental and path-dependent. Catching up the innovation ladder is complex, especially for more laggard regions, highlighting once more the risk of persistence deriving from backwardness and of falling behind. In fact, a polarization trend seems at place in EU regions, which amplifies the divide between knowledge-intensive, innovative and advanced regions, whose number has grown over time, and less advanced regions, trapped into their disadvantaged situation if not into decline.

The availability and exploitation of some local preconditions, however, can offer the opportunity to implement strategies, such as creation, diversification and upgrading strategies that can favor change and the move towards more advanced learning trajectory and paradigm. The empirical analysis presented in the paper in fact indicates that the regions that actually experienced such changes show a larger endowment of territorial assets enabling change, and this holds for all the strategies and types of move considered.

Our findings also allow some comparison of the relative effectiveness of the different strategies in delivering change. In particular, the diversification strategy seems the most promising one to achieve

a change in a region's learning paradigm. On the other hand, creation and upgrading strategies seem effective only in specific circumstances, though with different intensity. This conclusion is absolutely consistent with the increasing acceptance and popularity of diversification argument in the current academic debate (Boschma, 2015) and policy arena (Boschma, 2014; McCann and Ortega-Argilés, 2014).

Our results bring also important policy implications. First, regional innovation policies are highly complex (and subject to the risk of multiple failures). In fact, innovation is the outcome of regional learning processes deeply rooted and embedded in local socioeconomic structure and historical background. Moreover, learning processes evolve in a persistent path-dependent manner based on continuity, on the one hand, and in an evolutionary path-creation manner on the other. Therefore, being changes in both trajectories and paradigms incremental, regional innovation policies should be conceived in light of and targeted to the mode of innovation already present in the area. For this reason, innovation policies at the regional level should not be considered as sector policies only, but rather as place-based innovation policies (Boschma, 2014; McCann and Ortéga-Argiles, 2014).

Second, changes in regional learning paradigms demand complex evolutionary strategies pursued on the functional and relational dimensions. There is a high risk that the functional dimension – which are easier and quicker to develop – may become the focus of innovation policies, neglecting the relational dimension, which instead requires a long-term approach. This privileged focus on the functional dimension may explain the failure of innovation policies mainly devoted to the creation of knowledge-generating functions. A more promising approach could be that of stimulating a co-evolution of both dimensions. A strategy aimed at the dynamic matching of relational and functional elements is certainly at the same time the most successful and rewarding in the long-term but also the most difficult innovation policy to be pursued at a local level.

These considerations explain the high failure rate of past innovation policies as well as the complexity of making regions catching up the innovation ladder.

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ANNEX A. Variables description

Variables	Measure	Computation	Year	Source
Patents per capita	Size of the knowledge base	Count of patents per 1000 inhabitant	One value 2002-2004	Authors' calculation on CRENoS database
Citations received per capita	Formalization of the knowledge base	Count of citations received per1000 inhabitant	One value 2002-2004	Authors' calculation on CRENoS database
Technological diversification– OST30	Diversification of the knowledge base	Opposite of the Herfindal index on the technological classes of patents	One value 2002-2004	Authors' calculation on CRENoS database
GPT patents per capita	Basicness of the knowledge base	Count of patents in GPT (i.e., ICT, biotechnology and nanotechnology) per1000 inhabitant	One value 2002-2004	Authors' calculation on CRENoS database
SPT patents per capita	Applied-science knowledge base	Count of patents not in GPT (i.e., ICT, biotechnology and nanotechnology) per1000 inhabitant	One value 2002-2004	Authors' calculation on CRENoS database
Originality– OST30	Originality of the knowledge base	Opposite of the Herfindal index on the technological classes of citations made	One value 2002-2004	Authors' calculation on CRENoS database
Generality– OST30	Generality of the knowledge base	Opposite of the Herfindal index on the technological classes of citations received	One value 2002-2004	Authors' calculation on CRENoS database
Continuity	Continuity of the knowledge base	Opposite of the Herfindal index on the technological classes of citations made not in GPT	One value 2002-2004	Authors' calculation on CRENoS database
Specificity	Specificity of the knowledge base	Opposite of the Herfindal index on the technological classes of citations received not in GPT	One value 2002-2004	Authors' calculation on CRENoS database
Share of top occupations (%)	Functional advancement	Share of professionals, technicians and associates, and clerical support workers (ISCO 1 digit codes 2, 3, and 4) on total employment	Average value 2002-2004	European Labour Force Survey
LQ top occupations	Functional advancement	Regional share of professionals, technicians and associates, and clerical support workers (ISCO 1 digit codes 2, 3, and 4) on total employment divided by the EU share of professionals, technicians and associates, and clerical support workers on total employment	Average value 2002-2004	European Labour Force Survey
Share of managers (%)	Functional advancement	Share of production and specialized services managers (ISCO code 13) on total employment	Average value 2002-2004	European Labour Force Survey

Share of technicians (%)	Functional advancement	Share of science and engineering associate professionals (ISCO code 31) on total employment	Average value 2002-2004	European Labour Force Survey
Trademarks	Creativity	Count of trademarks per 1000 inhabitants	One value 2002-2004	EUROSTAT
Designs	Creativity	Count of designs per 1000 inhabitants	One value 2002-2004	EUROSTAT
Inventor inflows on population	Knowledge base intensity	Count of inventors per 1000 inhabitants	One value 2002-2004	AQR's database
R&D on GDP (%)	Knowledge base intensity	Share of R&D expenditures on GDP	Average value 2002-2004	CRENoS database
Employment in high-tech (%)	Knowledge base intensity	Employment in high-technology sectors (high-technology manufacturing and knowledge-intensive high-technology services, i.e., NACE Rev.1.1. sectors DG24.4, DL30, DL32, DL33, DM35.3, I64, K72 and K73) on total employment	Average value 2002-2004	EUROSTAT
Entrepreneurial risk perception	Risk perception	Composite indicator accounting for the population's risk acceptance and the general business risk proxied by the country's business disclosure rate	One value 2002-2011	REDI
Entrepreneurial technological adoption	Technology adoption	Composite indicator accounting for the share of new/nascent businesses in high-tech sectors, technological readiness, and employment in knowledge-intensive and high-tech firms	One value 2002-2011	REDI
Entrepreneurial competitive attitude	Competition	Composite indicator accounting for the number of competitors, the nature of competitive advantage, and business sophistication	One value 2002-2011	REDI
Entrepreneurial product innovation	Product innovation	Composite indicator accounting for the capacity to create new products and the region's potential to patent and create scientific publications	One value 2002-2011	REDI
Entrepreneurial process innovation	Process innovation	Composite indicator accounting for the capacity to create new processes and to invest in R&D	One value 2002-2011	REDI
Entrepreneurial ability	Potential for entrepreneurial activity	Composite indicator accounting for opportunity start-up, technology adoption, human capital and competition	One value 2002-2011	REDI
Co-patents per capita	Cross-regional technological knowledge networking	Count of cross-regional patents per 1000 inhabitant	One value 2002-2004	AQR's calculation on CRENoS database
Extra-regional citations made per capita	Cross-regional technological knowledge networking	Count of citations made to other regions per 1000 inhabitant	One value 2002-2004	AQR's calculation on CRENoS database

FP funding per capita	Cross-regional technological knowledge networking	Regional 5^{th} Framework Program funding per 1000 inhabitant	One value 1998-2002	CRENoS's calculation on CORDIS database
FP projects per capita	Cross-regional technological knowledge networking	Regional 5^{th} Framework Program projects per 1000 inhabitant	One value 1998-2002	CRENoS's calculation on CORDIS database

Control variables				
Agglomerated	Urbanization	Dummy variable taking value 1 if a region has a city with more than 300000 inhabitants and a population density of more than 300 inhabitants per sq. km or a population density between 150 and 300 inhabitants per sq. km and 0 otherwise	2000	ESPON
Urban	Urbanization	Dummy variable taking value 1 if a region has a city between 150,000 and 300,000 inhabitants and a population density of between 150 and 300 inhabitants per square kilometer (or a smaller population density - 100 and 150 inhabitants per square kilometer with a bigger center of more than 300,000) and 0 otherwise	2000	ESPON
Rural	Urbanization	Dummy variable taking value 1 if a region has a population density lower than 100 per square kilometer and a center of more than 125,000 inhabitants, or a population density lower than 100 per square kilometer with a center of less than 125,000 and 0 otherwise	2000	ESPON
Megas	Urbanization	Dummy variable taking value 1 if a region includes at least one of the seventy MEGAs—FUAs with the highest scores on a combined indicator of transport, population, manufacturing, knowledge, decision making in the private sectors and 0 otherwise	2000	ESPON
Capital	Capital	Dummy variable taking value 1 if the region hosts the country capital city and 0 otherwise	2000	EUROSTAT
GDP per capita	Economic wealth	Euro per capita	2002	EUROSTAT
Population	Size of the region	Number of inhabitants	2002	EUROSTAT