Evolutionary regional innovation patterns and economic dynamics

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Abstract

Conceptual reflections and empirical evidence on the evolution of regional innovation processes are increasing in recent years. This paper contributes to this debate by focusing on the long term implications that evolutionary changes in regional innovation patterns – intended as different combinations of territorial structural conditions and phases of the innovation process – can have on regional economic performance and dynamics. By applying the regional innovation pattern framework in a dynamic perspective, the paper shows that structural changes in regional innovation patterns positively influence regional economic performance and competitiveness. From these results, reflections on regional innovation policy in the EU context are drawn.

JEL codes: O31, R11

Keywords: regional patterns of innovation, evolutionary dynamics, economic dynamics

1. Introduction

Research on regional innovation processes has reached important achievements in the understanding of the conditions under which innovation occurs in a region, elaborated in the frame of several territorial innovation approaches (Moulaert and Sekia, 2003). Amongst the existing ones, regional innovation systems (RIS) (Fritsch, 2001; Cooke et al., 2004; Asheim et al., 2016), milieux innovateurs (Camagni, 1991), learning regions (Lundvall and Johnson, 1994; Hassink and Klaerding, 2012), social filter (Crescenzi and Rodríguez-Pose, 2011), regional patterns of innovation (Capello and Lenzi, 2013a) figure prominently. The common goal of these approaches is to account for the spatial heterogeneity of innovative activities and processes, dealing with the issues of where innovative activities concentrate and why some regions are more innovative than others. Indeed, an important and rich tradition of regional innovation studies has highlighted the relevance of innovation and local renewal for economic growth and enhanced productivity (Crescenzi and Rodríguez-Pose, 2011).

Yet, several authors are increasingly emphasizing the need of a deeper and richer comprehension of how these different local innovation modes can evolve over time and what the economic implications of such evolutionary processes can be (Asheim et al., 2016). Efforts exist in this direction, and in recent years advances have been made in the understanding of whether and how regional innovation processes can change over time, possibly leading to progresses towards more complex ones. Such evolutions are interpreted as the aggregate outcome of strategic individual behaviors of local actors leading to an endogenous switch and opening the way to alternative innovation modes, in accordance with recent debates in evolutionary economic geography (Asheim et al., 2016; Capello and Lenzi, 2017). However, reflections and empirical evidence on the influence that evolutionary structural changes in innovation processes – intended as changes in learning modes due to new territorial context conditions – can generate on regional economic performance and dynamics in the following years are still limited.

This paper aims to contribute to fill this gap by focusing on the long term implications of the evolution of regional innovation patterns. In particular, the paper draws on the concept of regional innovation patterns, conceived as 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 and Lenzi, 2013a and 2017). While representing a concept of structural innovation modes aimed at identifying the territorial key distinctive traits linked to each regional learning and innovation processes, regional innovation patterns present a dynamic nature as well, which requires the formation of new territorial enabling sources of knowledge and innovation creation, both in the functional as well as cognitive spheres. In particular, the functional domain refers to the presence in a region of knowledge creating functions/actors (e.g., universities, research centers, and local firms) whereas the cognitive domain refers to the (different types of) learning processes in a region, linked to alternative relational structure supporting knowledge and innovation creation and acquisition. In fact, specific intentional behaviors of local actors and territorial characteristics have been conceptualized and empirically identified as enablers of these structural changes and associated to the evolutionary dynamics detected in regional innovation patterns of 261 NUTS2 regions of the EU in the period 2002-2006 (Capello and Lenzi, 2017). What is still missing, and is addressed in this specific study, is to evaluate the effects of such structural changes on the regional dynamics. The perspective of this work is therefore broadened as to link the structural changes occurred in regional innovation patters to the economic dynamics of regions. The interest in such a link refers to the important policy implications that this analysis faces; it in fact helps in highlighting under which conditions a normative effort in making regions change their innovation pattern is reasonable, and helps in suggesting advances in the current scientific and policy debate on the future of the smart specialization strategy.

The rest of the paper is organized as follows. Section 2 argues in favor of adopting a structural approach to study regional innovation processes (and, by extension, the long term implications of their dynamics) by discussing alternative frameworks developed in the literature. While acknowledging the similarities with and legacy from previously developed frameworks, it presents the novelties and advantages of adopting the regional innovation pattern approach (Capello and Lenzi, 2013a). Section 3 elaborates on the link between the evolution of regional innovation patterns and economic dynamics. Section 4 describes the evolution of regional patterns of innovation in European NUTS2 regions. Section 5 introduces data and methods while Section 6 comments on the empirical results. Section 7 concludes with some reflections on regional innovation policies in Europe.

2. Regional innovation patterns: novelties with respect to existing approaches

As noted in the introductory section, several territorial innovation approaches (e.g. *milieu innovateur*, social filter, learning regions, RIS, regional innovation patterns) have highlighted the local conditions under which innovation occurs in an area, with the general (and common) aim to account for the spatial heterogeneity of innovative activities and the identification of regional conditions enabling local innovation (Moulaert and Sekia, 2003).

In fact, innovation is widely and commonly considered as a locally embedded phenomenon, highly dependent on the socio-economic and institutional conditions that shape each place and not simply on the pure endowment of cognitive inputs (Rodríguez-Pose and Crescenzi, 2008). By emphasizing the strict connection and interdependencies between local conditions and regional innovation outcomes (i.e. the place and context dependent nature of innovation), all these frameworks share, advocate and defend a structural approach to analyze regional innovation phenomena, i.e. they emphasize the relevance of contextual elements as to explain learning and innovation processes (Moulaert and Sekia, 2003; Martin and Sunley, 2006; Asheim et al., 2016). More importantly, they suggest that the study of innovation in space should not simply look at the intensity and types of innovation activities and processes conducted in an area but, primarily, at the combination of local conditions and innovative activities and processes. The richness of these studies is to elaborate the local conditions for innovation activities in different ways.

In the *milieu innovateur* approach, the key distinctive enabler of an enhanced local innovative and economic performance resides in the socio-economic relations among local actors in a specific area, the *milieu* (Camagni, 1991; Capello and Faggian, 2005). Such relations can take on two primary forms: formal relations dedicated to the exchange of knowledge with extra-regional selected partners (generally based on contracts and cooperation networks) and informal ones (the actual glue of the *milieu*) among local actors. Such informal relations, strictly embedded in the social structure of the local economy, favor processes of collective learning and the reduction of risk, uncertainty and transaction costs, through workers' mobility networks, spin-off mechanisms, supplier-customer relationships which enable the informal transfer of knowledge (Camagni, 1991 and 1995). Such relations represent a localized source of dynamic advantages and, by consequence, of innovation enablers. This approach focuses on the cognitive domain of the innovation process, by emphasizing the territorial conditions embedded in the local society at the basis of learning processes.

The social filter approach rests on the idea that each place is characterized by a unique combination 'of innovative and conservative elements that favor or deter the development of successful regional innovation' (Rodríguez-Pose, 1999, p. 82). Such elements, i.e. local socio-economic conditions, ultimately filter the creation and adoption of innovation and its transformation into economic activity. This approach is much interested in the identification of the functional elements that guarantee innovation processes to occur. Even if there is not a pre-definite set of such functional hindering / enabling elements, they tend to be related to high skills and higher dynamism in the labor market, such as population education, productive employment of human resources (e.g. activity and employment rate, especially in more productive sectors), and demographic structure (Rodríguez-Pose and Crescenzi, 2008).

The RIS approach for the first time introduces the idea that both a cognitive and functional approach are necessary at the same time to explain innovation processes. RIS highlights the process of knowledge creation as the result of the presence of specific functions/actors, grouped in two conceptual subsystems, one dedicated to the creation of new knowledge and the other composed of local firms dedicated to its exploitation in innovations. The interaction of these two subsystems, facilitated by the presence of informal institutions (e.g. shared norms, values and trust), gives rise to the process of knowledge creation and ensures therefore the functioning of a RIS (Asheim et al., 2016). This approach associates the cognitive process to the one developing formal knowledge, by suggesting the importance of the presence of knowledge-creation functions in all regions in order to develop an innovation process, with the consequence, however, to push all of them towards the same model of innovation, a strategy now widely recognised as unsuccessful (Capello, 2015). When different RIS are identified – territorially embedded RIS, regionally networked innovation systems (considered as the ideal-type RIS) and regionalized national innovation systems (Asheim and Isaksen, 2002; Asheim et al., 2016) – the distinction is based on the local presence/absence of the firms sub-system and the knowledge organizational/institutional infrastructure one and the intensity of the interactions among them. Therefore, the difference among types of RIS lies in the geographical location of different functions (national, local), giving rise to different intensity of knowledge creation, rather than on different cognitive mechanisms.[i]

In the same line of reasoning of RIS is the learning region approach, which builds on the idea that innovation processes nearly never take place in isolation but requires interactions across actors and organizations (Lundvall, 1992; Lundvall and Johnson, 1994). With respect to RIS, the learning region approach focuses on the cognitive aspects of an innovation process, highlighting the local conditions for knowledge creation; they reside in the institutional, cultural and geographical proximities that support interaction among local firms, giving rise to interactive learning, intended as learning between co-localized actors (Hassink and Klaerding, 2012). Innovation is fostered at most when interactions take origin from the grass-roots in a bottom-up, participatory and horizontal way (Asheim, 2012). However, nothing in the theory explains how and why these relations must necessarily be local; nor does it explain what territorial factors fuel the process of interactive learning. In this perspective, therefore, the learning region approach rather than a territorial approach, intended as a framework based on the relevance of context conditions for innovation, can be better considered as a regional approach, applied at the subnational, local scale, with no need to be rooted in and linked to territorial characteristics in order to make sense[ii].

The regional patterns of innovation approach conceptualizes the spatial heterogeneity of learning processes as alternative spatial variants/combinations of context conditions and of specific modes of performing and linking the different phases of the innovation process (Capello and Lenzi, 2013a). It makes the effort to combine the functional and cognitive dimension of knowledge creation, being decisively territorial in nature. In fact, each pattern is the result of specific (territorial) characteristics of the region and of specific relational structures embedded in the local economy supporting knowledge and innovation creation and acquisition. Given the way they are identified, regional innovation patterns not only differ significantly in terms of intensity as well as mix of knowledge and innovation activities but also in terms of functional and the cognitive elements supporting knowledge and innovation creation and acquisition. In the regional patterns of innovation framework, in fact, knowledge and innovation creating functions, in the form of institutions/organizations (e.g., universities, research centers, and local firms), available in a region play a role in the identification of the mode of innovation, as well as the different cognitive (learning) processes, linked to alternative relational structure supporting knowledge and innovation creation and acquisition. Informal relations (within the region) aimed to generate knowledge (e.g. informal exchange of knowledge that give rise to local collective learning processes) as well as long-distance relationships that take place between local actors and selected extra-regional partners, find in the regional innovation patterns a clear role, strongly linked to the functional elements.

In particular, three main archetypal patterns have been conceptualized (Capello and Lenzi, 2013a). In the *science-based pattern*, knowledge is mostly created by local actors, typically universities, R&D centres and large firms as well as exchanged on a bilateral basis across regions. In fact, local relationships are generally enriched by interregional cooperation with selected partners, as highlighted in most of literature dealing with knowledge and innovation creation and diffusion (Jensen et al., 2007; Mack, 2014). In the *creative application pattern*, entrepreneurial creativity and collective learning enable to access external knowledge and to use it for local innovation needs (Foray, 2009; Licht, 2009). In such context, external relations are essential to access locally unavailable (formal or informal) knowledge. In fact, knowledge sources 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). In the *imitative innovation pattern*, instead, relationships among actors (generally between local firms and dominant firms, typically multinationals) are aimed to the adoption of innovations new for the area as described in the literature dealing with innovation diffusion (Pavlínek 2002; Varga and Schalk 2004). In this context, typical of regions with weak local knowledge creation sources, external knowledge is acquired as embedded in innovations developed elsewhere and then replicated and, possibly, adapted locally.

Without contradicting (but rather with a strong legacy with respect to) existing literature, the concept of regional patterns of innovation introduces some novelties and advances in framing and explaining regional innovation processes with respect to the above mentioned approaches.

With the *milieu innovateur* approach, the regional patterns of innovation framework shares the focus on intra- and extra-regional relations as one of the main structural characteristic shaping innovative activities in regions. However, it enriches the *milieu innovateur* conceptualization by distinguishing different types of extra-regional relations according to different types of context conditions and innovation activities prevailing in a region.

With the social filter approach, the regional patterns of innovation framework shares the functional approach, by highlighting the role of human capital and local enabling factors as important drivers of innovation. However, it also introduces some important distinctions. First, the regional patterns of innovation approach contends that different types of local enabling factors are needed and suit different types / stages of the knowledge-to-innovation logical chain. Second, it stresses the relevance of the structure of selective (and not purely geography-based) intra- and extra-regional systems of relationships shaping local innovation processes. The importance of knowledge and innovation based ties in fact is somewhat disregarded in the social filter approach and, when taken into consideration, such linkages are conceptualized and empirically modelled simply on the basis of pure geographical proximity (Rodríguez-Pose and Crescenzi, 2008). Lastly, and possibly more importantly, the concept of regional patterns enables to take into account a larger variety of spatial innovation modes while superseding the risk (and weakness) of depicting a binary space made of innovation-prone vs innovation-averse regions (Rodríguez-Pose, 1999).

With the RIS approach, the regional patterns of innovation framework shares the idea that cooperation between knowledge-creation actors and knowledge users is vital, and that the functional and cognitive approach are required at the same time. However, it goes more in depth with respect to RIS in two aspects; firstly, it allows a more precise identification of the territorial conditions that explain such relations to take place and, especially; secondly, by separating the different phases of the innovation process, and recombining them in space on the basis of territorial preconditions, it opens the possibility to distinguish between different cognitive modes of knowledge creation and adoption. By doing so, different possible patterns of innovation emerge, differentiated between different cognitive processes supported by different territorial knowledge-creating and adopting functions.

The regional innovation patterns typology differs from the RIS one since it allows the different patterns of innovation to vary both in terms of functional and cognitive elements accompanying the innovation process. In the RIS typology, the difference among regional innovation modes primarily refers to the intensity of local interactions between sub-systems, absent in the case of the territorially embedded RIS (showing few relevant knowledge organizations), whereas fully developed in regionally networked innovation systems (Trippl et al., 2015). In the regional innovation pattern approach, instead, all types of cognitive modes are taken into consideration, from the science-based to the imitative innovation mode, through the spatial recombination of the different phases of the innovation process. The result is that also the imitative innovation approach finds a role and an identification in the regional innovation patterns, which instead in the RIS approach is considered a less fruitful analytical and policy framework (Asheim and Isaksen, 2002).

With the learning region approach, the regional patterns of innovation framework shares the emphasis on interactions among local agents as a fundamental source of (collective) learning and, by consequence, enhanced innovation capacity. However, the regional patterns of innovation concept complements the relevance of intra-regional relationships with that of extra-regional ties and distinguishes different types of extra-regional relational structure supporting knowledge and innovation creation and acquisition on the basis of specific local pre-conditions.

The regional patterns of innovation framework, therefore, by integrating complementary insights from different conceptual approaches, introduces some novelties with respect to previous conceptualizations and empirical descriptions of regional innovation phenomena. Without contradiction with previous research, it not simply emphasizes the territorially and structurally embedded nature of innovation phenomena but is also enriches their description by combining and differentiating in space structural conditions (internal and external) to the region and alternative types of local innovation activities and processes. In this approach, then, 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). As a consequence, alternative types of innovation modes or patterns (i.e. alternative combinations of local structural conditions and innovative activities and processes) can co-exist, thus superseding the idea of a binary space where regions are divided into innovative vs non innovative on the basis of the intensity of their innovative activities and processes.

This conclusion has important consequences for the study of innovation at the regional level and its implications on economic dynamics. Traditionally, in fact, regional innovation studies have approached the relationship between innovation and economic dynamics by focusing on whether (how much and under what conditions) changing and increasing the intensity of existing innovative activities and processes favor growth (Crescenzi and Rodríguez-Pose, 2011). On the other hand, the regional innovation pattern framework suggests to depart from this perspective and to concentrate on whether the capacity of alternative (and co-existing) innovation modes to evolve and to become more complex over time can affect economic dynamics.

The next sections aim precisely to develop further this intuition conceptually, by elaborating on the link between the evolution of regional innovation patterns and economic dynamics, and empirically, by describing the evolution of regional patterns of innovation in European NUTS2 regions.

3. The evolution of regional innovation patterns and economic dynamics

There is a long tradition of regional innovation studies pointing to the relevance of innovation for economic performance, regardless its measurement in terms of GDP (per capita) growth or in terms of productivity (Crescenzi and Rodríguez-Pose, 2011; Asheim et al., 2016). A central and common finding in this literature is that the sharp variations in the regional innovation endowment and capacity (i.e. in the intensity of regional innovation processes and activities) lead to threshold effects in the impact of innovative inputs on economic growth (Sterlacchini, 2008), meaning that better endowed areas benefit at most from an increase of innovative efforts (though with diminishing returns) and therefore on economic performance. For example, Crescenzi et al. (2007) study how social filter affects patent growth in EU and in the US. Similarly, Cooke (2004) describes how specific RIS configurations can ease more radical (and rewarding) types of innovative activities. Likewise, Capello and Faggian (2005) describe the relevance of collective learning for the innovative performance of firms located in *milieux innovateurs*. Capello et al. (2012) have highlighted the complementary effects of human and relational capital for regional growth and productivity, in the spirit of the *milieu innovateur* approach. On a similar vein, Rodríguez-Pose and Crescenzi (2008) have examined the positive mediation effect of social filter on regional growth in European regions. Importantly, some territorial factors (e.g. regional human capital endowment, regional social and relational capital endowment) not only act as enabler of local innovation but can also amplify the positive impact of innovation on regional economic performance. In fact, what matters for growth is the combination of innovative inputs and territorial elements and not simply the local knowledge and innovation endowment (Capello et al., 2012).

Yet, reflections and empirical evidence on the influence that evolutionary changes in regional innovation structures can generate on regional economic performance and dynamics in the following years are still limited. This is not accidental. In fact, only recently, research has moved towards the identification of how, why, and when regional innovation structures (i.e. modes or patterns) can transform, adapt, and evolve over time into more complex ones, even in backward areas (Asheim et al., 2016).

In the literature, such evolutionary changes are consistently interpreted as the aggregate outcome of strategic individual behaviors of local actors leading, endogenously, to alternative innovation modes (Asheim et al., 2016). In fact, deliberate action, purposive design, intentional behaviour, strategic decision, 'mindful deviations' of knowledgeable economic agents, notably entrepreneurs (but also policy makers), can represent endogenous drivers of novelty and, by extension, of a new innovation mode emerging in the region (Simmie, 2012).[iii]

Interestingly, this perspective has been recently extended and applied (conceptually and empirically) to identify alternative evolutionary pathways and enabling conditions favoring regional innovation patterns renewal and adaptation (Capello and Lenzi, 2017).[iv]

In a brief summary, the dynamics of regional patterns of innovation builds on the idea that any change from one regional innovation pattern to another requires an evolution of the two intertwined elements that characterise each pattern: the functional dimension, embedded in the local conditions, and the cognitive and associated relational dimension defining them (Capello and Lenzi, 2016b).

By elaborating on the intuition that learning, innovation and change are characterized by cumulative trajectory and paradigm patterns of evolution (Dosi, 1982), in the context of regional patterns of innovation, the dynamics of regional patterns of innovation can be interpreted in terms of ordered processes of change along and across specific 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 stemming from the functional and relational characteristics of territories. In short, regional learning paradigms represent regional systems of relationships (internal and external to the region) that shape the process upon which one looks for 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 characteristics, or its cognitive and relational characteristics or both.

Within each regional innovation patterns, different modes of innovation can arise in the reality, distinguishing one another on the basis of the type of knowledge (basic vs. applied, formal vs. informal, active vs. passive) and the intensity of the type of innovation specific of each paradigm (either imitation, or application or invention) (Capello and Lenzi, 2016b). These changes can be interpreted as alternative *regional learning trajectories* within each specific paradigm, whose evolution 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 type of knowledge.

Changes of paradigms or trajectories arise either from deliberate action, purposive design, intentional behaviour, strategic decision, 'mindful deviations' of knowledgeable economic agents, notably entrepreneurs (but even policy makers), or by spontaneous, unconscious, unplanned and uncoordinated process (i.e. disembodied economic forces). Both types of changes represent abstract evolutions that each region can face when shifting from one trajectory/paradigm to another. They apply to whatever type of paradigm/trajectory regions are specialised in. However, each change is complex, costly and risky.

Whether it is worth changing from one paradigm/trajectory to another represents an interesting research question. Conceptually speaking, however, this is not an easy task. Besides the simplistic observation of the novelty of this research line, the major difficulty in elaborating and advancing precise conceptual predictions on whether the evolution of regional innovation patterns brings positive effects on regional economic dynamics and in which innovation patterns such changes can be desirable and/or applicable at most resides in the very nature of the evolutionary changes in regional innovation patterns.

These changes, in fact, involve and depend on the evolution and dynamics of functional and cognitive (and the associated relational) elements, the constitutive blocks forging each regional innovation pattern (as described in Section 2). Importantly, as repeatedly illustrated by several authors from different disciplinary traditions[v], the laws of dynamics of such elements are characterized by path-dependence, which therefore orients and conditions the direction and (economic) success of any future change and makes their evolution an extremely slow and risky process, with high opportunity costs, possibly delayed benefits with respect to costs, and uncertain pay offs (Capello and Lenzi, 2016a).

Given the large consensus in the literature on the key role of innovation for economic performance, it is presumable that, by extension, a change and a complexification of regional innovation patterns can have a positive impact on economic dynamics, at least in the medium-long run when the gains from a shift towards a new and more complex pattern are likely to offset the respective initial adjustment costs. At the same time, the multifaceted nature of such changes makes extremely hard to anticipate (from a theoretical point of view) in which regional innovation patterns these dynamics would deliver the best outcomes. Hence, the reply to the conceptual question is better left to the empirical inquiry.

In order to progress in this direction and to uncover the consequences of innovation modes structural changes (also across different regional innovation patterns), the next section explains how regional innovation patterns have been empirically identified in EU regions and how regions evolved in terms of their regional innovation patterns in the period 2002-2006.

4. The dynamics of regional innovation patterns in European regions

Regional innovation patterns have been recently identified in European regions (i.e. 261 NUTS2 regions of 27 EU countries) for the period 2002-2004 and 2004-2006 (Capello and Lenzi, 2013a, 2017). As expected, while originally conceptualized in a group of three main ‘archetypal’ innovation patterns (see Section 2), five groups of regions have been obtained empirically by means of cluster analysis.[vi] In fact, each conceptual pattern can show distinct processes of knowledge accumulation and knowledge acquisition channels for innovation discovery, depending on different cognitive bases.

In detail, two clusters can be associated to the *science-based pattern* according to the basic vs. applied nature of the scientific knowledge base, i.e. respectively the *European science-based area* and the *Applied science area*. In the present context, basic scientific knowledge is the one 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 general purpose technologies such as biotechnology, ICT, nanotechnology. The opposite applies to the applied scientific knowledge (Capello and Lenzi, 2013a).

Two clusters can be associated to the *creative application pattern,* according to the formal vs. informal nature of the knowledge base, i.e. respectively the *Smart technological application area* and the *Smart creative diversification area.* 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, based on professional practices and experience (Capello and Lenzi, 2013a).

Finally, one cluster can be associated to the *imitative innovation pattern*, i.e. the *Imitative innovation area*. Importantly, while fully consistent with previous knowledge bases classifications, namely the threefold distinction between analytic, synthetic and symbolic knowledge bases (Asheim et al., 2016)[vii], the distinction between basic versus applied scientific knowledge and formal versus informal knowledge, enriches existing knowledge typologies. 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 knowledge (i.e. symbolic) knowledge.

The identification of regional innovation patterns in two distinct periods of time (2002-2004 and 2004-2006) enables to detect which regions in the EU were able to change their innovation pattern in the period considered. While most of the regions maintained their original pattern (177 out of 261)[viii], some of them were able to shift towards alternative and more complex innovation patterns. Regions usually moved from the *Imitative innovation pattern* to the *Smart and creative diversification* one and from the *Smart technological application pattern* to the *Science-based* ones while there are no regions moving from the *Imitative innovation pattern* to the *Science-based* ones. Most of changes occurred in the close proximity to the prevailing pattern; indeed, 80% of regions that changed their innovation pattern (50 out of 62) moved to the adjacent one (e.g. from the *Imitative innovation pattern* to the *Smart and creative diversification* one, and so on), meaning that progresses are gradual and not abrupt. Table A1 in Appendix lists the NUTS2 regions that changed their innovation pattern in the period considered.

The next section details data and methods applied to investigate whether such evolutionary changes had any impact on regional economic dynamics and whether this impact varies across patterns (i.e. depending on the innovation pattern of origin).

5. Methodology and data

To reply empirically to the question whether the change in regional innovation patterns generate economic advantages to regions, a regional growth model has been estimated, designed to test for the impact of the presence of a change in regional innovation pattern on regional growth (measured as the annual average regional real GDP per capita growth rate), and to check whether this effect varies across the different regional innovation patterns presented in the previous Section. In doing so, the model takes into consideration classic explanatory variables such as the initial level of GDP per capita, employment and capital (in the frame of the Solow's model) and human capital (in the frame of Lucas's model and many later contributions, also at the regional level).[ix]

The model estimated is therefore:

$$\Delta GDP\_pc_r = \alpha_0 + \beta_1 GDP\_pc_r + \beta_2 \Delta empl_r + \beta_3 \Delta K_r + \beta_4 FDI_r + \beta_5 Competences_r + \beta_6 Education_r + \beta_7 change\ of\ innovation\ pattern_r + \varepsilon_r \quad \text{(Eq. 1)}$$

where ΔGDP_pc_r is the annual average regional real GDP per capita growth rate in the period 2006-2014.

To unravel the impact of a change in regional innovation patterns across EU regions, firstly, the dummy variables for regional innovation patterns[x] were introduced and next interacted with the variable capturing a change in regional innovation patterns. Hence, the enlarged model to be estimated can be written as in Equation 2 below:

$$\Delta GDP\_pc_r = \alpha_0 + \beta_1 GDP\_pc_r + \beta_2 \Delta empl_r + \beta_3 \Delta K_r + \beta_4 FDI_r + \beta_5 Competences_r + \beta_6 Education_r + \beta_7 change\ of\ innovation\ pattern_r + \beta_8 D_r + \beta_9 change\ of\ innovation\ pattern_r * D_r + \varepsilon_r \qquad \text{(Eq. 2)}$$

where D_r represents the dummy variable for regional membership to the different regional patterns of innovation (the *Imitative innovation area* being the reference case).

The 2006-2014 period includes the years of the burning of the financial crisis that fully started in Europe in 2008. In particular, the years 2007-2009 presented a sharp decline in economic growth followed by a quick rebound in 2010 and another slowdown in 2011-2012. From 2012 onwards, recovery and growth seem rather stable (see Figure A.1 in Appendix). Therefore, the regional annual average real GDP per capita growth rate in the period 2006-2014, while capturing the regional GDP per capita trend in the period considered, still averages out the peaks and troughs experienced by EU regions, especially in some country blocks. In order to prove the robustness of the results, then, the same equations have been estimated by changing the period in which the dependent variable is computed. In particular, the regional annual average real GDP per capita growth rate was computed for a period of crisis (2007-2009) and for a period of recovery (2012-2014) to check whether the final results for the aggregate period 2006-2014 reflect more a decline trend or a recovery pattern (see Section 5).[xi]

Beyond the initial level of GDP per capita (measured as regional real GDP per inhabitant in natural logarithm), the model includes the following variables:

a) Employment

The model includes an indicator of total employment growth rate; this variable also enables to assess whether GDP per capita growth was driven by employment (in the case of a positive effect) or productivity increases (in the case of a negative effect).

b) Capital

The model includes two variables to measure the importance of capital for growth: the growth rate of capital and a measure of foreign direct investments (FDI) intensity.

The capital stock series at the regional level is not available from public databases and official sources. The capital stock series – elaborated by the Centro Ricerche Economiche Nord Sud (CRENoS), University of Cagliari, Italy – was constructed by applying the perpetual inventory method on investment series in the years 1985–2006. Specifically, K_r, the capital stock of region r at time t, is obtained as the sum of the flows of gross investments in the previous periods with a constant (across regions and over time) 10% depreciation rate (d), as is customary in this kind of exercise (Marrocu et al., 2013), as follows:

$$K_{r,t} = (1 - d)K_{r,t-1} + I_{r,t-1} \qquad \text{(Eq. 3)}$$

The capital stock value for the initial year (i.e., 1985) was computed as the sum of investment flows, $I_{r,t}$, in the ten preceding years (i.e., 1975–1984).

The role of external investments (and, thus, of a region’s economic attractiveness) is captured through an indicator of FDI penetration rate measured as number of FDI per 1,000 inhabitants.

Both were expected to affect the GDP per capita growth rate positively, and to generate a push effect on the local economy.

c) Human capital

The importance of human capital has been captured through two indicators. First, the share of tertiary educated (ISCED 5 and 6) population accounts for the average level of education and formal qualification in the population. Second, the share of employment in blue-collar (i.e. low added value) occupations accounts for actual competencies required in the labor market. The former is expected to show a positive sign on growth and the latter a negative one.

d) Change of regional innovation pattern

This is a binary variable taking value 1 if the region experienced a change in its innovation pattern[xii] and 0 otherwise. This categorization has conceptual and empirical reasons. On the conceptual ground, it enables to contrast regions that upgraded their innovation pattern (regardless the radicalness of such a change) against the others; this choice is in our opinion meaningful and appropriate to the goal of the paper as our primary interest it to understand the longer-term consequences on economic growth of changes in regional innovation patterns. On the empirical ground, this categorization is consistent with the actual distribution of moves. In fact, as noted in Section 3.2, most of regions, when changing their pattern, moved to the adjacent one (80%). At maximum, regions moved to the second adjacent pattern. Overall, 62 regions out of 261 have been able to change towards a more complex pattern of innovation while 22 did the opposite. Therefore, upward changes and changes in non-adjacent patterns were treated in the same way, while downward changes were put equal to 0, grouped together with the cases of no move at place.

Finally, a dummy variable for Eurozone countries and a set of country group dummies have been included to control for the uneven growth pattern across European countries in the period considered.[xiii]

In terms of estimation methods, the usual controls for spatial dependency were implemented on the base of Lagrange multiplier tests. As the analysis reported in the next section shows, the spatial error model seems the most appropriate in the present context (i.e. Lagrange multiplier tests are significant for the error model but not for the lag model) and therefore the results presented are based on this specification.

The description of the variables with their sources, summary statistics and correlations are in Tables A.2, A.3 and A.4 in Appendix.

6. The impact of regional innovation pattern evolution on economic dynamics

Table 1 reports the estimate of Eq. 1 and 2. Starting from the control variables, results confirm previous literature and suggest that a process of convergence is still at place in the period considered, as attested by the negative and significant coefficient of the regional real GDP per capita level at the beginning of the period. Yet, growth occurred at the expenses of an expansion of employment (i.e. economic growth was led by productivity increases rather than by employment growth) whereas the growth of domestic capital (i.e. domestic investments) had a negligible role. On the other hand, foreign capital had an important role in fostering growth; in fact, foreign investments were particularly targeted to the new member states of the Union that, overall, performed better in the period considered (Capello et al., 2015). Turning to the human capital variables, they consistently show that regional growth was linked to a higher share of highly educated population (i.e. positive and significant coefficient of the education variable) and of higher added value occupations (i.e. negative and significant coefficient of the variable measuring employment in low added value occupations).

In terms of the main variable of interest, results indicate that the change of regional innovation pattern produces longer-term consequences on economic dynamics (Table 1, model 1), thus supporting the expectation put forward in Section 3. Importantly, this result is stable in terms of significance and coefficient's magnitude with respect to the introduction of the regional innovation pattern dummy variables (Table 1, model 2). On their turn, the dummy variables for regional innovation patterns do not differ significantly from the reference case (i.e. the *Imitative innovation area*), confirming previous results that each pattern has an efficiency in generating growth and that growth is not only dependent on local knowledge intensity (Capello and Lenzi, 2013b). Importantly, robustness checks, implemented by changing the time span considered to compute the dependent variable, suggest that a change in regional innovation pattern does not seem significant to surf the initial years of crisis (i.e. the effect of the variable is in fact insignificant for the period 2007-2009; Table 2, models 1-2). On the other hand, the positive effects of a change in the regional innovation pattern primarily unfolds during the last years of recovery (i.e. the effect of this variable is in fact positive and significant for the period 2012-2014; Table 2, models 4-5). These results are also robust to the inclusion in the analysis of the regions in the *European science-based area* that by definition cannot change their innovation pattern (endnote ix and Table A.5 in Appendix).

Interestingly, the interactions between the regional innovation pattern dummies and the variable for a change in regional patterns present all a negative and significant coefficient with respect to the reference case (i.e. *Imitative innovation area*). Regions in the *Imitative innovation area* seem to benefit relatively more with respect to the other groups from an upgrade of the current innovation mode, suggesting that structural changes can be especially rewarding in areas with a lower endowment of knowledge and innovation.

Finally, when changing the time span considered to compute the dependent variable, results provide a far more mixed picture. In a period of crisis, regions in the *Imitative innovation area* seem better equipped to surf the crisis than the other groups of regions when they are able to engage in radical structural changes of their innovation pattern. In fact, all the interactions between the regional innovation pattern dummies and the variable for a change in regional patterns present a negative and significant coefficient with respect to the reference case (i.e. *Imitative innovation area*). On the other hand, regions in the other patterns but the *Imitative innovation area* are better placed to surf the economic crisis even if they are not able to change their own innovation pattern (positive and significant coefficient for the dummy variables representing regional innovation patterns membership; Table 2, column 3). This effect can be related to the predominant type of innovative activities conducted in regions in the *Imitative innovation area*, which are primarily imitative and therefore less costly, less risky and with shorter-term returns on economic growth. Differently, in a period of recovery and expansion, the capacity to engage in radical structural changes of the current innovation pattern seems to play a more relevant role for regions in the *Applied science area*, which seem those better positioned to enjoy the positive effects of a change in their innovation pattern. Again, this effect can be related to the predominant type of innovative activities conducted in this group of regions, which are highly knowledge- and technology-intensive, based on patents and therefore highly costly and risky, but probably more rewarding in the longer term. Instead, in absence of changes in the existing innovation pattern, regions in the *Imitative innovation area* seem in general better equipped to take advantage of general positive economic climate than the other groups of regions (the coefficients of the regional innovation pattern dummies are negative and significant with respect to the reference case, i.e. the *Imitative innovation area*; Table 2, column 6).

Table 1. The impact of the evolution of regional innovation patterns on economic growth

Dependent variable: Average annual regional real GDP per capita growth rate 2006-14	1	2	3
Regional real GDP per capita (2006) (log)	-0.0105***	-0.0100***	-0.0103***
	(0.003)	(0.003)	(0.003)
Employment growth (2000-6)	-0.0507*	-0.0528*	-0.0687***
	(0.029)	(0.029)	(0.026)
Capital growth (2000-6)	0.0106	0.0119	0.0124
	(0.018)	(0.018)	(0.018)
Regional FDI penetration rate (2005-7)	0.0038***	0.0037***	0.0037***
	(0.001)	(0.001)	(0.001)
Share of graduate population (25-64 years) (2006)	0.0003***	0.0003***	0.0003***
	(0.000)	(0.000)	(0.000)
Share of low added value occupations (2002-4)	-0.0318***	-0.0275**	-0.0263**
	(0.011)	(0.013)	(0.012)
Change of regional innovation pattern (2002-6)	0.0028**	0.0028**	0.0108***
	(0.001)	(0.001)	(0.003)
Smart and creative diversification area (2002-4)		-0.0015	0.0007
		(0.003)	(0.003)
Smart and technological application area (2002-4)		-0.0029	-0.0006
		(0.003)	(0.003)
Applied science area (2002-4)		-0.0008	0.0011
		(0.003)	(0.004)
Change of pattern*Smart and creative diversification area			-0.0096***
			(0.004)
Change of pattern*Smart and technological application area			-0.0090**
			(0.004)
Change of pattern*Applied science area			-0.0080**
			(0.004)
Constant	-0.0458**	-0.0440*	-0.0485**
	(0.022)	(0.023)	(0.023)
Lambda	0.9712***	0.9711***	0.9718***
	(0.027)	(0.027)	(0.026)
Robust Lagrange multiplier (error) p – value	0.000	0.000	0.000
Robust Lagrange multiplier (lag) p – value	0.595	0.563	0.273
Squared correlation	0.531	0.535	0.545
Country groups and euro dummies	YES	YES	YES
Joint test on the significance of country groups and euro dummies p - value	0.000	0.000	0.000
Observations	241	241	241

Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 2. Robustness check – dependent variable average annual regional real GDP per capita growth rate 2007-2009 and 2012-2014

Dependent variable: Average annual regional real GDP per capita growth rate	**2007-2009**			**2012-2014**		
	1 - SEM	2 – SEM	3 – SEM	4 - OLS	5 - OLS	6 - OLS
Regional real GDP per capita (2006) (log)	-0.0238***	-0.0250***	-0.0258***	0.0021	0.0051	0.0058
	(0.005)	(0.006)	(0.006)	(0.005)	(0.005)	(0.005)
Employment growth (2000-6)	-0.0557	-0.0554	-0.1079*	-0.0230	-0.0329	-0.0183
	(0.084)	(0.082)	(0.056)	(0.042)	(0.042)	(0.045)
Capital growth (2000-6)	-0.0147	-0.0289	-0.0253	0.0638*	0.0760**	0.0733**
	(0.033)	(0.033)	(0.032)	(0.032)	(0.031)	(0.031)
FDI penetration rate (2005-7)	0.0075***	0.0066***	0.0063***	0.0006	0.0007	0.0012
	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)	(0.002)
Education (25-64 years) 2006)	0.0007***	0.0007***	0.0008***	0.0002*	0.0003**	0.0002*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Low added-value competencies (2002-4)	-0.1196***	-0.1269***	-0.1232***	-0.0106	0.0042	0.0011
	(0.024)	(0.027)	(0.025)	(0.017)	(0.018)	(0.018)
Change of regional innovation pattern (2002-6)	-0.0014	-0.0001	0.0272***	0.0050**	0.0041**	-0.0037
	(0.002)	(0.002)	(0.006)	(0.002)	(0.002)	(0.006)
Smart and creative diversification area (2002-4)		0.0103**	0.0177***		-0.0097***	-0.0118***
		(0.005)	(0.005)		(0.003)	(0.003)
Smart and technological application area (2002-4)		0.0076	0.0159***		-0.0104**	-0.0130***
		(0.006)	(0.006)		(0.004)	(0.004)
Applied science area (2002-4)		0.0066	0.0134*		-0.0101*	-0.0133**
		(0.007)	(0.007)		(0.005)	(0.005)
Change of pattern*Smart and creative diversification area			-0.0301***			0.0057
			(0.007)			(0.007)
Change of pattern*Smart and technological application area			-0.0320***			0.0091
			(0.008)			(0.007)
Change of pattern*Applied science area			-0.0285***			0.0107*
			(0.007)			(0.006)
Constant	-0.1066***	-0.1173***	-0.1320***	0.0086	0.0248	0.0325
	(0.023)	(0.028)	(0.026)	(0.019)	(0.021)	(0.020)
Lamba	0.7843***	0.7859***	0.8310***			
	(0.181)	(0.192)	(0.141)			
Robust Lagrange multiplier (error) p – value	0.021	0.027	0.033	0.476	0.355	0.251
Robust Lagrange multiplier (lag) p – value	0.961	0.902	0.558	0.309	0.358	0.385
Squared correlation (models 1 to 3)/ R2 (models 4 to 6)	0.489	0.504	0.500	0.524	0.544	0.549
Country groups and euro dummies	YES	YES	YES	YES	YES	YES
Joint test on the significance of country groups and euro dummies p - value	0.000	0.000	0.000	0.000	0.000	0.000
Observations	241	241	241	241	241	241

Note: The GDP per capital level has been kept at 2006 and not at the beginning of the period considered to compute the dependent variable to ease comparisons with Table 2 in the text. The same regressions have been estimated by using GDP per capital level at 2007 in models 1 to 3 and GDP per capital level at 2012 in models 4 to 6. Results are qualitatively unchanged and available upon request from the authors. Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

7. Conclusions

The empirical analysis presented in the paper has shown that structural changes in innovation patterns do have longer-term consequences on economic dynamics. This conclusion brings to some reflections in terms of policy implications in that it fully ascribes the current efforts, especially at the EU level, to progress and renew regional economic and innovative structures, as advocated by the smart specialization strategy. Importantly, the findings of the paper suggest that structural change can be beneficial in whatever type of innovation pattern, but especially in less knowledge and innovation intensive areas in times of crisis.

Given these results, reflections on how to make regions move towards a more complex innovation patterns become compelling, theoretically, empirically and, primarily, from a policy perspective. The academic and policy debates, consistent with the place-based approach to regional innovation policies (Boschma, 2014), put particular emphasis on the role of diversification as the principal path to be followed to achieve structural changes, in line with the smart specialization strategy approach.

Recent papers have however proposed alternative pathways to diversification as to achieve such radical changes. Some authors in fact argue that under certain circumstances less advanced, ‘thinner’ areas have limited opportunities of diversification but, at the same time, can have more possibilities of experimentation and radical changes as there are less constraints and inertia that may divert and suppress the emergence of alternatives (Trippl et al., 2015; Simmie, 2012). In such contexts, therefore, other pathways can be explored and exploited to achieve changes in innovation patterns. Additionally, upgrading of the current innovation activities and creation of new ones 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 (Capello and Lenzi, 2017).

It would be very interesting, then, to explore in which innovation contexts (i.e. patterns) alternative pathways are more likely to deliver such evolutionary changes and their long term consequences on economic performance. This is certainly a relevant and promising research direction to pursue in the near future.

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APPENDIX

Table A.1. List of NUTS2 regions changing their innovation pattern

Regional pattern of innovation 2002-2004	**Regional patterns of innovation 2004-6**			
	Smart and creative diversification area	**Smart technological application area**	**Applied science area**	**European science-based area**
Imitative innovation area	ITH1 -Provincia Autonoma Bolzano/Bozen ITF4 -Puglia ITF5 -Basilicata ITF6 -Calabria ITG1 -Sicilia ITG2 -Sardegna MT00 -Malta	BG34 -Prov. Luxembourg (B)		
Smart and creative diversification area		ITC3 -Liguria ITI3 -Marche ITF1 -Abruzzo	DE80 -Mecklenburg-Vorpommern FI19 -Länsi-Suomi EL12 -Kentriki Makedonia EL22 -Ionia Nisia EL41 -Voreio Aigaio EL42 -Notio Aigaio PT15 -Algarve PT18 -Alentejo RO32 -Bucuresti - Ilfov UKI1 -Inner London	
Smart technological application area			DK04 -Midtjylland DK05 -Nordjylland IE01 -Border, Midland and Western PT11 -Norte SE12 -Östra Mellansverige SE21 -Småland med öarna SE22 -Sydsverige SE23 -Västsverige SE31 -Norra Mellansverige SE32 -Mellersta Norrland SI02 -Zahodna Slovenija UKD6 -Cheshire UKF2 -Leicestershire, Rutland and Northamptonshire UKG1 -Herefordshire, Worcestershire and Warwickshire UKH2 -Bedfordshire and Hertfordshire UKH3 -Essex UKI2 -Outer London UKJ1 -Berkshire, Buckinghamshire and Oxfordshire UKJ2 -Surrey, East and West Sussex UKJ3 -Hampshire and Isle of Wight UKJ4 -Kent UKK1 -Gloucestershire, Wiltshire and Bristol/Bath area	GR24 -Sterea Ellada
Applied science area				AT34 -Vorarlberg BE21 -Prov. Antwerpen BE24 -Prov. Vlaams-Brabant BE31 -Prov. Brabant Wallon DE22 -Niederbayern DE26 -Unterfranken DE27 -Schwaben DE72 -Gießen DE91 -Braunschweig DEB3 -Rheinhessen-Pfalz DED4 -Chemnitz DED5 -Leipzig DEF0 -Schleswig-Holstein DEG0 -Thüringen FI1B -Helsinki-Uusimaa FI1C -Etelä-Suomi PT17 -Lisboa SE11 -Stockholm

Source: Adapted from Capello and Lenzi (2017)

Table A.2. Variables description

Indicators	Computation	Year	Source
Regional real GDP per capita growth	Regional real GDP annual average rate of growth	2006-2014	EUROSTAT
Regional real GDP per capita level	Real GDP / population	2006	EUROSTAT
Employment growth rate	Total employment annual average rate of growth	2000-2006	EUROSTAT
Capital growth rate	Capital annual average rate of growth	2000-2006	CRENoS database on EUROSTAT data
FDI penetration rate	Number of FDI per 1,000 inhabitants	Average value 2005-2007	FDI-Regio, Bocconi-ISLA
Low added-value competencies (human capital)	Share of craft and related trades workers, plant and machine operators, and assemblers on total employment	Average value 2002-2004	European Labour Force Survey
Education (human capital)	Share of people aged 15 and over with tertiary education (ISCED 5 and 6) on total population	2006	EUROSTAT
Change of regional innovation pattern	Binary variable taking value 1 if a region changed its innovation pattern towards a more complex one and 0 otherwise	One value 2002-2006	Authors' elaboration

Table A.3. Descriptive statistics

Variable	Mean	S.d.	Min	Max
Average annual regional real GDP per capita growth (2006-2014)	0.254	1.668	-4.241	.04.262
Real GDP per capita (2006)	23188	11805	2503	90375
Employment growth (2000-6)	1.107	1.756	-3.385	13.553
Capital growth (2000-6)	3.043	3.695	-5.881	20.205
FDI (2005-7)	0.192	0.586	0	6.810
Education (2006)	22.606	8.197	8	45.700
Low added-value competencies (2002-4)	24.297	6.715	7.892	46.777
Change of innovation pattern (2002-6)	0.257	0.438	0	1
Imitative innovation area (2002-4)	0.154	0.361	0	1
Smart technological application area (2002-4)	0.357	0.480	0	1
Smart creative diversification area (2002-4)	0.282	0.451	0	1
Applied science area (2002-4)	0.207	0.406	0	1

Note: Number of observations is 241. GDP deflated at 2005.

Table A.4 correlation matrix

N.	Variable	1	2	3	5	6	6	7	8	9	10	11
1	Average annual regional real GDP per capita growth (2006-14)	1										
2	Real GDP per capita (2006)	-0.435*	1									
3	Employment growth (2000-6)	-0.295*	0.201*	1								
4	Capital growth (2000-6)	-0.065	-0.182*	0.056	1							
5	FDI penetration rate (2005-7)	0.241*	0.004	-0.112	0.242*	1						
6	Education (2006)	0.005	0.553*	0.178*	-0.054	0.184*	1					
7	Low added-value competencies (2002-4)	0.115	-0.581*	-0.029	0.264*	0.046	-0.594*	1				
8	Change of innovation pattern	-0.090	0.238*	0.013	-0.051	0.153*	0.141*	-0.170*	1			
9	Imitative innovation area (2002-4)	0.304*	-0.665*	-0.116	-0.011	-0.043	-0.404*	0.269*	-0.040	1		
10	Smart technological application area (2002-4)	-0.242*	-0.028	0.116	0.239*	0.060	-0.150*	0.100	-0.181*	-0.317*	1	
11	Smart creative diversification area (2002-4)	-0.0995	0.304*	0.016	-0.139*	0.019	0.300*	-0.195*	0.116	-0.267*	-0.467*	1
12	Applied science area (2002-4)	0.126	0.288*	-0.052	-0.119	-0.054	0.204*	-0.141*	0.120	-0.218*	-0.381	-0.321*

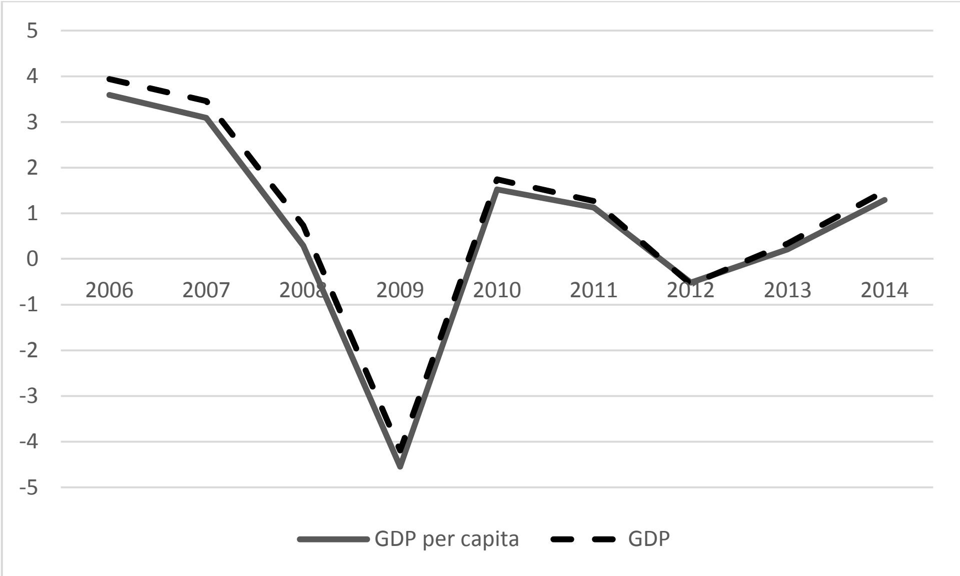
* $p < 0.05$

Table A.5. Robustness check - inclusion of the European science-based area regions (estimates of equation 1)

Dependent variable: **Average annual regional real GDP per capita growth rate**	**2006-2014** **(1)**	**2007-2009** **(2)**	**2012-2014** **(3)**
Regional real GDP per capita (2006) (log)	-0.0117***	-0.0264***	0.0017
	(0.003)	(0.005)	(0.004)
Employment growth (2000-6)	-0.0559**	-0.0538	-0.0299
	(0.028)	(0.082)	(0.041)
Capital growth (2000-6)	0.0151	-0.0172	0.0626*
	(0.018)	(0.033)	(0.032)
FDI penetration rate (2005-7)	0.0036***	0.0082***	0.0004
	(0.001)	(0.002)	(0.001)
Education (25-64 years) (2006)	0.0003***	0.0006***	0.0003**
	(0.000)	(0.000)	(0.000)
Low added-value competencies (2002-4)	-0.0223*	-0.1206***	-0.0039
	(0.012)	(0.023)	(0.016)
Change of regional innovation pattern (2002-6)	0.0026**	-0.0009	0.0047**
	(0.001)	(0.002)	(0.002)
Constant	-0.0537***	-0.1154***	0.0053
	(0.020)	(0.019)	(0.017)
Lambda	0.9680***	0.7295***	
	(0.029)	(0.200)	
Robust Lagrange multiplier (error) p - value	0.000	0.028	0.440
Robust Lagrange multiplier (lag) p – value	0.501	0.900	0.284
Squared correlation (models 1 and) – R2 (model 3)	0.549	0.539	0.517
Country groups and euro dummies	YES	YES	YES
Joint test on the significance of country groups and euro dummies p - value	0.000	0.000	0.000
Observations	261	261	261

Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Figure A1. Regional real GDP per capita and GDP growth rate, 2006-2014 (% change on the previous year)



Source: Own elaborations on EUROSTAT data

[i] Implicitly, then, the RIS approach suggests that both sub-systems should be fully developed and interacting in order sustain local innovation at most, and that the weaknesses, unbalances and/or under-development of any of the two undermines local innovation capacity. For a similar discussion, see: Capello (2015).

[ii] For a similar discussion, see: Capello (2015).

[iii] However, on purely theoretical grounds, it is not possible to exclude that the emergence of a new pattern can be driven by a spontaneous, unconscious, unplanned and uncoordinated process (i.e. disembodied economic forces) which represents the second source of evolutionary change, as claimed by some authors (Trippl et al., 2015).

[iv] It is worth mentioning that this perspective has been applied also in the frame of the RIS approach, with the goal to study the emergence and unfolding of new industrial paths of local development (Trippl et al., 2015) and not the evolution of regional innovation structures.

[v] See among others: Nelson and Winter, 1982; Dosi, 1982; Martin and Sunley, 2006; Simmie, 2012; Asheim et al., 2016.

[vi] 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 (2013a).

[vii] For a synthetic presentation of the knowledge bases literature in a RIS perspective, see: nature Asheim et al., (2016).

[viii] This is not a counterintuitive result, since the changes analyzed are of a structural nature.

[ix] For a similar approach, see Capello and Lenzi (2016b).

[x] Regions in the European science-based areas (20 observations) by definition cannot experience any upward change. In the empirical analysis, therefore, they have been excluded. A robustness check of the results of estimation of equation 2 has been carried out also by including these regions. Results are qualitatively unchanged and available in Table A.5 in Appendix.

[xi] The period 2009-2012 is more volatile presenting both recovery and decline with respect to the others (Figure A.1 in Appendix). The other periods instead present a clearer trend and are therefore preferable as they enable a clearer interpretation.

[xii] The changes that occur between 2002-2004 and 2004-2006 are the outcome of a long process of adjustment that develops its final step in the short period considered. A recent paper (Capello and Lenzi, 2017) shows that such changes are linked to the accumulation, over the past, of structural characteristics fundamental to move to another pattern.

[xiii] Country group dummies are defined as follows: South, the reference case (Greece, Italy, Portugal and Spain); North: (Denmark, Finland, and Sweden); West (France, Ireland and UK); Center (Austria, Belgium, Germany, Luxemburg and The Netherlands); Baltic countries (Estonia, Latvia and Lithuania); Central and Eastern European Countries (Czech Republic, Hungary, Poland, Slovakia and Slovenia); Romania and Bulgaria; Malta and Cyprus. The Eurozone dummy variable takes value 1 for regions in the following Eurozone countries: Austria, Belgium, Cyprus, Germany, Greece, Spain, Estonia, Finland, France, Ireland, Italy, Latvia, Luxemburg, Malta, The Netherlands, Portugal, Slovakia, Slovenia. Lithuania was excluded because adoption of euro occurred in 2015, after the period under consideration.