Territorial Patterns of Innovation in Europe

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Abstract

This paper investigates over the way in which regions innovate. The conceptual framework departs from the simple idea that scientific activities equates knowledge, assuming that the presence of local knowledge produced by research centers, universities and firms was a necessary and sufficient condition for increasing the innovative capacities in local firms, fed by local spillovers. In particular, the paradigmatic jump in interpreting regional innovation processes lies in a conceptual framework interpreting not a single phase of the innovation process, but the *different modes of performing the different phases of the innovation process*, highlighting the *context conditions* (internal and external to the region) that accompany each innovation pattern. The paper conceptually identifies different territorial patterns of innovation, and empirically test their existence in Europe. Interesting results emerge from the European territory, witnessing the existence of large differences in the territorial patterns of innovation. These results strongly support normative suggestions towards *thematically/regionally focused innovation policies*.

1. Introduction

Innovation and knowledge diffusion at regional level attracted the interest of regional economists and geographers since the end of the 1960s, when the neoclassical paradigm interpreting innovation as a "manna from heaven", equally distributed among firms and in space, was put into question. Since then a large literature has been developed on the creation and diffusion mechanisms of knowledge and innovation at regional level.

The theoretical approaches to innovation and knowledge creation in space are all interesting per se, and over time built a rich scientific apparatus on the way knowledge and innovation take place in space. Their richness is witnessed by the multiple scientific paradigms on which they find their roots; from economic geography, to evolutionary theory of innovation, to neo-Schumpeterian theories on local development, to evolutionary geography, and enrich the understanding of local innovation processes.

All the existing theoretical approaches have one aspect in common, which represents the limits of the present scientific know-how on local knowledge and innovation. All these theories base their reflections on *one particular phase* of the innovation process, often interpreted as the crucial one, being either knowledge creation, innovation creation, innovation diffusion or knowledge diffusion. Some theories even interpret knowledge and innovation as coinciding processes, giving for granted that if knowledge is created locally, this inevitably leads to innovation, or if innovation takes place, this is due to local knowledge availability. A similar short-circuit is assumed between knowledge / innovation and performance, expecting a productivity increase in all cases in which a creative effort, a learning process, an interactive and cooperative atmosphere characterize the local economy.

Instead, invention, innovation and diffusion are not necessarily intertwined, even at the local level, since factors that enhance the implementation of new knowledge can be quite different from the factors which stimulate innovation. Firms and individuals which are leading an invention are not necessarily also leaders in innovation or in the widespread diffusion of new technologies. The history of technology and innovation is full of examples of this kind; the fax machine, first developed in Germany, was turned into a worldwide successful product by Japanese companies. Similarly, the anti-lock brake systems (ABS) was invented by US car makers but became prominent primarily due to German automotive suppliers (Licht, 2009).

These reflections suggest that innovation can be the result of different patterns, different modes of performing each phase of the innovation process. The variety of innovation patterns explains the failure of a "one size fits all" policy to innovation, like the thematically/regionally neutral and generic R&D incentives, with the expectation to develop a knowledge economy everywhere. On the contrary, innovation patterns typical of each specific area have to be identified, on which ad-hoc and targeted innovation policies can be drawn.

This paper aims at contributing to this end, and building on the existing literature, it suggests a new conceptual framework to read the innovation potentials at regional level, by highlighting possible different territorial patterns of innovation (sec. 2). Moreover, the paper develops an empirical analysis based on a rich dataset for all 268 NUTS2 regions of the 27 EU Member Countries in order to empirically test the existence of the different territorial patterns of innovation (sec. 3). Interesting results emerge, that highlight an even more fragmented reality than what conceptually foreseen (sec. 4-5). Interesting policy implications emerge (sec. 6).

2. Territorial patterns of innovation

2.1. A proposed definition and a framework

The paradigmatic jump in interpreting regional innovation processes lies nowadays in the capacity to build on the single approaches developed for the interpretation of knowledge and innovation a conceptual framework interpreting not a single phase of the innovation process, but the *different modes of performing the different phases of the innovation process*, highlighting the *context conditions* (internal and external to the region) that accompany each innovation pattern. In this way, we are able to take into consideration alternative situations where innovation builds on internal knowledge, or where local creativity allows, even in front of the lack of local knowledge, an innovative application thanks to knowledge developed elsewhere and acquired via scientific linkages, or where innovation is made possible by an imitative process of innovations developed outside the region.

This new interpretative paradigm – the innovation patterns paradigm, stressing complex interplays between phases of the innovation process and spatial context or territorial conditions – adds two new elements with respect to the previous theoretical paradigms (Capello, 2011). First of all, it disentangles knowledge from innovation, addressing the two as different (and subsequent) phases of an innovation process, each phase calling for specific local elements for its development, and having a different natural location depending on the presence of the factors that support their development. This approach departs from the assumption of a invention-innovation short circuit taking place inside individual firms (or their territories) operating on advanced sectors, as well as an immediate interaction between R&D/higher education facilities on the one hand and innovating firms on the other, thanks to spatial proximity.

The temporal necessarily sequentiality between knowledge source and innovation, and between innovation and economic performance – the so called "linear model of innovation" – has been heavily criticized since it is rooted in the idea that innovation can be analyzed as a "rational" and "orderly" process (Edgerton, 2004). However, we strongly believe that: i) scientific advance in many cases is a major source of innovation, fully recognizing that they are neither necessary nor sufficient conditions for innovation to take place; ii) an alternative model where "everything depends on everything else", with no specific structure of the innovative system fully and clearly specified, does not help in generating a conceptual analytical model able interpret the systemic, dynamic and interactive nature of innovation; iii) self-reinforcing feedbacks from innovation to knowledge and from economic growth to innovation and knowledge play an important role in innovation processes. The impact of science on innovation does not merely reside in the creation of new opportunities to be exploited by firms, but rather in increasing research productivity and therefore the returns to R&D, through the solution and exploitation of technical problems, elimination of research directions that have proven wrong from a scientific perspective and provision of new research technologies (Nelson, 1959; Mowery and Rosenberg, 1998; Balconi et al., 2010). We therefore strongly support the concept of a "fragmented (spatially diversified) linear model of innovation", in which the patterns of innovation are a linearization, or partial block linearization of an innovation process where feedbacks, interconnections and non-linearities, in the form of increasing returns, find a prominent role.

Secondly, the concept of "patterns of innovation" calls for the identification of the context conditions, both internal and external to the region, that support the different innovation phases; these context conditions become integral part in the definition of a *territorial pattern of innovation*. In this sense, the approach does not look for the territorial capabilities that allow territories (in general) to exploit innovation and knowledge, like the presence of human capital. The conceptual framework looks for the *territorial specificities (context conditions)* that are behind *different modes of performing the different phases of the innovation process* and that become integral parts of a territorial pattern of innovation.

An integrated conceptual framework like this one identifies the local conditions that guarantee: a) the shift from local knowledge to innovation; b) the acquisition of external knowledge to innovate locally; c) the acquisition of external innovation for imitation with different degrees of creativity. In order to identify the context conditions that accompany each phase of the innovation process we can make use of the existing and well established literature; the conceptual effort rests on the identification of the combination of the different context conditions that allow the presence of different phases of the innovation process, and give rise to alternative patterns of innovation.

2.2. Differentiated territorial patterns of innovation

A territorial pattern of innovation is made of a combination of *territorial specificities (context conditions)* that are behind *different modes of performing the different phases of the innovation process*. Among all possible combinations, the most interesting ones are the following, reflecting different knowledge and innovation aspects:

a) an endogenous innovation pattern in a scientific network, where the local conditions are all present to support the creation of knowledge, its local diffusion and transformation into innovation and its widespread local adoption so that higher growth rates can be achieved. Given the complex nature of knowledge nowadays, this pattern is expected to show a tight interplay in the creation of knowledge with other regions, and therefore being in an international scientific network. This pattern can be easily built from the conceptual point of view on all the literature dealing with knowledge and innovation creation and knowledge diffusion;

b) a creative application pattern, characterized by the presence of creative actors interested and curious enough to look for knowledge, lacking inside the region, in the external world, and creative enough to apply external knowledge to local innovation needs. This approach is conceptually built on the literature on regional innovation creation;

c) an imitative innovation pattern, where the actors base their innovation capacity on imitative processes, that can take place with different degrees of creativity in the adaptation of an already existing innovation. This pattern is based on the literature dealing with innovation diffusion.

a) An endogenous innovation pattern in a scientific network

A first and straightforward territorial pattern of innovation is an endogenous one referring to a situation in which a region is endowed of local conditions for knowledge creation and for turning knowledge into innovation, so to guarantee a productivity increase and regional growth. This model relies on specific *internal context conditions* that explain knowledge creation and diffusion, as well as innovation by looking at the internal structural conditions of a region, have been widely analyzed by the literature.

Knowledge creation is in general dependent on an urban environment, where material and non-material elements supporting scientific knowledge find a natural location. The main elements that have been underlined as the sources of knowledge creation, being material and non-material, stem from indivisibility and synergies, i.e. from agglomeration and proximity, the two elements characterizing urban environments:

- urban size per se (McCann, 2004), especially concerning the creation of large human capital pools and wide labour markets (Lucas, 1988; Glaeser, 1998);
- diversity, concerning the variety of activities and the possibility for specializations in thin sub-sectors and specific productions, thanks to the size of the overall urban market (Jacobs, 1969 and 1984; Quigley, 1998);
- contacts and interaction, allowing face-to-face encounters reducing transaction costs (Scott and Angel, 1987; Storper and Scott, 1995);
- synergies, thanks to proximity, complementarity and trust (Camagni, 1991 and 1999); in more formalized models, these same effects stem from complexity of the urban system and synergetics (Haken, 1993);
- reduction of risk of unemployment for households, thanks to the thick and diverse urban labour market (Veltz, 1993);
- trans-territorial linkages, emerging from the international gateway role of large cities, particularly crucial in a globalising world (Sassen, 1994).

The literature has not confined itself to the identification of territorial elements of knowledge creation. Reflections on the territorial elements that explain the capacity of a region to use its knowledge for *innovation creation* have been put forward. In particular, creativity and recombination capability to translate scientific, basic or applied knowledge into innovative application, require a relational space, where functional and hierachical, economic and social interactions are embedded into geographical space. Geographical proximity (agglomeration economies, district economies) and cognitive proximity (shared behavioural codes, common culture, mutual trust and sense of belonging) guarantee the *socio-economic and geographical substrate* on which collective learning processes can be incorporated, mainly due to two main processes (Camagni and Capello, 2002):

- the huge mobility of professionals and skilled labour – between firms but internally to the local labour market defined by the district or the city, where this mobility is maximal), and
- the intense co-operative relations among local actors, and in particular customer-supplier relationships in production, design, research, and finally knowledge creation.

The translation of knowledge into innovation is facilitated by interaction and co-operation, by the reduction of uncertainty (especially concerning the behaviour of competitors and partners), of information asymmetries (thus reducing mutual suspicion among partners) and of probability of opportunistic behaviour under the threat of social sanctioning (Camagni, 1991 and 1999), all elements that are confirmed by many regional economics schools (Bellet et al., 1993; Rallet and Torre, 1995; Cappellin, 2003; Camagni and Capello, 2009).

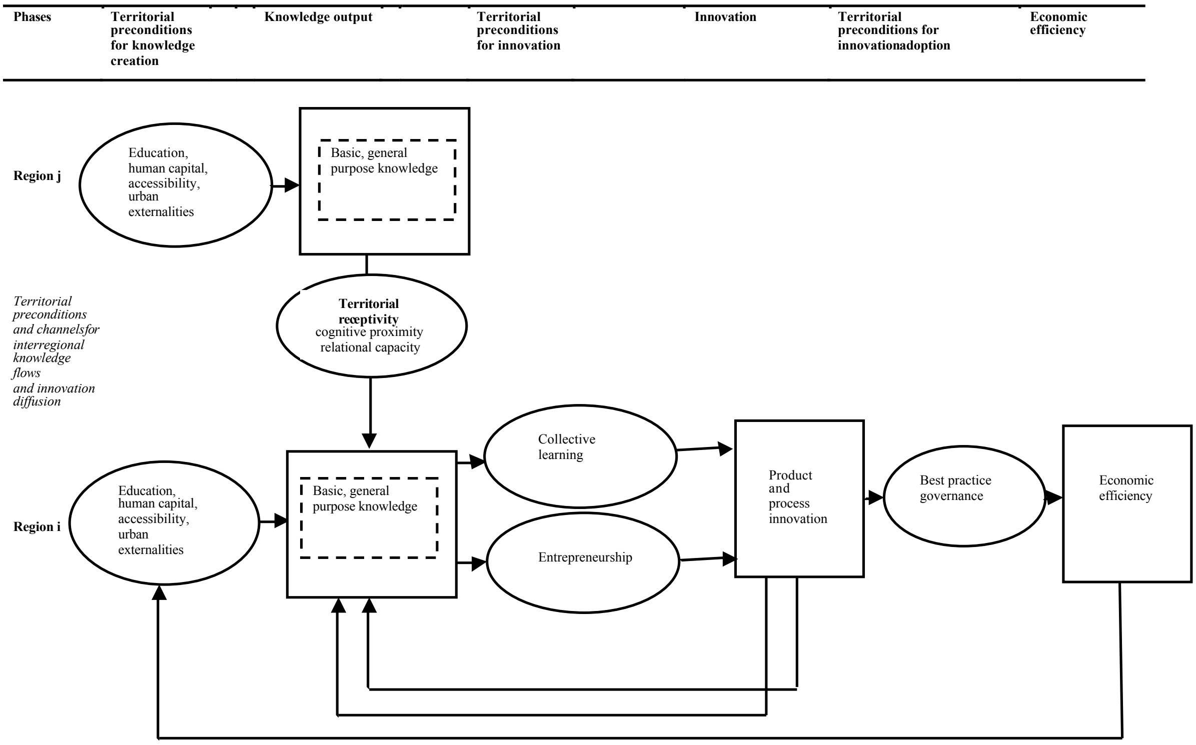
Another group of literature dealing with the capacity of a region to translate knowledge into innovation is the knowledge filter theory of entrepreneurship, put forward by Acs and Audretsch (Acs et al. 2004). It provides an explicit link between knowledge and entrepreneurship within the spatial context, where entrepreneurs are interpreted as the innovative adopters of new knowledge. This theory posits that investments in knowledge by incumbent firms and research organizations such as universities will generate entrepreneurial (innovation) opportunities because not all of the new knowledge will be pursued and commercialized by the incumbent firms. The knowledge filter refers to the extent that new knowledge remains un-commercialized by the organization creating that knowledge. These residual ideas are those that generate the opportunity for entrepreneurship. The interesting aspect of this theory is that the capabilities of economic agents within the region to actually access and absorb the knowledge and ultimately utilize it to generate entrepreneurial activity is no longer assumed to be invariant with respect to geographic space, as has been always thought. In particular, diversified areas, in which differences among people that foster looking at and appraising a given information set differently, thereby resulting in different appraisal of any new idea, are expected to gain more from new knowledge.

Notwithstanding the internal capacities to generate knowledge, given the complex and systemic nature of knowledge and innovation, in most cases regions reinforce and complement their internal knowledge with external one, through diffusive, mostly un-intentional, knowledge patterns based on spatial proximity ("spatial linkages"), subject to strong distance decay effects, and/or through intentional relations based on a-spatial networks or non-spatially mediated channels ("a-spatial linkages") that may take place both at short and long distances based on the organization of different forms of transfer and exchange of information and knowledge than the pure spatial proximity.

An innovation pattern of this kind can be labeled "*endogenous innovation pattern in a scientific network*" (Figure 1). In front of a territorial pattern of innovation of this kind, the natural innovation policy aim is the achievement of the maximum return to R&D investments. An aim like this calls for the importance of a specialization in R&D at European level, that guarantees the achievement of a critical mass of researchers, equipments and R&D resources; this critical mass is interpreted as fundamental in order to achieve the desired goal, for the research work to become effective and to achieve an acceptable research performance.

Based on the indivisibility rule associated to research activities in general, and to general purpose technologies in particular, the idea of a smart specialization in R&D activity has pervaded the innovation economic debate, calling for an European Research Area allowing agglomeration processes to occur, giving rise to centres of excellence. This can only be done within an integrated research space in which knowledge is exchanged within a solid and efficient network among centres of excellence, that become regions specialized in the basic inventions. Regions showing "an endogenous innovation pattern in a scientific network" can become one of these centres; the specialization of each centre in general purpose technology research activities can become a policy mission.

Figure 1. Endogenous innovative pattern in a scientific network



The innovative model in this territorial innovation pattern is a typical supply-driven model; from scientific activities, from an invention, a subsequent co-invention of applications leads to a number of innovations mainly brought about by inventors and co-inventors of applications.

The conditions for a region to acquire knowledge from outside its boundaries can be regarded as *territorial receptivity* (Table 1), broadly defined as the capability of the region to interpret and use external knowledge for complementary research and science advances, or more generally absorptive capacity of a region à la Cohen and Levinthal (1990). More specifically, receptivity is made of different aspects, according to the nature of knowledge, and its diffusion. If a modern view of knowledge is adopted, learning and interaction processes are put at the forefront, and knowledge is considered as complex semi-public or co-operative. Its diffusion is subject to strong spatial barriers and follows widely unpredictable creative processes. Knowledge creation and learning often depend on combining diverse, complementary capabilities of heterogeneous agents.

Given these characteristics, receptivity is first of all dependent on a *relational capability* required to guarantee that a region is in general made of individuals, firms and institutions oriented towards a cooperative and synergic attitude, nourished by trust and sense of belonging, in order to guarantee collective and interactive learning processes. In this sense, our conceptual work takes advantage of the reflections developed in the French school of proximity (Rallet, 1993; Rallet and Torre, 1995; Torre and Rallet, 2005), and in the evolutionary geography school (Boschma and Lambooy, 1999; Boschma, 2005); complexity of science and knowledge evolution, together with bounded rationality which generates cognitive constraints of actors, leads economic agents to search in close proximity to their existing knowledge base, which provides opportunities and sets constraints for further improvement (Boschma, 2005). Knowledge evolution therefore takes place in a cumulative way, localized around a technological paradigm, in cooperation among actors with a strong complementarity within a set of shared competences. For this reason, a third component of territorial receptivity is *cognitive proximity* among regions, necessary for a region to acquire knowledge from another one, to understand and use it in a creative way (Table 1).

Table 1. Preconditions for interregional exchange of knowledge and innovation

	Territorial Receptivity	*Territorial Creativity*	*Territorial Attractiveness*
Preconditions to receive	Relational capacity	Openness to innovation	Limited labour costs
Preconditions to exchange	Cognitive proximity	Sectoral proximity	Income differentials
Channels for exchange	Scientific networks Co-patenting Migration of inventors	Participation in industrial associations	Foreign direct investments

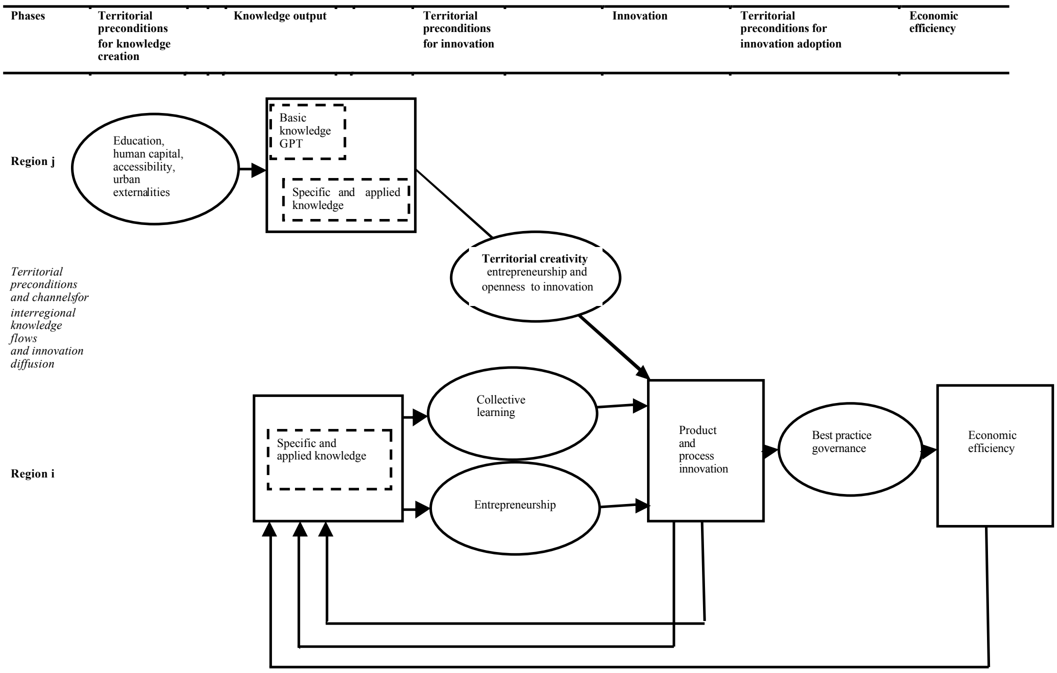
All these features are more easily to be found in metropolitan areas. They are the main sites of innovative activity, the 'incubators' of new knowledge: cities are the principal centres of research, given their large pools of expertise, and the availability of advanced services (finance and insurance) ready to carry the risk of any innovative activity. The fuel for a continuing knowledge and innovation process in cities lies in the density of external, particularly international linkages maintained and developed by individuals, groups, associations, firms and institutions, what is increasingly called relational capital (Camagni, 1999) coupled with a large diversity of competences on which complementary knowledge can find a common cognitive sphere.

b) Creative application pattern

The reality shows also that some regions are late comers and mainly users of general purpose, basic technologies; experience shows that being a latecomer in core technologies has serious implications, that last for long, and are difficult to reverse. Foremost, technological leaders are facilitated to expand into new science and technology fields and create conditions for reiterating such processes in further emerging science and technology area.

Reality is full of examples in which invention and innovation are not intertwined. Factors that enhance the implementation of new knowledge can be quite different from the factors which stimulate invention and innovation. Invention, innovation and diffusion are not necessarily intertwined, even at the local level. The linkage between basic knowledge and innovation is therefore in many cases not so evident, and many regions exist in which innovation takes place on the basis of basic knowledge acquired from outside and of specific know-how in local application sectors. In this case, innovation activity finds its roots in a merging of general purpose technology knowledge, coming from networking with leading regions, with local specialized knowledge in the region (Figure 2). In this pattern, a particular case is the investments in the "co-invention of applications" that is development of the applications in one or several important domains of the regional economy, without embarking in expensive basic R&D activities with insufficient critical mass of human and financial resources (Foray, 2009; Foray et al., 2009).

Figure 2. Creative application pattern



In this innovation pattern, regions have to succeed in developing an original and unique knowledge domain, based on its productive vocations; therefore regions have to discover the research and innovation areas in which they can hope to excel. This discovery comes from firms, that have to achieve combinations between technologies and various elements of the value chain, and construct very different and unpredicted specific niche competitive advantage. In this sense, this innovation pattern is supply driven, in that it depends on the creativity and recombination capability of potential innovating firms, that - thanks to their internal specific knowledge - identify a gap in a possible application of general purpose technologies, and put their creative effort in order to overcome such a gap.

This does not necessary mean that regions have to specialize in one or a few knowledge domains. In an innovation pattern like this the evolutionary trajectories of innovation can either be specialized, can progress by means of the evolution of "platforms" that combine many technologies, but can also be the result of differentiated technological fields in which local firms operate. The common features of all these possible forms in which this innovation pattern can take place is that the move from invention to innovation resides in creativity, recombination capability, ability to identify at the same time new needs and the right basic technology of local actors, ability to recombine local knowledge and external knowledge anew. In this sense, the innovation process is the result of an active role of collective actors of a region, especially potential innovators/adopters, which leads to innovation creation, despite the lack of ability in knowledge creation.

The territorial conditions for this innovation pattern to occur are linked to the concept of *territorial creativity*. This is made of entrepreneurs able to actually access and absorb the knowledge produced in the world and ultimately utilize it to invent co-applications; this can more easily happen in a context open to innovation, which nourishes itself of external knowledge useful for its local purposes and needs. The probability to interact in this kind of innovative pattern is between regions with a similar technological vocation. Participation to industrial associations and / or the exploitation of external experts represent the channel through which the flow of knowledge comes into the region (Table 1).

Regions in which this innovation pattern finds a natural location are the second ranked urban regions, characterized by high accessibility to metropolitan leading regions, with a local labour market fed by human capital in general formed in first ranking urban areas. But it is also the case of highly specialized areas, like local districts, where specialized knowledge cumulates over time and where the needs of technological jumps are often solved by merging specific local competences with new basic knowledge from outside through what has been labeled trans-territorial networking (Camagni, 1991). In the milieu innovation theory, these networking capabilities have always been thought of as a way to feed local specialized knowledge with technological novelties at the frontier, to jump on a new technological paradigm, something impossible to achieve only by cumulating specialized technological knowledge inside the area. This latter bears the inevitable risk to lock the area into a technological pattern, with no possible way out.

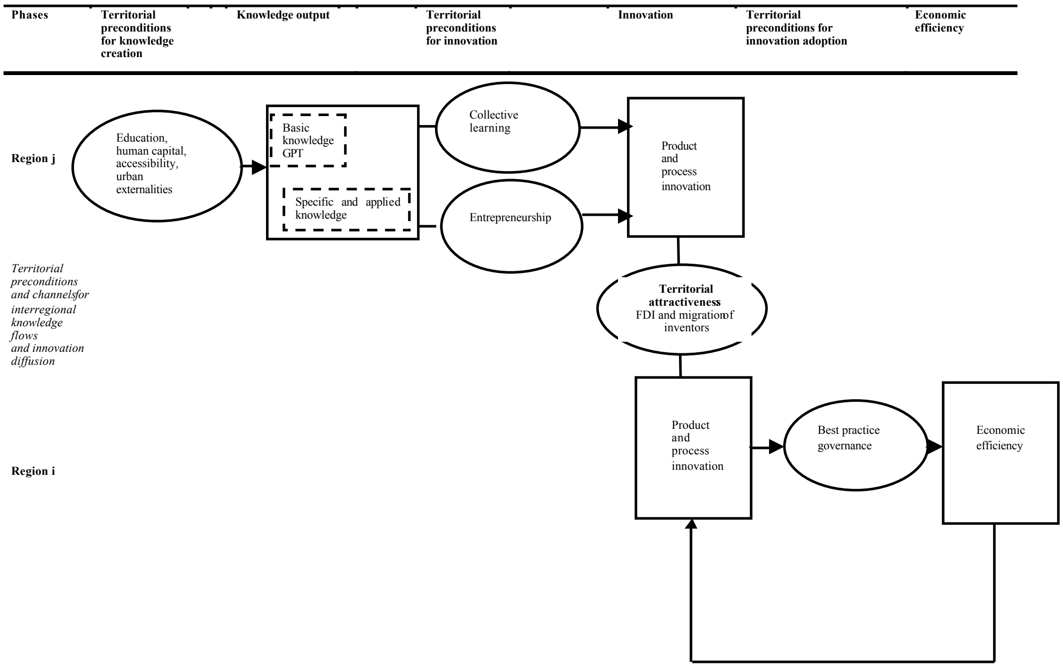
c) Imitative innovation pattern

Another innovation pattern which can be envisaged is an imitative innovation pattern, a situation in which a region innovates since it receives innovation from outside. The pattern presented in Figure 3 is an adoption innovation pattern, where the technological developments at the local level are the result of a passive attitude - in terms of invention, knowledge creation and innovation generation – of a region, which is fed by external actors of innovation already developed elsewhere (Figure 3). This innovation pattern calls back to the large existing literature on "innovation adoption", which from the work of the geographer Hägerstrand (1952) onward tries to interpret the spatial channels and mechanisms of innovation adoption.

This imitative pattern is not necessarily the less productive and efficient innovation pattern; regions can be creative and fast in the imitation phase, by deepening and improving productivity in existing uses, by adapting existing uses to the specific local needs, by adjusting products to local market interests, by forging innovation processes on local productive needs. Regions can also be more passive and imitate innovation from outside as conceived elsewhere.

Especially in the latter case, the right innovation policy for this pattern has nothing to do with the efficiency in R&D activities, or in supporting co-inventing applications. In this case policy actions have to be devoted to achieve the maximum return to imitation, and this aim is achieved through a creative adaptation of already existing innovation, i.e. through adoption processes driven by creative ideas on the way already existing innovation can be adopted to reply to local needs.

Figure 3. Imitative innovation pattern



Channels through which innovation is acquired from outside the areas are in fact foreign direct investments (Table 1); product, process, managerial, organizational innovation embedded in large multinationals can be the channel through which innovation is brought into catching-up regions. One of the traditional channels through which external innovation penetrates an area is through foreign direct investments. *Territorial attractiveness* is the precondition for regions to acquire external innovation; a large final market (market seeking) and/or labour cost competitiveness (efficiency seeking) are the preconditions to become attractive areas for FDI (Dunning, 2001 and 2009; Cantwell, 2009). Regions exchanging innovation through FDI are regions with strong income differentials.

Imitative innovation patters are typical of Eastern countries that have, over the last two decades, shown a decisive economic performance, mainly based on foreign direct investments, and all the innovative capacity brought about by multinationals. The efficiency of this innovation pattern can be high, giving rise to strong positive feed-back loops from growth to innovation through higher financial resources to invest in the innovation process. The high rate of growth can produce higher living standards and higher quality of life in these countries. The ways through which innovation is attracted from outside the region may evolve in a second stage towards other channels like mobility of inventors, that find their determinants in economic growth potentials, in expected high wages and in high quality of life potential.

Conceptually speaking, these three patterns represent the different ways in which knowledge and innovation can take place in a regional economy. Each of them represents a different way of innovating, and calls for different policy styles to support innovation. An R&D incentive policy can be extremely useful for the first kind of innovation pattern; incentives to co-inventing application (the typical Schumpeterian profits), enhancing the ability of regions to change rapidly in response to external stimuli (such as the emergence of a new technology) and to promote "shifting" from old to new uses, is a good policy aim for the second pattern. The maximum return to imitation is the right policy aim of the third innovation pattern, and this aim is achieved through a creative adaptation of already existing innovation, i.e. through adoption processes driven by creative ideas on the way already existing innovation can be adopted to reply to local needs.

In the rest of the paper the aim is to identify whether the innovation patterns exist in the real world. To accomplish such a task, a rich dataset with different indicators, measuring both the knowledge and innovation sphere, as well as the internal and external context conditions to generate and acquire knowledge and innovation, is built for all NUTS 2 of all 27 EU Member countries (sec. 3).

The methodology used to identify the territorial patterns of innovation is a cluster analysis, a statistical methodology able to cluster into groups the observations according to their proximity among variables on which the clusters are identified. In our case, the variables on which we identified the clusters are the degree of knowledge and innovation produced in a region; the variables identifying the context conditions help in identifying the clusters (sec. 4 and 5).

3. Data description and methodological notes

3.1. The dataset

To identify innovation patterns across European regions, we rely upon an original data set being collected and developed in the frame of an ongoing ESPON (European Spatial Observation Network) project, the KIT (Knowledge, Innovation and Territory) project, which encompasses several dimensions of knowledge and innovation creation and diffusion processes.

Data collection is based on EUROSTAT NUTS2 classification. The choice of using the administrative areas in empirical analyses is a long disputed debate. In particular, we chose NUTS2 regions for two different reasons. The first reason is a conceptual one; NUTS3 regions are oftentimes too small to encompass functional urban areas, while NUTS1 regions tend to be too large to be able to highlight local effects within their boundaries. The second reason is a practical one, related to the scarcity of data, especially innovation data, at NUTS3.

The richness of our dataset lies on the fact that it all elements that characterize the territorial patterns of innovation, namely:

I. Knowledge and innovation creation;
II. Regional preconditions for knowledge and innovation creation;
III. Inter-regional knowledge and innovation flows;
IV. Regional preconditions to acquire external knowledge and innovation.

Grouped in this way, indicators are fully mentioned and described in Table 2. Most of them are traditional indicators, others are more innovative, and require an explanation on the way they are built.

Table 2. Indicators and measures

Indicators	Measures	Computation	Year	Source
Knowledge				
Knowledge	Share of patents	Regional share of EU total patents	Total patents in the period 1998-2001	Authors' elaboration on CRENoS database
Specialization in GPTs	Index of specialization on patents in GPTs (i.e. nanotech, ICT, biotechnology)	Location quotient of regional GPT patents	Total patents in the period 1998-2001	Authors' elaboration on CRENoS database
Generality	Opposite of the Herfindal index on the technological classes of forward citations*	Generality = 1 – $H_{forward}$ $H_{forward} = \sum_{j=1}^{n} \left(\frac{n_{ij\_forward}}{n_{i\_forward}}\right)^2$	Total patents in the period 1998-2001	Authors' elaboration on CRENoS database
Originality	Opposite of the Herfindal index on the technological classes of backward citations*	Originality = 1 – $H_{backward}$ $H_{backward} = \sum_{j=1}^{n} \left(\frac{n_{ij\_backward}}{n_{i\_backward}}\right)^2$	Total patents in the period 1998-2001	Authors' elaboration on CRENoS database
Capabilities (knowledge embedded in human capital)	Share of SMEs managers and technicians	Factor analysis on the share of managers of SMEs and technicians	Average value 1997-2001	European Labour Force Survey
Innovation**				
Product and/or process innovation	Firms introducing a new product and/or a new process in the market	Share of firms introducing product and/or process innovations	One value for the period 2002-2004	Authors' elaboration on CIS (Eurostat) data
Marketing and/or organizational innovation	Firms introducing a marketing and/or an organisational innovation	Share of firms introducing marketing and/or organizational innovations	One value for the period 2002-2004	Authors' elaboration on CIS (Eurostat) data
Product innovation	Firms introducing a new product in the market	Share of firms introducing a product innovation	One value for the period 2002-2004	Authors' elaboration on CIS (Eurostat) data
Process innovation	Firms introducing a new process in the market	Share of firms introducing a process innovation	One value for the period 2002-2004	Authors' elaboration on CIS (Eurostat) data
Product and process innovation	Firms introducing both a new product and a new process in the market	Share of firms introducing both product and process innovations	One value for the period 2002-2004	Authors' elaboration on CIS (Eurostat) data
Regional preconditions for knowledge creation				
Scientific human capital	Share of inventors	Share of inventors on population	Average value 1999-2001	AQR elaborations on CRENoS database
Highly educated human capital	Share of highly educated people	Share of people aged 15 and over with tertiary education on total population	Average value 1999-2001	Eurostat
Accessibility	Rail and road network length by usable land	Km of rail and road network on usable land	2000	ESPON
Regional preconditions for innovation creation				
Entrepreneurship	Share of self-employment (local units in wholesale and retail excluded)	Number of local units (wholesale and retail sectors excluded) on total EU local units	Average value 1999-2004	Eurostat
Collective learning	Concentration in manufacturing sectors	Herfindal index on the share of employment in manufacturing sub-sectors***	Average value 1999-2001	Eurostat
Strategic vision on innovation	Perception of innovation as relevant for growth	Factor analysis on Eurobarometer questions on innovation importance to economic performance**** and broadband penetration rate	2005	Eurobarometer 63.4 and Eurostat
Regional preconditions for external knowledge and innovation acquisition				
Receptivity	Capacity of the region to interpret and use external knowledge (proxied by the degree of networking)	5th Framework Program funding per capita	Average value 1998-2002	Authors' elaboration on CRENoS database
Creativity	Sensibility, interest and openness to innovation	Factor analysis on Eurobarometer questions on sensibility, interest and openness to innovation****	2005	Eurobarometer 63.4
Attractiveness	Regional wage differential with respect to the EU average	$W_{Reg\_i} - W_{EU\ average}$	Average value 1999-2001	Eurostat
Inter-regional knowledge and innovation flows				
Knowledge potential	Share of patents in GPT of all other regions weighted by cognitive proximity	Sum of the share of patents of all regions, but the focal one, weighted by the cognitive proximity to the focal region	Total patents in the period 1998-2001	Authors' elaboration on CRENoS database

Capability potential	Capabilities of all the other regions weighted by technological proximity	Sum of the capabilities of all regions, but the focal one, weighted by technological proximity to the focal region	Average value 1997-2001	European Labour Force Survey and Eurostat
Innovation potential	FDI penetration rate	Number of FDI in manufacturing on total population	Average values 2005-2007	FDI-Regio, Bocconi-ISLA
Proximity matrices				
Cognitive proximity	Inter-regional knowledge similarity in a digit-1 technological class multiplied by interregional knowledge variety in digit-2 technological classes belonging the digit-1, summed over classes (Inter-regional related variety) *****	$\sum_{k=1}^{7} p_{Ak} \cdot p_{Bk} \cdot (1 - \sum_{k=1}^{30} p_{Ak} p_{Bk})$	Total patents in the period 1998-2001	Authors' elaboration on CRENoS database
Sectoral proximity	Inter-regional similarity in production specialization	Euclidean proximity between regional location quotients in 6 different manufacturing sectors***	Average values 1998-2001	Eurostat
Regional settlement structure and stage of development				
Agglomerated regions	NUTS2 with more than 300,000 inhabitants and a population density of more than 300 inhabitants per km sq., or a population density between 150 and 300 inhabitants per km sq.	Dummy variable equal to 1 if the region is classified as agglomerated	2000	ESPON
New member states (EU12)	Bulgaria, Cyprus, Czech Republic, Hungary, Estonia, Latvia, Lithuania, Malta, Poland, Romania, Slovakia, Slovenia	Dummy variable equal to 1 if the regions is located in a EU12 country	2004	Eurostat

* Patent citations are here classified according to the 7 technology fields classification developed by OST (see also footnote 3 for further details).
** See the website http://www.espon.eu/main/Menu_Projects/Menu_AppliedResearch/kit.html for the estimation methodology.
*** Six manufacturing sub-sectors are considered, namely: Food, beverages and tobacco; Textiles and leather; Coke, refined petroleum, nuclear fuel and chemicals; Electrical and optical equipment; Transport equipment; Other manufacturing.
**** See Annex 1 for the list of variables used in the factor analysis.
***** Similarity is measured as the degree to which the distribution of patens across technological classes in two regions overlaps. It is the product of the share of region's A patents in class k times the share of region's B patents in class k, summed over classes. It equals 1 for regions with exactly the same distribution of patents across classes, and 0 for regions with no patents in the same classes. Variety is the complement to 1 with respect to similarity. Two-digit are represented by the 30 technology fields of the OST classification, and 1-digit by the 7 OST main technological fields (see footnote 3 for further details on the OST classification).

I. Knowledge and innovation creation

Knowledge data mostly rely upon patent data available from the OECD REG-PAT database[1] from which we make use of selected information. Firstly, a region's knowledge base size is measured through a traditional indicator of the share of a region's patents in Europe in the period 1998-2001.

Moreover, a list of indicators capturing the type of knowledge - in terms of its basic nature, generality, originality - present in the region has been built. The degree of basic knowledge in the region has been measured through the presence of General Purpose Technologies (GPTs) in a region, we computed for each region i a technological specialization index on the basis of the number of patents applied for by in GPTs[2]. The focus on these technologies is motivated by the fact that they are considered to have wider applications, large adoption and diffusion potential and,

[1] Patents are assigned to regions according to the respective inventors residence address as available in patent documents. Fractional count is applied. The authors gratefully acknowledge Crenos - University of Cagliari (Italy) for access and use of their patent database.
[2] GPTs includes nanotechnology, biotechnology and ICTs, as also claimed by some literature (Foray et all., 2009). We assigned patents to these technologies on the basis of their IPC code (see also footnote 3) following the OECD classification.

ultimately, greater economic impact (Foray et all., 2009). The specialization index is computed as the share of GPTs at regional level for the period 1998-2001 with respect to the European share of patents in GPTs.

Pervasiveness is captured through a *generality* index (Hall et al., 2001), that is an adapted Herfindal index on the technological classes[3] of the citations received (i.e. *forward citations*) by the patents applied for by in the period 1998-2001. More general and pervasive knowledge is used in a wider spectrum of diverse technological applications and it is thus of greater technological value than more specific and targeted knowledge.

Originality of the knowledge produced, i.e. the extent to which the knowledge being developed in each region is original as compared to the state of the art and recombines pieces of knowledge distributed across different technical fields, is measured through an *originality* index (Hall et al., 2001). This is also an adapted Herfindal index on the technological classes of the citations made (i.e. *backward citations*) by the patents applied for by in the period 1998-2001. More original knowledge is likely to be associated to previously unexplored technological applications and to more radical inventions.

Lastly, to capture the knowledge that is not directly expressed in patent activities, and is instead embedded in human capital available in a region in the form of *technical and managerial capabilities*, an indicator was derived from a factor analysis synthesizing the share of small and medium size enterprises (SMEs) managers and physical and engineering science associate technicians on total employment. In fact, skilled and specialized human capital has to be considered as an important repository of embedded and tacit knowledge and can identify the pool of capabilities locally available.

Innovation data have been built by the authors on the basis of data from the Community Innovation Survey (CIS) EUROSTAT database. In particular, innovation indicators are based on national CIS4 wave figures (covering the 2002-2004 period), next developed at the NUTS2 level. As in the case of knowledge, a general indicator of the degree of innovation is the degree of product and or process innovation developed in the region. Moreover, to capture the type of different innovation, we made use of different questions of CIS: only product innovations, only process innovations, product and process innovations (both types of innovation simultaneously as well as all the first three main typologies altogether), and marketing and/or organizational innovations.[4]

I. Regional preconditions for knowledge and innovation creation

Indicators on the regional preconditions for knowledge creation are traditional indicators highlighted by the literature. From all indicators, two kinds were available, i.e. the degree of scientific human capital present in the region, measured by the share of inventors and by the share of highly educated people, and the degree of accessibility (transport infrastructure) that exists in the

[3] Every patent is attributed to one or more technological classes according to the International Patent Classification (IPC). We reclassified patents according to a 30 technological field classification that aggregates all IPC codes into 30 technological fields, and next into 7 main technological fields. This is a technology-oriented classification, jointly elaborated by Fraunhofer Gesellschaft-ISI (Karlsruhe), Institut National de la Propriété Industrielle (INPI, Paris) and Observatoire des Sciences and des Techniques (OST, Paris). For the computation of the generality and the originality indexes, we used the 7-class classification.

[4] For an in-depth explanation of the estimation methodology of NUTS2 CIS data, see the interim report of KIT, http://www.espon.eu/main/Menu_Projects/Menu_AppliedResearch/kit.html.

region. What lacks is the presence of high-level functions, like universities and research centres, for those no reliable data exist. The availability of a dummy capturing the size of cities in a region (the so called agglomerated regions) is of help to fill out the lack of these data.

For what concerns the capacity of a region to translate knowledge into innovation, the local preconditions derive from the milieux innovateurs theory and from the knowledge filter theory that stress the presence collective learning and entrepreneurship as elements that allow knowledge to be turned into useful innovative applications. Entrepreneurship is measured as the share of local units, with the exclusion of wholesale and retail sectors that create distortion in the proxy. Collective learning is indirectly measured through the degree of concentration in manufacturing sectors, with the idea that the higher the concentration in particular sectors, the higher the (unintended) exchange of knowledge among local firms, as claimed by the theory of the milieu innovateurs (Camagni, 1999) and innovative clusters (Cooke, 2001, Asheim and Coenen, 2005).

II. Inter-regional knowledge and innovation flows

Knowledge and innovation potential of a region also heavily depend on the capacity of regions to attract, absorb, originally recombine and adopt knowledge and innovations sourced from other regions. To measure the flows of inter-regional knowledge and innovation, i.e. the external knowledge and innovation potential of a region, specific indicators were built.

In particular, to capture the potential benefits that may accrue to each region *i* from the pool of basic (GPTs) knowledge developed by other regions (i.e. *knowledge potential*), we computed the sum of the share of all GPTs patents developed by all the N-*i* regions weighted by a measure of cognitive proximity between each pair of regions. In fact, the flows of basic knowledge are to a limited extent influenced by gravity type behaviours, proxied by physical proximity, and much more by similar background, cognitive map and common basic knowledge that two regions have. For this reason, the potential acquisition of basic knowledge of other regions is weighted by the degree of cognitive proximity that pairs of region have.

Cognitive proximity within actors of a region has been defined in terms of related variety, i.e. the presence of complementary knowledge within a set of shared and common knowledge (Boschma, 2005). This idea is here transferred at the inter-regional level, and it is measured as the inter-regional knowledge similarity in a specific technological field *i* multiplied by the interregional knowledge variety in the technological sub-fields of field *i* among each pair of regions. We in fact assume that the capacity to absorb and to use GPT knowledge sourced from other regions depends on two main elements. First, it positively depends on two regions sharing a common knowledge basis and cognitive frame in macro technological fields (i.e. two regions are similar in their cognitive (i.e. patent) profile). Second, it is more likely when two regions are specialized in different albeit related and complementary technological sub-fields within the same macro field (i.e. provided a common knowledge base, two regions are more likely to exchange complementary rather than the same type of knowledge). Table 2 further illustrates the construction of this indicator.

Next, to capture the potential benefits that may accrue to each region *i* from the pool of embedded knowledge available in other regions (i.e. *capabilities potential*), we computed the sum of the capabilities in all the N-*i* regions weighted by a measure of technological proximity between each pair of regions. The exchange of capabilities is in fact higher, the higher the similarities in terms of sectoral specificities is. In particular, sectoral proximity is measured as the distance between pairs of regions in their location quotient on the basis of employment data in six manufacturing sectors. The greater this similarity, the greater the opportunity to benefit from embedded knowledge in human capital sourced from other regions, i.e. capabilities external to the region.

Finally, to take into account the potential benefits that may accrue to each region *i* from the pool of innovations developed in other regions (*innovation potential*), we draw on the evidence that multinational corporations and foreign direct investments (FDIs) can be considered as learning mechanism and innovation diffusion channel (Cantwell and Iammarino, 2003; (Castellani and Zanfei, 2004). We thus computed the number of FDIs in each region in the manufacturing sector and discounted it by the regional population size.

III. Regional preconditions to acquire external knowledge and innovation

The knowledge and innovation potentials are likely to be enhanced by specific regional preconditions for external knowledge and innovation acquisition.

Receptivity is defined as the capability of the region to get in contact with, interpret and use external knowledge for complementary research and science advances. It therefore represents the precondition of a region to acquire knowledge from outside and make efficient use of it. The degree of relational capital is a good proxy of such a capacity. For this reason, an indicator of the 5th framework funding per capita is built.

Creativity is instead necessary for a region to achieve knowledge and turn it into local innovation, adding to internal specific capabilities, not necessary embedded in formal knowledge. This variable is measured through a factor analysis on the Eurobarometer questions on sensibility, interest and openness to innovation of local population.

Attractiveness is meant to be the capacity of a region to receive innovation developed outside the region and apply it to the local needs. If innovation mainly comes through advanced multinational firms, from which the tissue of local firms can imitate managerial, organizational, product and process innovation, a good proxy of attractiveness is the low labour cost, measured through the regional wage differentials from the European average.

3.2. Methodological specificities

To combine regions into groups and to identify different patterns of knowledge and innovation across regions, a cluster analysis was performed, with the aim of describing the variety of attitudes and knowledge and innovation behaviors across European regions. The purpose of the clustering exercise is that of enlightening commonalities and differences across regions. This exercise is next integrated with a multinomial logistic regression, which aims at exploring the relevance of region specific variables in the different knowledge and innovation modes.

Table 3. Mean values by cluster and in EU and ANOVA test statistical significance (p-value)

Variables	Creative imitation area (1)	Smart upgrading diversification area (2)	Smart specialisation area (3)	Knowledge diversification area (4)	European research area (5)	EU average	ANOVA P-value
Number of observation	37	86	67	52	20	262	
Variables used in the cluster exercise							
Knowledge (%)	0,01	0,13	0,40	0,48	1,53	0,35	p<0.01
Product and/or process innovation (%)	18,14	27,58	38,43	46,36	63,16	35,54	p<0.01
Marketing and/or organisational innovation (%)	13,94	22,05	19,61	39,33	51,07	25,99	p<0.01
Knowledge							
Specialisation in GPT	0,68	0,65	0,84	0,86	0,92	0,76	p<0.05
Share of patents in GPT (%)	18,66	17,95	22,91	23,58	25,24	20,85	p<0.05
Generality	0,242	0,531	0,730	0,724	0,801	0,592	p<0.01
Originality	0,384	0,636	0,759	0,749	0,804	0,661	p<0.01
Capabilities	-0,30	0,36	-0,04	-0,29	-0,81	-0,01	p<0.01
Innovation							
Product innovation (%)	4,13	5,01	15,38	12,20	23,46	10,40	p<0.01
Process innovation (%)	5,88	10,65	12,23	12,97	13,41	11,05	p<0.01
Product and process innovation (%)	8,13	11,91	13,97	21,66	26,29	14,97	p<0.01
Regional preconditions for knowledge creation							
Scientific human capital (%)	0,001	0,005	0,013	0,018	0,034	0,01	p<0.01
Highly educated human capital (%)	5,38	7,97	10,77	10,91	11,24	9,12	p<0.01
Accessibility (%)	12,42	17,46	31,47	34,70	59,52	26,62	p<0.01
Regional preconditions for innovation creation							
Entrepreneurship (%)	14,39	14,83	10,73	9,24	8,61	12,04	p<0.01
Collective learning	26,10	29,07	29,13	29,50	28,86	28,75	p<0.05
Strategic thinking on innovation	-0,87	-0,36	-0,07	0,22	0,48	-0,14	p<0.01
Regional preconditions for external knowledge and innovation acquisition							
Receptivity (thousands euro per capita)	3799,39	16016,29	25015,88	30147,05	41220,50	21068	p<0.01
Creativity	0,39	-0,05	-0,03	-0,59	-0,96	-0,13	p<0.01
Attractiveness	9,45	1,54	-1,98	-2,66	-8,23	0,25	p<0.01
Inter-regional knowledge and innovation flows							
Knowledge potential	6,22	5,84	6,35	6,36	6,56	6,18	p<0.05
Capabilities potential	-0,91	0,07	-5,13	-49,50	-92,33	-18,60	p<0.01
Innovation potential	51,57	55,22	55,48	30,73	20,60	47,16	not significant
Regional settlement structure and stage of development							
EU12	30	17	6	3	0	56	not applicable
Agglomerated	4	15	30	15	13	79	not applicable

In particular, we performed a k-means cluster analysis[5] based on the degree of knowledge and innovation that is in general produced by a region. In our conceptual approach in fact knowledge

[5] We opted for the k-means approach since, in the literature, it is preferred to hierarchical approaches (Afifi et al., 2004).

and innovation take place in different stages of the production process and can mix in a variety of ways. In particular, the cluster analysis was run with two innovation variables and one knowledge intensity variable; for the innovation variables, the share of firms introducing product and/or process innovation and the share of firms introducing marketing and/or organizational innovations were chosen, since they encompass the largest category of innovators and can thus take into account different innovation typologies. For the intensity of knowledge production, the indicator of the region's knowledge base size (i.e. the share of EU total patents) was inserted.

We considered different statistical criteria to identify the appropriate number of clusters to be retained, such as the relationship between within-cluster and between-cluster variance, but also the number of firms per cluster and, more importantly, the interpretability of the results in terms of innovation patterns. We finally extracted five clusters; each cluster includes a reasonable portion of observations, so that they can be plausibly interpreted as patterns of innovation.

Intriguingly, performing an ANOVA exercise on the variables presented in Table 2 provides interesting additional information that allows emphasizing the differences among clusters in terms of key distinctive territorial characteristics. Table 3 synthesizes the results of the ANOVA exercise and presents the mean value of the variables across the five clusters, in EU27 and (in the last column) the significance level of the ANOVA test.

4. Territorial innovation patterns across European regions

The variables used for the clustering exercise in Table 3 at a first sight simply provide a ranking of EU27 regions in terms of their endogenous knowledge and innovation performance, from cluster 1 (the least knowledge and innovation intensive) to cluster 5 (the most knowledge and innovation intensive). However, this description risks to be somehow too straightforward and to hide a greater variety of knowledge and innovation potentials and behaviors. The ANOVA exercise is very helpful in this regard and helps to better qualify the cluster description and identification.

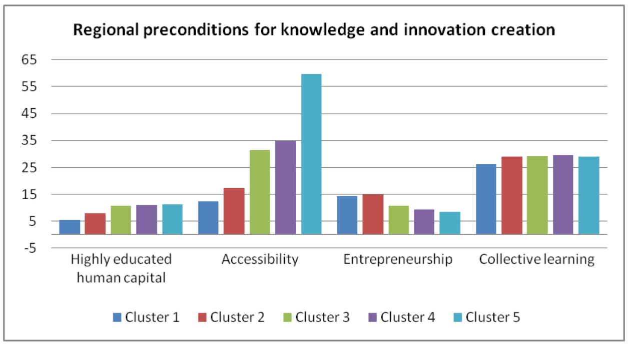
In fact, by carefully looking into the descriptive variables of each cluster, the picture obtained is extremely rich in terms of cases of innovation and knowledge production associated to external and internal preconditions.

The first interesting result is that, differently from the conceptual approach proposed in Section 2, we empirically detect a larger variety of possible innovation patterns; we identify two clusters that can be associated to our conceptual Pattern 1, albeit with some relevant distinctions between the two, two clusters that can be associated to Pattern 2, again with some differences between them, and one cluster that can be associated to Pattern 3. Interestingly, the five groups show sizeable differences in the variables considered in the clustering exercise.

Cluster 5: a European Research Area

Cluster 5 is composed of regions that are the most knowledge and innovation intensive. Their innovative attitude is well above the EU average across all dimensions (i.e. product, process, marketing and/or organizational innovation). This couples with a very strong knowledge orientation which is more directed to GPTs than in the other cases (and above the EU average) both in terms of amount of knowledge developed as well as in terms of specialization profile. Interestingly, this knowledge tend to be of greater generality and originality, that is of greater technological value and more radical than the EU average. The regions in this cluster are also well endowed with those pre-conditions frequently associated to greater endogenous capacity of knowledge creation, namely the presence of highly educated population and, more importantly, the presence of scientific human capital, here measured by the share of inventors on total population. Their accessibility is also the highest (Fig. 1), indicating that, probably, these regions cover to a large extent more urban and metropolitan settings (as confirmed by the variable accounting for the number of agglomerated regions), which are traditionally more open and fertile environments for new ideas generation (Carlino et al., 2007).

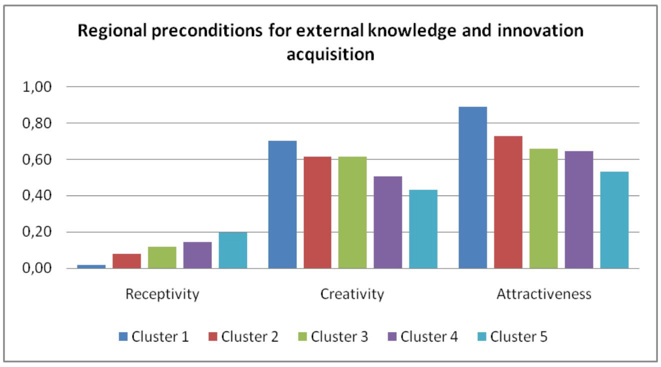
Figure 1. Regional preconditions for knowledge and innovation creation (%), by cluster



The indicators of regional preconditions for innovation creation, on the other hand, do not show the highest values across EU27. In particular, these regions are less entrepreneurial than the EU average. However, the variable accounting for collective learning shows a comparable value to the EU average and, interestingly, the regions in this cluster seem to have a more strategic vision and thinking on the role of innovation for performance, competitiveness and economic growth. As to the variables related to the preconditions for knowledge and innovation acquisition, these regions outperform the others in terms of their propensity to networking (i.e. *receptivity*) whereas they look less creative and attractive than the EU average (Fig. 2). Lastly, their capabilities and innovation potentials are lower than the EU average whereas their knowledge potential is greater than the EU average.

All in all, these observations suggest that these regions show a strong knowledge and innovation orientation which is primarily linked to their endogenous capacity to create new knowledge and to efficiently translate it into new products and processes as well as into managerial and/or organizational changes. This marked orientation suggests that these regions can potentially host the so-called *European Research Area* (Foray et al., 2009; Pontikakis et al., 2009) and, accordingly, we chose this label to identify this group. Map 1 shows that these regions are mostly located in Germany, with the addition of Wien, Bruxelles, and Syddanmark in Denmark.

Figure 2. Regional preconditions for external knowledge and innovation acquisition (normalized values), by cluster



Cluster 4: a knowledge diversification area

Cluster 4 includes a wider group of regions which share similar characteristics with regions in cluster 5, although most of the variables show lower mean values. In particular, this is the case of the share of EU total patents, which is almost halved, as well as the share of scientific human capital. Interestingly, the relevance of GPTs is lower both in terms of share of GPTs patents developed as well as in terms of specialization profile. Importantly, these regions look more entrepreneurial, creative, attractive and with a larger capabilities potential than regions in cluster 5, albeit less than the EU average. These regions thus maintain a rather strong knowledge and innovation intensity, i.e. form a knowledge area, but, differently from the ones in cluster 5, they are less focused on GPTs, and, accordingly, more technologically diversified.

Map 1 shows that these regions are mostly agglomerated and located in central and northern Europe, namely in Austria, Belgium, Luxembourg, France (i.e. Paris), Germany, Ireland (i.e. Dublin) Denmark, Finland and Sweden with some notable exceptions at East such as Praha, Cyprus and Estonia and at South such as Lisboa and Attiki.

We are in front of strong knowledge producing regions, that distinguish themselves from the European Research Area for their diversified knowledge production profile. From the normative point of view, these regions have the chance to strengthen their position by specializing themselves in the production of applied knowledge, making use of the basic knowledge produced from the European research area. If this is the case, this group can become the '*Knowledge diversification area*' of Europe.

Cluster 3: a smart specialization area

Regions in cluster 3 look quite different from regions in cluster 5. They are comparable to regions in cluster 4 in terms of size of the knowledge base and its characteristics (i.e. relevance of GPTs, generality and originality), show greater endowment of embedded knowledge in human capital (i.e. capabilities) but they are different in terms of innovation profile. In particular, they have a stronger orientation towards product innovation, are somehow weaker in terms of process in innovation (albeit being more innovative than the EU average also according to this dimension) and are among the weakest performers in terms of marketing and/or organizational innovation.

Regional preconditions for knowledge and innovation creation, but entrepreneurship, are similar to those of regions in cluster 4, albeit more limited (Fig. 1 above). Differently, regional preconditions for knowledge and innovation acquisition, namely creativity and attractiveness, are more favorable to regions in cluster 3 than to regions in clusters 4 and 5, whereas receptivity is comparable to cluster 4. Also, the capabilities and innovation potentials are larger than in cluster 4 and the knowledge potential is comparable to clusters 4 and 5.

All in all, these regions experience the greatest advantage in terms of product innovation, accompanied by a high degree of knowledge potential flows and internal preconditions to translate external knowledge into innovation, thanks to high creativity. These results suggest that these regions are able to efficiently translate internal and external knowledge into new specific commercial applications. Cluster 3 can easily represent our conceptual Pattern 2, the creative application pattern, where co-invention of application is the result of internal creativity and external basic knowledge. It includes mostly agglomerated regions in EU15, such as the northern part of Spain and Madrid, Northern Italy, the French Alpine regions, the Netherlands, Czech Republic, Sweden and the UK (Map 1). Normative interventions should strengthen these peculiarities and push this group of area to become the '*Smart specialization area*' of Europe.

Cluster 2: a Smart upgrading diversification area

Cluster 2 shows some distinctive traits that clearly discriminate regions in this group from the others. In particular, the knowledge and innovation variables show smaller values than the EU average but the capabilities indicator, which takes the highest mean value in this cluster. This suggests that the not negligible innovation activities carried out in regions belonging to this cluster mainly rely upon tacit knowledge embedded into human capital. Also, regions in this cluster look highly entrepreneurial (this variable takes the highest mean value in this cluster) and, importantly, are strongly endowed with those characteristics such as creativity and attractiveness that help to absorb and to adopt innovations developed elsewhere. Additionally, whereas the knowledge potential does not look prominent, the capabilities and innovation potentials are well above the EU average. Thus, the key advantages of these regions reside in their embedded human capital and the entrepreneurial and creative attitudes that can be wisely exploited in the pursue of upgrading innovative strategies. These regions are mainly located in Mediterranean countries (i.e. most of Spanish regions, Central Italy, Greece, Portugal), in EU12 agglomerated regions in Slovakia and Slovenia, Poland and Czech Republic, few regions in northern Europe, namely in Finland and the UK (Map 1).

In these regions, a different type of Pattern 2 emerges with respect to cluster 3. In these regions, internal innovation capacity is highly fed by external knowledge, as it is the case for cluster 3, but the type of knowledge that is acquired from outside is neither basic nor applied formal knowledge; these regions highly take advantages from external knowledge which is embedded in technical and organizational capabilities, in technicians and SMEs managers (Cooke, 2005); thanks to the high degree of creativity present in the area, these regions are able to take advantage from specific capabilities present in regions with similar sectoral profiles, and innovate in different products in different industries (Fig. 3).

Normative interventions should strengthen this innovative attitude and push these regions to become the 'Smart upgrading diversification area' in Europe.

Map 1. Territorial patterns of innovation in Europe

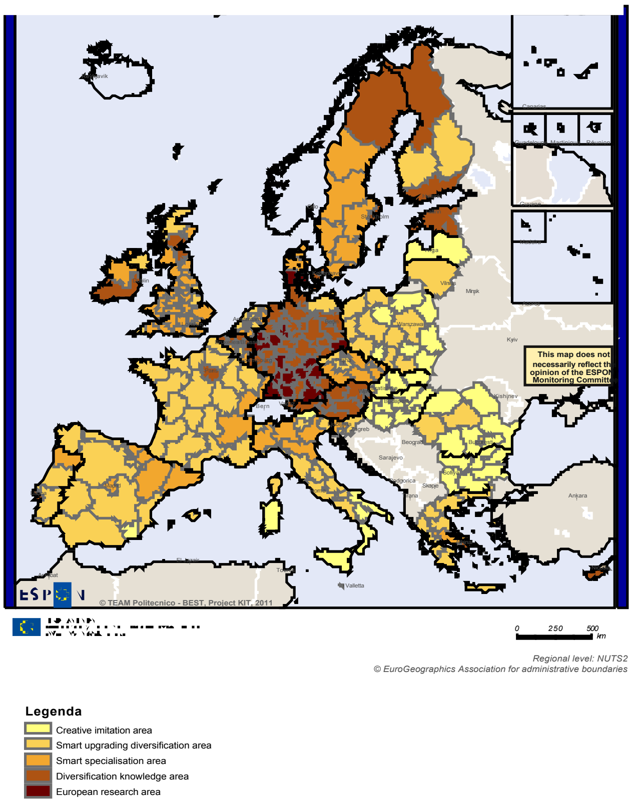
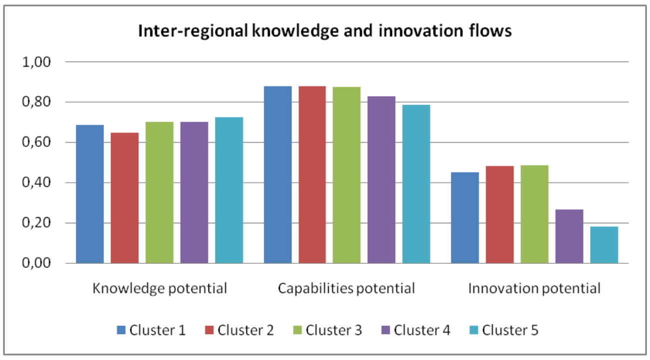


Figure 3. Inter-regional knowledge and innovation flows (normalized values), by cluster



Cluster 1: a creative imitation area

Finally, the last group (i.e. cluster 1) could be associated to Pattern 3. In fact, it is composed of regions that have a rather narrow knowledge and innovation profile and are the least performers in both respect. However, some key distinctive traits characterize this cluster. In particular, entrepreneurship, creativity, attractiveness, capabilities and innovation potentials show greater than the EU average values. Especially attractiveness is stronger than in the other clusters (Fig. 4). These dimensions can be enhanced and supported to creatively embrace new adoption, imitation and innovation strategies. For this reason, these group of regions can form a "*creative imitation area*" in

Europe. Most of these regions are in EU12 such as all regions in Bulgaria and Hungary, Latvia, Malta, several regions in Poland, Romania, and Slovakia, but also in Southern Italy (Map 1).
The high level of creativity, entrepreneurship and collective learning present in thus cluster provide potential assets to turn, in an evolutionary perspective, this area into a smart upgrading diversification area, through normative intervention that help exploiting creativity and entrepreneurship for increasing indigenous innovation activities, and not only for imitative innovation.

5. The link between territorial elements and innovation patterns

To further support the descriptive evidence presented in Section 4 and to better understand the most relevant territorial elements associated to each knowledge and innovation pattern and their interplay, we compared the five clusters across some key territorial characteristics. This exercise has two additional advantages. First, the identification of the key traits discriminating between clusters associated to the same conceptual pattern, namely, between clusters 2 and 3, and between clusters 4 and 5; second, from a normative point of view, by emphasizing the crucial distinctive characteristics associated to each group of regions, it provides some indications on the most likely directions to which policy intervention could be targeted.

To this aim, we estimated the following multinomial logistic model, where the dependent variable is the probability of region *i* to belong to cluster *j* (Pr):

$$\Pr(Y_i = j) = \frac{\exp(x_i'\beta_j)}{\sum_{m=1}^{5}\exp(x_i'\beta_m)} \qquad \textit{for } j = 1, \ldots, 5$$

where Y_i is the dependent variable (i.e. cluster membership), x_i are case-specific regressors (including the intercept) and β_j is a vector of coefficients, which is set at zero for cluster 1, which is the base category[6]. Therefore, it is worth emphasizing that the coefficients have to be interpreted in relative terms, i.e. in comparison with the reference category that in Table 4 is cluster 1, the creative imitation area.

On the ground of our conceptual approach (Section 2) and the result of the cluster and ANOVA analyses (Section 4), we selected a set of independent variables that could capture some distinctive regional traits that can be associated to different knowledge and innovation attitudes and patterns. In particular, we mainly focus on regional preconditions to knowledge and innovation creation and acquisition. This choice is functional in our conceptual and empirical strategy as these can more easily become policy targets.

Before discussing the results, it is important to stress that the econometric model is here used for descriptive purposes to compare groups of regions across some key territorial elements. The set of regressions proposed and commented in the following are to be interpreted as descriptive ones, and

[6] The ordinal attribute of the dependent variable would make the estimation of an ordinal logit a more appropriate methodological choice. However, this failed to meet the parallel regression assumption and several covariates failed to pass the Brant test assessing the parallel regression assumption at the single variable level. Thus, we resorted to estimate the multinomial logit model described in the text. The multinomial logit model is also preferred because it allows emphasising the differences across groups of regions in the territorial elements most likely associated to each pattern of innovation.

no causation link is assumed to run from the independent variables to the dependent ones, since they are likely to be affected by endogeneity issues. Therefore, the following regression coefficients are to be interpreted as a set of partial correlation indices, which help to provide a description of the elements that are associated to different knowledge and innovation patterns.

Table 4. Territorial characteristics relevance across clusters

	Smart upgrading diversification area – Cluster 2		Smart specialisation area – Cluster 3		Knowledge diversification area – Cluster 4		European research area – Cluster 5	
	Coeff.	Std.Err.	Coeff.	Std.Err.	Coeff.	Std.Err.	Coeff.	Std.Err.
Specialization in GPT	-0,761	0,851	-0,967	1,025	-0,836	1,100	0,419	1,900
Generality	0,788	1,271	3,189**	1,684	1,405	1,864	24,156***	8,944
Capabilities	1,371***	0,427	1,591***	0,442	1,589***	0,479	0,522	0,930
Scientific human capital	6,067	4,385	10,723**	4,549	11,134***	4,575	13,224***	4,617
Highly educated human capital	24,737	17,313	33,667*	18,145	18,729	19,403	3,910	29,132
Accessibility	0,113	4,428	1,720	4,385	2,736	4,425	2,957	4,441
Entrepreneurship	-1,936	5,666	-5,254	6,981	-20,27***	8,056	-21,042	13,368
Collective learning	15,368*	8,072	22,073***	8,569	24,893***	9,083	26,971***	11,109
Strategic thinking on innovation	0,089	0,593	0,180	0,625	0,005	0,636	-0,497	0,770
Receptivity	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Creativity	0,593	0,375	0,898**	0,465	-0,429	0,477	-1,608**	0,711
Attractiveness	-0,078	0,137	-0,032	0,148	-0,063	0,150	-0,259	0,168
Constant	-5,379*	2,927	-11,008***	3,392	-8,851**	3,796	-30,422***	8,960

Robust standard errors. Wald chi2(48) = 207,47; Prob > chi2 = 0.0000; Log likelihood = −231.356; Pseudo $R2$ = 0.3966
***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.
Base case: Cluster 1 (Creative imitation area).

The comparison between the creative imitation area (cluster 1) and the smart upgrading diversification area (cluster 2) suggests that the key distinctive traits of the latter reside in a larger pool of locally available capabilities (i.e. tacit knowledge embedded into human capital) and, moderately, in a greater level of collective learning that facilitates the circulation, socialization and ri-elaboration of local knowledge. The comparison between the creative imitation area and the smart specialization area (cluster 3) indicates that the latter has a significantly stronger knowledge orientation in terms of the generality of the knowledge produced as well as the capabilities and the human resources available (both scientific and highly educated human capital). Additionally, the level of collective learning and creativity are higher, supporting the idea of a faster and more efficient recombination of knowledge into new products development. The knowledge diversification area is better endowed with capabilities, scientific human capital and collective learning but are far less entrepreneurial than cluster 1 regions. Lastly, the European research area (cluster 5) confirms its strong knowledge intensive profile and show greater knowledge generality, a larger scientific human capital base, greater level of collective learning but a lower entrepreneurial attitude. Importantly, no difference emerges among regions in the importance attached to receptivity suggesting that all types of regions can take advantage from the learning, knowledge and innovation opportunities deriving from knowledge networks.

By changing the reference case, we can gain some additional insights on the most relevant distinctions among these groups of regions. In particular, by setting the smart upgrading diversification area as reference,[7] its comparison with the smart specialization area, also associated to the conceptual Pattern 2, specifies that the two clusters clear differ in the capacity to generate internal knowledge, much more associated to the smart specialization area, which, moreover, shows a stronger capacity to recombine internal and external knowledge via collective learning into superior innovative performance.

Lastly, by setting the knowledge diversification area (cluster 4) as reference (estimates not reported but available upon request), its comparison with the European Research Area, also associated to the conceptual Pattern 1, specifies that the two clusters clearly differ in their knowledge intensity and generality that guarantees a superior endogenous innovative performance in the European Research Area despite the latter is characterized by a less visible creative attitude and a lower level of attractiveness. Interestingly, the smart specialization area (cluster 3) shows a comparable level of knowledge intensity to the knowledge diversification area but differs in terms of its greater entrepreneurial and creative attitude that sustains a superior capacity of screening, selecting and absorbing the most appropriate knowledge and turning it into new products.

All in all, this suggests that the creative imitative regions exhibit some advantages in terms of entrepreneurship and creativity that could be strategically exploited as key assets in launching innovation upgrading policies. However, the benefits of these policies to fully unfold require also a strong engagement in catching up the other groups of regions especially in terms of human capital and capabilities endowment. The smart upgrading diversification regions can rely upon a stronger local knowledge base in terms of capabilities and a high level of entrepreneurship and creativity that guarantee not negligible level of innovation in all dimensions (albeit below the EU average). These elements represent their competitive advantage and have to be supported in innovation policies which, nevertheless, can also be oriented toward promoting a process of greater technological specialization and enhancing the local knowledge base and intensity so to approach the smart specialization regions. These latter have their greatest advantage in the combination of a rather marked technological specialization mixed to a strong knowledge intensity, based both on endogenous knowledge capacity but also on the ability to screen, to select and to absorb external knowledge, and to locally recombine and adapt it via collective learning. This enables a substantial innovation performance (especially in terms of product innovation) not much far from the knowledge diversification regions. These share a very similar profile with the European Research Area albeit with a more limited knowledge and innovation intensity, and experience thus the opportunity either to catch up the European Research Area regions by hugely investing in the upgrading of their knowledge basis or to join the smart specialization regions by initiating a process of increasing technological specialization on the one hand, and by promoting an entrepreneurial and creative attitude, on the other. Lastly, European Research Area regions can be considered the most advanced in terms of knowledge and innovation performance and rely this advantage upon their superior knowledge basis. Keeping this status thus requires a mix of policy initiatives oriented to the promotion and support of research activities and the diffusion of scientific and technical competencies.

6. Conclusions

The main idea put forward in this work is that the pathways towards innovation and modernization are differentiated among regions according to local specificities, and these differentiation explains

[7] Estimates not reported but available upon request.

why a single overall strategy is likely to be unfit to provide the right stimuli and incentives in the different contexts.

The paper departs from the idea that R&D equals knowledge and that knowledge equals innovation. The distinction between the process of invention in general purpose, basic technology, pervading horizontally different sectors once invention is turned into an innovation, and the process of inventing an application of a basic knowledge in a specific sector, innovating in new products and new market niches is vital to understand the present patterns of innovation. This becomes even more important if we think that the factors that stimulate new knowledge, invention, innovation and innovation diffusion differ; invention and innovation are not necessarily intertwined and this gives rise even at the local level to very different and multi-faced situations; some regions have the capacity to go through all phases of the "linear model", from knowledge creation to innovation and growth, with all feed-backs that can be foreseen from growth to knowledge and innovation. Other regions reinforce this "linear model", exchanging knowledge with other regions gaining complementary assets through a scientific network. There is however a completely different situation in which regions innovate by combining their creative thinking with basic knowledge cumulated in other regions, developing co-inventing applications. Finally, another territorial innovation pattern can be identified by a situation in which regions innovate that to a creative imitation of innovation developed elsewhere.

This paper shows that the territorial patterns of innovation conceptually depicted exist in reality. The data show that the real world is even more fragmented than what expected, and that within the same pattern different behaviours exist. Among the knowledge creation patterns, the real data distinguish within the basic knowledge specialized regions, what is called the "European research area", where the general purpose technology research activities can be concentrated and economies of scale in research activities exploited. But data tell us also that another group of regions exists where less general and more applied research is produced; these regions should be pushed towards the production of applied diversified knowledge, and leave the basic knowledge been produced by the European research area.

Within the creative application pattern, the reality shows two distinct behaviours. From one side, regions emerge that take advantage from specialized formal knowledge and innovate on the basis of this knowledge. These are probably what the literature refers to as the smart specialization areas, where the co-invention of application emerges of basic knowledge produced outside. On the other side, regions exist that exploit knowledge embedded in human capital, in experience, in learning by doing, represented by capabilities built on specific productive vocations of some areas. In this sense, these regions innovate on the basis of external capabilities that, once acquired, merge with local creativity and give rise to a high product innovation performance.

These results strongly suggest that each territorial innovation pattern calls for specific ad-hoc innovation policy goals: the maximum return to R&D investment can be the right goal for a region specialized in knowledge creation, but cannot be at the same time the right policy goal for regions that innovate by exploiting external knowledge, or for regions that imitate innovation processes. For the former, the ad-hoc policy goal is the maximum return to co-inventing applications, which happens when the region promotes changes in response to external stimuli (such as the emergence of a new technology). A maximum return to imitation, pushing towards a creative imitation, is instead the right policy aim for regions that rely on external innovation processes. Each region has to succeed in discovering its territorial innovation pattern, and only through the awareness of the original and unique territorial innovation pattern a region can hope to excel in exploiting innovation efficiency.

A next step for future research is the measurement of efficiency and effectiveness of each pattern of innovation on growth; our impression is that none of these patterns is by definition superior to another and, on the contrary, each territorial pattern may provide an efficient use of research and innovation activities generating growth. But this statement calls for empirical analysis and this is the future research questions we will address.

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Annex 1. Eurobarometer Survey

To extract the factor ‘Strategic vision on innovation’, we used the following questions from the Eurobarometer Survey 63.4:

- Innovation simplifies everyday life (% of people mentioning this statement)
- A company that sells an innovative product or service improves the image of all its products or services (% of people mentioning this statement)
- A company which does not innovate is a company that will not survive (% of people mentioning this statement)
- Innovation is essential for improving economic growth (% of people mentioning this statement)
- Broadband penetration rate (%of households with broadband access) from Eurostat.

To extract the factor ‘Creativity’, we used the following questions from the Eurobarometer Survey 63.4:

- In general, to what extent are you attracted towards innovative products or services, in other words new or improved products or services? (% of people that are very or fairly attracted to new products)
- Compared to your friends and family, would you say that you tend to be more inclined to purchase innovative products or services? (% of people that are more inclined than the average to buy innovative products)
- - In general, when an innovative product or service is put on the market and can replace a product or service that you already trust and regularly buy, do you quickly try the innovative product or service at least once? (% of people that shift easily consumption patterns towards innovative products)
- Innovative products or services are most of the time gadgets (% of people not mentioning this statement)
- - Innovative products or services are a matter of fashion (% of people not mentioning this statement)
- The advantages of innovative products or services are often exaggerated (% of people not mentioning this statement)

We extracted the two factors by means of principal component analysis and applied a varimax with Kaiser normalization rotation method. The percentage of variance explained is 62,54. In this analysis, within each component, we considered the variables with a factor loading greater than 0.55.