Mapping Exaptation as Source of Smart Specialization in European Regional Policy Between Tacitness and Codification

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1 Introduction

The year 2020 is the last of the current European Framework Program. From 2021, a new set of policies will guide the development of European regions. The concept of smart specialization has been a cornerstone in this last European framework program (McCann and Ortega-Argilés 2015). Through the smart specialization strategy, the European Commission attempted to combine the advantages of both horizontal and vertical policies and, at the same time, minimize their respective disadvantages (Foray 2016, 2018). Horizontal policies are intended to create the framework conditions to lever the competitiveness of single countries and regions independently form their specific specializations. These policies are designed to stimulate long-term investment in general-purpose and high impact technologies, such as biotech and digital technologies, which can be applied to several different industries. However, not all industries and regions are equally prepared to exploit the potential enabled by investments in the development of those technologies. Exploiting the potential generated by those investments requires the availability of complementary sources to contextualize/translate that potential into a value that can be easily appropriated by firms embedded in a specific industry/specific region. Thus, the smart specialization strategy has been implemented to stimulate the local and endogenous production of those complementary resources.

The time has not yet come to take the stock on smart specialization strategy as policy framework mechanism that has guided the development of EU regions in the past 7 years. However, what is certain is that the smart specialization strategy has completely ignored exaptation as a tool for strengthening smart specialization.

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Exaptation is the cooption of an existing technologies to new and unanticipated domain of application (Andriani and Cattani, 2016, 2017; Mastrogiorgio and Gilsing 2016). It evolves in two phases (Cattani 2005, 2006). In the first phase, the know-how related to a technology is accumulated to serve a specific function without anticipation of its future usage. In the second phase, this know-how is co-opted and exploited to serve another and unanticipated function. This implies that expiation does not involve any significant technological advancement. Differently, the novelty stays in where this technology is (re-)applied and evolve. Exaptation also implies a discontinuity in the technological lineage as it is driven by functional shift in the domain of application. For this reason, exaptation is often a trigger for radical innovation and technological breakthroughs.

Exaptation is a source of smart specialization because it implies the exploitation of an existing specialization into a new field of knowledge development (Boschma et al. 2017; De Noni et al. 2018). In this perspective, exaptation is very different from traditional forms of innovation, which relies on the recombination of knowledge across technologically distant but lightly related fields. Differently, exaptation is incremental on the technological side, but drive radical and significant impacts on the applications' sides. In this sense, exaptation represents an opportunity even for lagging-behind regions, which often do not hold the capacity to hook into high-tech innovation trajectories, to enter those trajectories by exploiting their unique specificities and specializations.

However, exaptation requires specific competencies and abilities. First, exaptation is an analogical innovation. It is driven by a chain of analogies linking one domain of application to another (Andriani and Cattani, 2016). Therefore, it relies more on tacit knowledge and embedding rather than on codified knowledge and calculation. Second, it requires the capacity to scan for alternative contexts where a given technology can be applied (Dew et al. 2004). Both those competencies are peculiar and, therefore, should be objective of specific policymaking in order to stimulate their development and consolidation in regions. The objective of this paper is indeed to show the potential embedded in exaptation as a specific tool for enhancing smart specialization and to provide policymakers with some initial advice on how to design a smart specialization policy that supports also exaptation.

The paper is structured as follows. In the first part of the paper, we address the concept of exaptation. We highlight the origin of this concept and explain how this concept has been recontextualized in the field of management. We also highlight the debate its re-contextualization in the field of management has triggered off. Then, in the second part of the paper, we review the metrics that have been applied in the field of management to measure exaptation and we discuss the main advantages and disadvantages associated with each of those metrics. Then, we apply the metric by De Noni et al. (2018) to assess the distribution of exaptive patent across EU regions in two subsequent 10-year windows. Our analysis highlights that exaptive patents are endogenously generated into innovation-intensive regions while this is not the case into lagging-behind regions, which could benefit more from the exploitation of this innovation mechanisms. Finally, in the last part, we provide some initial advice on how to draft smart specialization policy that includes exaptation as a smart tool.

2 Exaptation: Genesis of the Concept

The term exaptation has been originally coined by Gould and Vrba (1982). They introduce this term to name characters that are co-opted to a new use from a previous function or no apparent function at all. In the first case, from a previous function, characters have been shaped by natural selection. Differently, in the second case, from no apparent function, natural selection did not play any role in shaping the co-opted characters. An example of exaptation are the feathers of birds, which were selected for a thermoregulating function and later co-opted to the flying function. In the second case, the relevance of exaptation is associated with phenomena like genetic drifts, which implies the accumulation of genetic code that does not play any apparent function. In both cases, anyway, exaptation implies a discontinuity in the biological lineage of species.

The introduction of the term exaptation in the vocabulary of evolution has been long opposed (Dew 2007). This is for two reasons. First, its acceptance implies questioning the primacy of selection in the theory of evolution. In fact, in exaptation of the second type, selection does not play any role in the initial evolution of a character. However, also in the first case, the cooption from a precedent function implies a discontinuity in the selection function. This leads us to introduce the second reason why the introduction of the term exaptation has been fiercely opposed, which is the fact that implies a discontinuity in the evolution process. In fact, differently from what is claimed by the Darwinian theory of evolution, evolution is not always the result of small variations positively selected by the environment, but maybe a consequence of the shift in the functioning of certain characters. However, what is even more important is that, according to Gould and Vrba, exaptation may be the reason for short periods of radical changes punctuating evolution. Therefore, according to Gould and Vrba, periods of creative destruction are not only the result of exogenous factors, but endogenous.

In the managerial literature, the term exaptation has been originally introduced by the historian economist Mokyr (1990) to describe the existence of discontinuity in the evolution of technological lineages and explain the rise of new and emergent punctuated equilibria. However, Mokyr limits himself to a metaphoric use of this term, but never attempted to develop a comprehensive theory of technological exaptation. There are, however, two contributions that have signed a change of pace in the conceptualization of exaptation in the managerial literature. Those are Dew et al. (2004) and Cattani (2006). Dew et al. (2004) contribute to the literature offering a comprehensive classification of technological exaptation and showing how exaptation is associated with true Knightian uncertainty, the rise of new markets and the role of entrepreneurship. In truth, Cattani (2006) does not use the term exaptation, but preadaptation. In so doing, Cattani emphasizes the phase in which knowledge is accumulated without anticipation of its future use. His goal, in fact, is to highlight the distinction between luck and foresight. That is, the distinction between the phase in which knowledge is accumulated without anticipation of its future usage and, therefore, luck plays a dominant role, and the phase in which the opportunity to reuse an existing artifact/know-how into a new and distant domain is perceived and is consciously actively exploited and levered (foresight). Therefore, between a phase in which entrepreneurship is not involved and a phase in which Knightian entrepreneurship is levered in the rising of a new market.

Those two contributions are not only relevant for their content, but because have fed a debate, which has been hosted in the pages of Industrial and Corporate Change, between Dew and Cattani on the opportunity to use exaptation rather than preadaptation. A similar debate took place between evolutionary biologists. On the one hand, Darwinian evolutionary biologists argued that there was no need for a new term such as exaptation since Darwin already introduced the term preadaptation to name characters that were shaped by natural selection for other purposes and then were co-opted to their present function. On the other hand, scholars supporting the use of the term exaptation, contended that the use of the term preadaptation hides the attempt to support the primacy of adaptation over other forms of evolution. That is, a view of evolution as gradual and based on natural selection of small inherited variations that increase the individual's ability to compete, survive and reproduce. Therefore, a view of evolution that relegates discontinuity and punctuation to minor factors in the history of evolution.

The terms of this debate, recontextualized within the boundaries of the evolutionary theory of technological change, lead contenders to discuss one of the key assumptions on which this theory is grounded. That is, the role of intentionality compares to selection in the evolution of technologies or said differently the extent to which designers foresee and control the success of their variations. In fact, as Cattani argues in the reply to Dew's commentary, a key difference between biology and technology is that foresightful evolutions occur in the context of technology. Technological change is driven by variation and selection, but those are neither blind nor natural. In their original paper, Dew et al. (2004) define three possible sources of exaptation. Two of them are defined as nonadaptive. That is, technological features that were not originally selected for their function. In both cases, those features are selected as part of a bundle. However, in the first case, those features are neutral to the selection environment and indeed do not make any contribution to the performance of the technology. Differently, in the second case, those features are selected even if are negatively draining on the performance of the whole. However, according to our point of view, even if those features were not selected for their contribution to the performance of the whole, it is still difficult to imagine that designers, especially in the case of features with a negative impact on the overall performance, did not spend any time in trying to optimize the costs of those components. Therefore, even if those features may seem nonadaptive, they were selected as part of a bundle carrying on a specific purpose, which has played a significant role in shaping the designers' intentionality in the development of those features. Therefore, even in those cases, we believe it is more appropriate to say that the origin of those features is adaptive.

However, differently from Cattani (2008), we do not believe that preadaptation is a better term. The main reason is that it is a term that preserves an adaptive view of technological change, which is mainly grounded on knowledge recombination and see radical innovation as the result of the recombination of knowledge across a large variety and cognitively distant technological fields. Differently, the term exaptation marks a discontinuity with this perspective and highlights the cooption of already existing artifacts and indeed know-how to a new function as an alternative and complementary trigger of the process of radical innovation. In this perspective, we believe exaptation is a better term than pre-adaptation as it stimulates scholars to focus on the functional shift rather than only on the origin of the knowledge. Therefore, on the specific factors facilitating enterprises and entrepreneurs in seeing the value in the reapplication of an existing artifact to a new domain (Dew et al. 2004).

3 Drivers of Exaptation

There are four main drivers of exaptation highlighted in the literature.

The first is complexity and near decomposability. Near decomposability is a characteristic of the architecture of the complex system. It can be thought of as boxes-within-boxes hierarchy with an arbitrary number of levels. Its special characteristic is that the intensity of the equilibrating interaction is stronger within boxes than between boxes at the same level than between boxes located at different levels all the way to the top of the hierarchy (Simon 1995). This implies that the behavior of the single boxes can be taken as independent from that of others in the short run, but the consequence of changes taking place within a box is going to get reflected on the behaviors of the others in the long run. This organizational architecture has been proven to carry significant evolutionary advantages. It is, given the level of complexity, more resilient than non-decomposable architecture because less sensible to the effect of external shocks. Second, it is, given the level of complexity, more adaptable than a non-decomposable system. This is because each component, at least in the short run, maybe optimized independently from others. Third, it saves on coordination costs as it is based on feedbacks and self-coordination between subparts (local processes). However, this peculiar architecture is responsible for the endogenous and punctuated character of evolution. In fact, the near independence between subparts implies that evolution may take place independently within subparts at different levels of the hierarchical architecture without any significant change in the overall system. However, when the cumulative effect of those changes reach a certain threshold, even apparently insignificant changes may trigger off cascading effects and network externalities with radical consequences on the functionality and structure of the overall system.

The concept of near decomposability is tied intertwined with one of the modularity and functional modules. Modularity, in fact, is a systematic concept that describes how complex systems can be decoupled into subsystems that perform nearly independently of each other (Andriani and Carignani 2014; Simon 1962). In this context, a functional module is defined as a physical subpart that performs a well-defined and single function, where the function is an emergent property resulting from the interaction between designers' intentional function (what the object is designed for) and what the object is selected for, which is the result of the aggregated actions of people and organizations that select and modify artifacts according to the intended or emergent usage. Exaptation entails a functional shift. Therefore, exaptation reflects a change of function that may take place at different levels of the hierarchy and resonate at different levels of the hierarchy as well. Based on this observation, Andriani and Carignani (2014) define three types of exaptation: internal, external, and radical. Internal exaptation is functional shift at the level of the internal module without any significant change in the domain of application of the entire system (the artifact). External exaptation, differently, is a change in the domain of application of an existing artifact that does not resonate/induce any change of the internal structure and indeed on the function of the internal modules. Finally, radical exaptation is the result of an internal module changing its function and leading to the generation of a completely new system built around the exapted module.

Furthermore, Mastrogiorgio and Gilsing (2016) highlight the existence of an inverted U-shaped relationship between technological complexity and exaptation. Modularity, on the one hand, implies the hiding of information within modules. On the other hand, it highlights the role of a specific subset of information that ensures coordination between modules. Therefore, on the one hand, a high level of complexity as a result of the decomposition into many subparts strongly bounded together reduce inventors' capacity to reuse modules into a different context. This is because the interface is too specific to the functionalities of the two modules. On the other hand, reducing the complexity into a small number of modules implies that large part of the information is hidden within each module. Therefore, also, in this case, designers find difficult to see opportunities in exapting the functionality incorporated within modules.

Near decomposability and complexity are only two conditions for knowledge accumulating without anticipation of its additional potential uses. There are other drivers contributing to the rise of exaptive innovation. Dew et al. (2004) highlight the impossibility to state ex-ante all the possible applications of a technology, which is mainly a consequence of bounded rationality. Another driver is entrepreneurship. According to Shane and Venkataraman (2000), entrepreneurship is the capacity to discover, evaluate and exploit opportunities to create future goods and services. In this perspective, exaptation represents a specific type of entrepreneurial opportunity, which is related to the opportunity to reapply the functionality of an existing artifact into a new domain of application. According to Dew et al. (2004), exaptive innovation is associated with true Knightian uncertainty and entrepreneurship, which is amenable to probabilistic calculation. Even if Cattani (2005, 2006) does not make any explicit reference, entrepreneurship is a key driver in the transition from the state of "pre-adaptation", when knowledge is accumulated without anticipation of its future usage, and exaptation, when that knowledge is levered to the new domain of application with intention and foresight. The lack of entrepreneurship precludes the capacity to see opportunities in exploiting an existing artifact into a new domain. Finally, Mastrogiorgio and Gilsing (2016) add the capacity to draw analogy across fields as a specific driver of the exaptive capacity of both inventors and entrepreneurs and users.

4 Measuring Exaptation

One of the main problems in developing a comprehensive and grounded theory of exaptation is to measure exaptation. This is especially important if the goal is to assess quantitatively the effects of different factors on the likelihood of exaptation. This is because one of the requirements in the definition of exaptation is that exapted knowledge is accumulated without anticipation of its future use. In the literature, to our knowledge, there are three methods to measure exaptation. Those methods refer to two different types of artifacts: patents and off-label uses.

The first method has been proposed by Mastrogiorgio and Gilsing (2016). This is specific to U.S. Patents because based on the distinction between OR class and XR classes, which is available only in the USPTO-NBER patents database. The OR class is mandatory and reflects the most comprehensive claim or main function of the invention. XR classes can be more than one and reflect alternative applications envisioned by the inventor(s) at the time when the patent is granted. According to Mastrogiorgio and Gilsing (2016), exapted patents are those cited by patents registered into a different OR class compared to the OR class and XR classes of the focal one. Therefore, the focal patent is exapted because, at the time when it was granted, inventors could not envisage the OR class of citing patents as the possible domain of application. In this perspective, exaptation is defined as a fraction of the number of forward citations received from OR classes different from the OR class and XR classes of the focal patents. Thus, the higher the number the more the knowledge embodied in the focal patent have been exapted in unanticipated domains of application.

The second method, which has been proposed by Andriani et al. (2017), is specific to the pharmaceutical industry. It exploits the fact that new molecular entities (NMEs) are approved for specific uses from a formal institution. However, experimentation through exposure to different contexts reveals new uses for drugs based on positive side effects. This is called off-label uses, which are not approved but registered in the commercial database DrugDex. Therefore, crossing data from those two sources, Andriani at el. (2017) identify NMEs that have been approved for use, but then are later exploited for alternative uses, such as in the case of Viagra. In their metric, Andriani et al. (2017) introduce also the notion of distance. That is, the distance between entry and emergent use, where distance is measured as a function of the length of the pathway between the two uses (diseases) in the tree-like structure of the International Classification of Diseases. Long-distance exaptations refer to molecules that are applied into a different general class (first-level bifurcation) compare to the one of entry. Intermediate distance refers to exaptations between two subclasses within the same general class (second-level bifurcation). Finally, short distance exaptations are those between functions within the same subclass (third or lower bifurcation level).

Finally, the third method has been proposed by De Noni et al. (2018). Like Mastrogiorgio and Gilsing (2016), it refers to patents. However, it is more generic as it is based on data available on OECD RegPat and Patent Quality Indicators database.

Exaptation is assessed based on the combination of two patent quality indicators: originality and radicalness. Originality refers to the breadth of the technological fields on which a patent relies. The larger the number of diverse knowledge sources embodied in a patent the larger the originality of the patent. Differently, radicalness is defined as the extent to which a focal patent relies on knowledge sources classified into different technological domains compare to those in which that focal patent is applied/granted. According to De Noni et al. (2018), the patent is exaptive if it is, at the same time, incremental (low originality) and radical (high radicalness). Therefore, it does not include significant technological changes, but it is applied to different technological domains.

All these three indicators have pros and cons. They are specific. On the one hand, both Mastrogiorgio and Gilsing (2016) and De Noni et al. (2018) refer to technological patents. Therefore, their indicators can be applied only in the case of patented technological inventions. However, there are evidence showing that tacit knowledge plays a significant role in exaptation. This is also supported by the positive relationship holding between complexity and exaptation. Furthermore, those indicators refer to invention and not to innovation. Regarding the pros and cons of each indicator, Mastrogiorgio and Gilsing (2016) have designed an indicator that well suited to capture non-anticipation as a requirement for exaptation. However, in doing so, they had to restrict their sample only to USA-patents. Furthermore, their indicator captures only one dimension of the exaptive process. That is, the technological shift. But does not assess the extent to which the exapted knowledge is cumulative and incremental. Differently, the indicator proposed by De Noni et al. (2018) does not specifically capture non-anticipation, but it does not restrict the sample only to USA-patents and assesses the incremental and cumulative nature of the exapted knowledge.

Finally, the indicator proposed by Andriani et al. (2017) is probably better designed to capture exaptation. First, it refers to innovation and not only to invention. In fact, it assesses exaptation between entry use and off-label uses. That is, between the use defined at the end of the trial process and emerging uses resulting from the market exploitation of side effects observed in daily practices. Second, it also captures non-anticipation as the inventors of the molecule did not envision off-label uses. Third, it also assesses the length of the exaptation path. However, as the other indicators, this also has limitations. First, as Mastrogirgio and Gilsing (2016), this indicator captures only the functional shift, but not the incremental nature of knowledge embodied in the molecules. Second, its application is limited only to the pharmaceutical industry.

5 Exaptation as Driver of Smart Specialization in Regions

The smart specialization concept is a driving force both behind both the new 'Innovation Union' flagship program of the European Commission and the EU cohesion policy reforms. It originated in the literature analyzing the productivity gap between the United States and Europe (McCann and Ortega-Argilés 2015). This literature has highlighted the key role played by technological linkages and spillovers between industries and regions in explaining this productivity gap. However, it has also stimulated further reflection within the so-called K4G group, which originally conceptualized the idea of smart specialization and drew the initial guidelines for its development and implementation.

The smart specialization strategy aims at solving two problems related to past innovation policies implemented in Europe (Foray 2016, 2018). The first is the partial failure of horizontal policies, in which resources are allocated in a horizontal manner avoiding any preferential interventions and acting on general framework conditions. Even if these policies are required for a region being competitive, do not stimulate the production of those complementary resources and competencies that are required for the existing industrial system being capable to exploit the transformative potential and dynamism generated by the improvements in general framework conditions. For instance, investing in the development of the 5G infrastructure does not necessarily trigger off the starting up of new entrepreneurial initiatives capable to exploit the innovative potential made available by the large availability of this infrastructure within a region. This is even more true in lagging-behind regions, which lack the organization thickness required to self-produce those complementary resources and competencies. The second is the failure of the so-called MOPs (Mission Oriented Policies), which are grounded on the role of the omniscient planner.

The solution proposed by the smart specialization strategy relies on the definition of priorities between transformative activities and on the role of entrepreneurial discovery. Transformative activities are "collection of innovation capacities and actions, that have been extracted as it were from an existing structure or several structures, to which can be added extra-regional capacities and that is oriented toward a certain structural change" (Foray 2018, p. 818). The objective, therefore, is not finance neither a single project nor a sector as whole, but rather the local process of entrepreneurial discovery to integrate and combine dispersed, fragmented, and hidden local knowledge to open and explore a new domain of market and technology opportunities. Thus, entrepreneurship plays a dual function. On the one hand, it does the actual work of discovering information that is otherwise extremely costly, if not impossible, to collect. On the other hand, it produces information about the value of the prospected new area of specialization for the region.

Even if the smart specialization strategy points out the importance of levering on existing specialization to stimulate the generation of new areas of opportunities on which to construct the future competitiveness of a region, it remains rather unspecific on how policymakers should select transformative activities. In this perspective, a rather accredited solution is the one grounded on the trade-off between technological relatedness and technological complexity Balland et al. (2019).

According to this view, valuable innovations are the result of the recombination of knowledge available into different industries/technological fields. Therefore, regional competitiveness and growth depend on the variety of knowledge sources available. However, given the breadth and depth of the variety, not all combinations work the same. There are combinations that are more efficient than others because, on the one hand, reduce the cost of recombination across specializations, but, on the other hand, stimulate creativity. Those are the combinations maximizing the level of technological relatedness between regional specializations. That is, combinations adding up areas of knowledge specialization strongly interconnected and often combined in the production of new knowledge. Therefore, according to this view, regions hold a competitive advantage compared to others when, for some historical reason, have combined, within their geographical boundaries, a large set of specific resources and skills complementing each other in the process of innovation. Balland et al. (2019) transpose the concept of technological relatedness and connect it to the one of smart specializations. Therefore, according to their view, regions should invest in transformative activities connecting local bundle of specializations to related global trajectories of innovation. However, in their view, technological relatedness is also constraint as it prevents regions to enter more complex technological developmental paths, which lead to stronger economic growth.

However, there are already scholars voicing their concern about the possible risks associated with smart specialization strategy focusing only on technologically related innovation paths (Castaldi et al. 2015; De Noni et al. 2018). As suggested by Castaldi et al. (2015), one may expect that the related variety hypothesis to hold for innovation in general. However, it should be recognized that innovation based on the recombination between previously unrelated pieces of knowledge implies that new relations are established in the form of artifacts that paves the way for future innovation to follow suit. Even if Castaldi et al. (2015) remain tied to a combinatorial and adaptive view of innovation, they highlight the importance of unrelatedness, which settle the opportunity to establish new connections between previously unrelated sources of knowledge, as a significant driver of path-breaking innovation and economic growth. This opportunity has been so far overlooked for the high costs and risks associated to combine cognitively distant sources of knowledge. Differently, exaptation is also a driver of radical and path-breaking innovation. However, it does not require covering the cognitive distance between many highly diversified knowledge sources, but levers on an existing artifact to enter a new and emerging innovative trajectory. Therefore, it enables the opportunity to lever of existing specialization to enter emerging and path-breaking innovation trajectories. Therefore, exaptation is an opportunity, still overlooked, for smart specialization in regions.

6 The Map of Exaptive Patenting in European Regions

In the previous section, we highlight exaptive patent as a potential source of smart specialization in regions. In this section, we map the occurrence of exaptive invention in European regions as a way to highlight the opportunities associated with lever of exaptation as a source of smart specialization. The results of our analysis are summarized in Fig. 1a, b, which refers to 284 European regions (defined at NUTS2 level). Exaptive patents are assigned to each region according to a regionalization process based on the addresses of inventors and accounting for inventors share. In

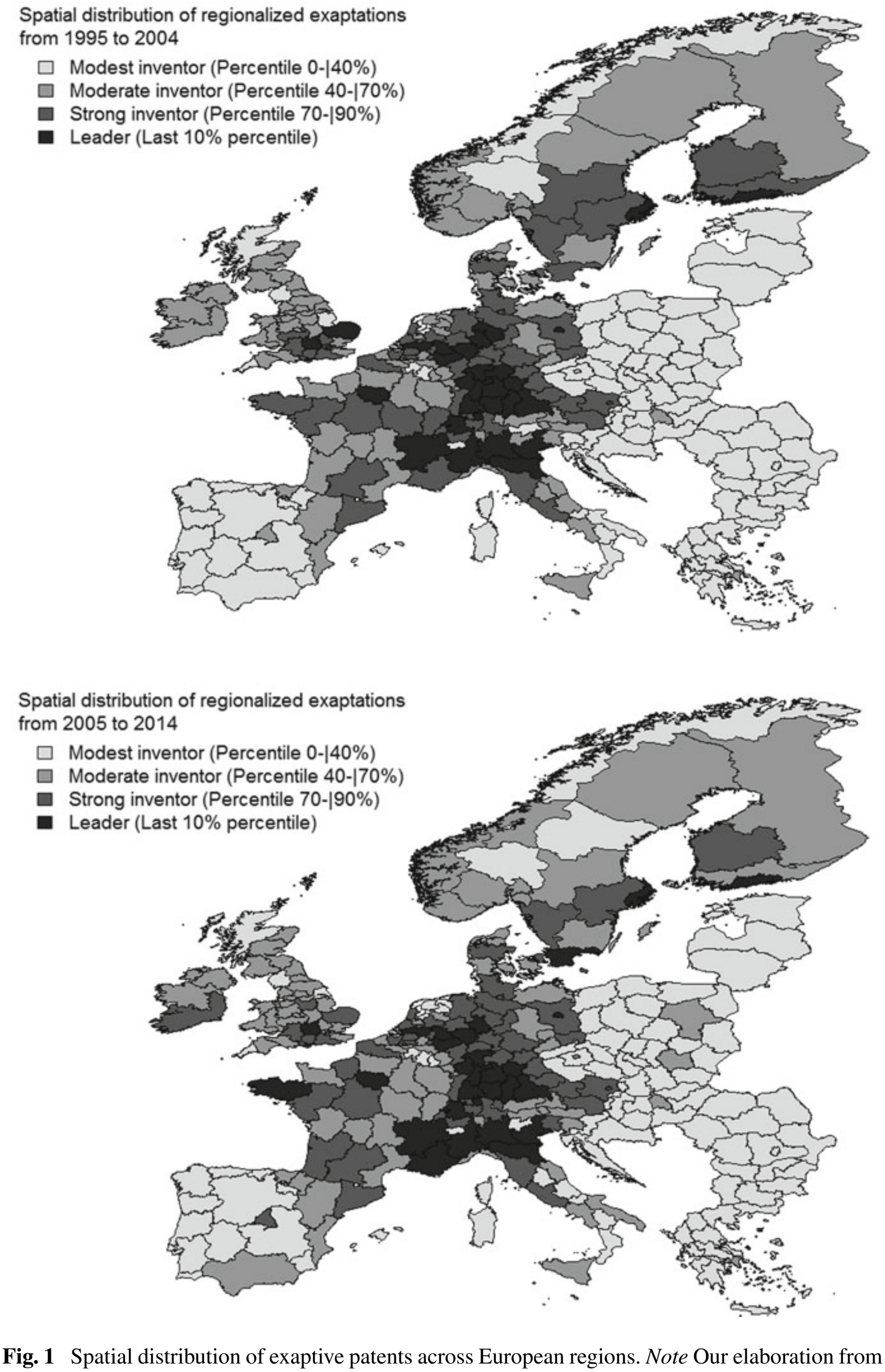

Fig. 1 Spatial distribution of exaptive patents across European regions. *Note* Our elaboration from OECD-RegPat database (version release July-2019). Data refers to the number of exaptive EPO patents involving at least a European inventor. Patents are regionalized based on inventors' addresses. Thus, a fractional counting is carried out in case of interregional co-patents

other words, collaborative patents, involving more than one inventor not coming from the same region, are fractionalized. Two 10-year windows are represented by referring to the priority year of patents. While Fig. 1a refers to exaptive patents registered from 1995 to 2004, Fig. 1b illustrates the most recent period from 2005 to 2014. In the figures, regions are classified, based on the percentile distribution, in modest inventors (less than 40th percentile), moderate inventors (between 40th and 70th percentile), strong inventors (between 70th and 90th percentile) and inventor leaders (more than 90th percentile). The four groups are colored through a grayscale, where the darker regions correspond to the more exaptive ones.

The spatial distribution in Fig. 1a reveals that the most performing regions in terms of exaptive patents are localized in central Europe, and specifically in West Germany (plus Berlin), North Italy, South England, South Scandinavia, and France. Referring to the spatial distribution of EPO (European Patent Office) patent across European regions in De Noni et al. (2018), exaptive patents result to be embedded within the most inventive regions. This suggests that high-intensive regions with extended and complex knowledge domains are more inclined to support exaptation than lagging-behind regions. It might be linked to a more developed institutional thickness, which better supports a creative disruption process by moving knowledge from one technological field to another one.

Figure 1b does not suggest a large change in the distribution of exaptation performance across regions moving to the most recent 10-year time window. Better performance is registered in France and Spain while worst performance is registered in some regions in Germany and the UK. Stable are, among others, Italy and Scandinavian. High exaptation performances are mainly carried out in metropolitan areas like Milan, Paris, Berlin, and London, too. The higher potential of large cities in boosting exaptation might suggest the role played by universities and R&D services which are frequently bounded in urban areas and are able to better support firms in experimentation and radical innovation processing. Smart cities also attract a large number of R&D resources in terms of human and financial capital, public and private funds as well as foreign investments. Finally, urban density rises the spatial proximity effects and increases the opportunities for collaboration, knowledge diffusion, and cross-fertilization processes. All these elements likely make cities the best loci for exaptation.

If an evident gap exists between high-intensive and lagging-behind regions, Fig. 2 specifically explores the relative exaptation performance of strong inventors and leader regions[1] in order to better control for different potentials across regions. An exaptation rate is implemented by measuring the relative accounting of exaptive papers as referred to the total numbers of patents filed in the region. The percentile distribution of exaptation rate highlights the relevant role of some German, French, and Italian regions (Fig. 2a) as well as the growing relative performance of Paris and Provence regions (Fig. 2b). Exceptionally, the map suggests the increasing relative performance of Ireland and the Netherlands.

[1]Modest and moderate inventor regions are not included because of the low number of patents which make relative indicators lowly performing.

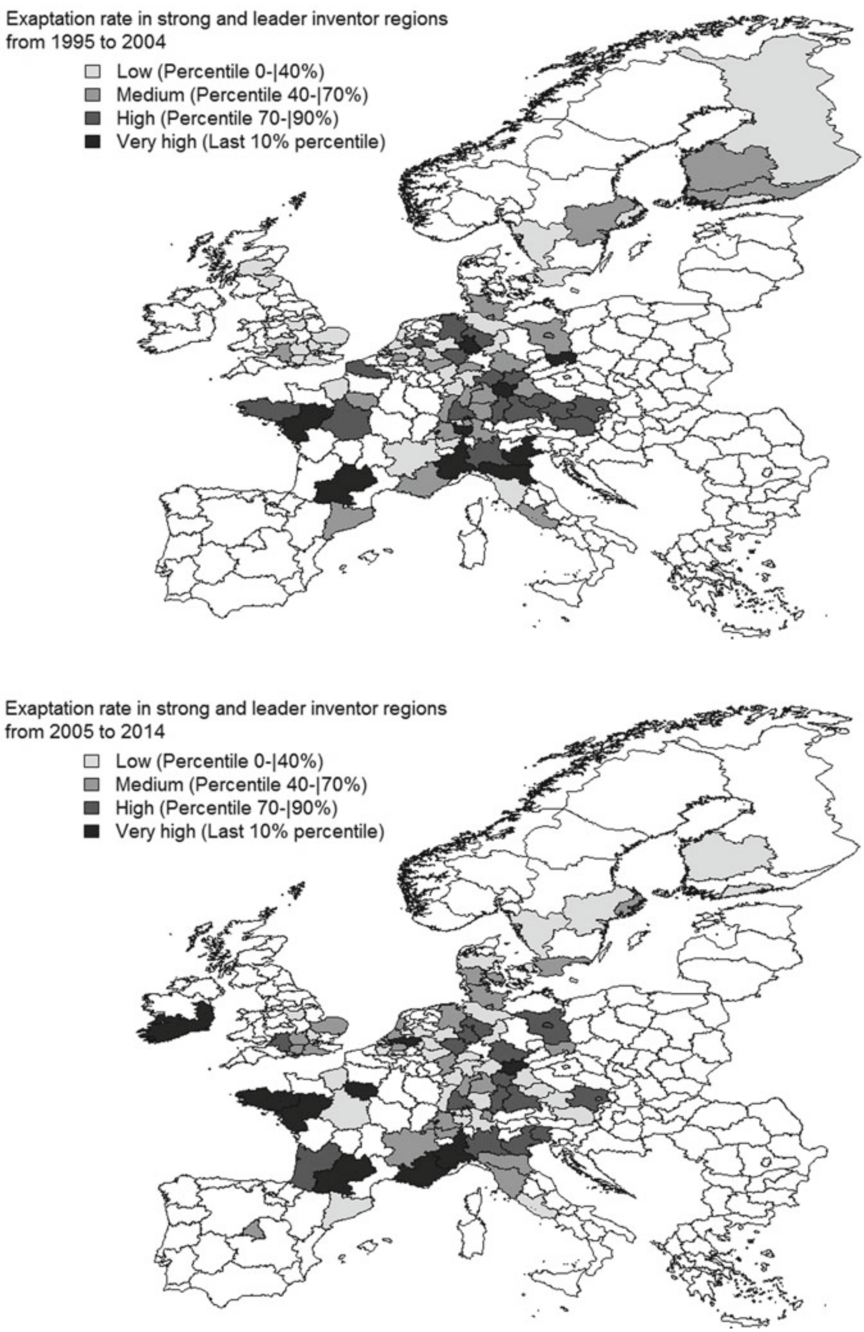

Fig. 2 Exaptation rate across European strong and leader inventor regions. *Note* Our elaboration from OECD-RegPat database (version release July-2019). Data refers to the number of exaptive EPO patents involving at least a European inventor. Exaptation rate is computed as the share of regionalized exaptive patents on the total number of patents

To sum up, the large number (in absolute terms) of exaptive patents within German regions is likely fostered by a very performing regional innovation system able to support collaboration, cross-fertilization, and knowledge spillovers and to produce incremental, radical as well as exaptative inventions. The exaptation propensity, however, is lower than other regions and is inclined to decrease in the last period. The same for the most inventive Italian regions like Lombardy, Emilia Romagna, and Veneto. Only Piedmont in Italy appears to be highly performing in both absolute and relative terms. In Spain, only Madrid and Catalonia attempt to catch up with the most innovative regions in terms of exaptation performance.

The best practices concerns some French regions like Ile de Framce (Paris), Bretagne, Pays de La Loire, Midi-Pyrenees (Tolouse) and Provence which disclosed a higher propensity to produce exaptation in spite of a slighter patent portfolio (compared to some knowledge-intensive German regions) and further reveal an increasing exaptation potential.

7 Enhancing the Competitiveness of EU Regions Through Smart Specialization and Exaptation Toward Local Industrial Policy Able to Sustain Innovation Ecosystems Trajectories

Now we can translate an exaptation trajectory in a path for policy in the European Union. For all reasons described upon in Europe is urgent a shift from vertical policy to horizontal policy and necessary to unify industrial policy oriented to the promotion of ecosystems crossing metropolitan area, clusters and multi-district, traditional sectors and territories able to enlarge and extent building platform to recoupling division of labor (in Smithian meaning) and division of knowledge (in Nonaka meaning) also as reconnecting tacitness and codified resources. In particular with more attention to tacitness as a frontier of power on a matching between serendipity and exaptation extending variety. Primarily, because competitiveness is no longer between companies but between regions as the self-contained frame of triangulation: manufacturing-services-intelligence in public and private alliances. Secondarily, because we need of more large division of labor at multilevel trajectories (people, companies, and territories) in a cognitive sense toward growing servitization able to increase both radical variety and customization moving quality of context (product, services, intelligence, and territories) increasing externalities and appropriability. Thirdly, because we need to push smart specialization in connection with quadruple innovation helix in a hard interaction between regional-local level and national-global level reducing duplication of industrial policy.

We can do this along four main trajectories of specialization action, inside the transition between a century of conflict to a century of negotiation and now toward intelligent collaboration with Fourth Industrial Revolution (digital world, AI, Cloud computing, simulation, Big Data) overcome the multilevel division of labor realized by Fordism in twentieth century between: rationality and creativity, technology and nature, individuality and community, science and arts, decision and culture.

1. Function of interaction between multiple public-private actors of cohesive communities
2. Agglomeration of common interests via local and transnational networks
3. Sectoral/intersectoral shared innovation with strong local roots
4. Knowledge Economy: networking, TLC, Internet, sharing activity.

We start by a focalization on knowledge-based society about for main points reinforcing horizontal industrial policies:

a. Central pre-and post-manufacturing phases for product and process innovation;
b. Centrality of intangible assets (knowledge, innovation, HR, organizational and social capital, human and semantic);
c. New actions and framework programs for innovation and knowledge;
d. Diffuse trajectory on sustainability and responsibility unifying actions on product, services, and intelligence with intermediate and final users.

Points developed by 6th European Framework Program (2002–2006) as a hard integration as reinforcing cross-industry trajectories of next UE Commission Program (2020–27):

(i) University-industry relations; (ii) Public research centers; (iii) Industrial technology development

(iv) Promotion of competition to encourage innovation; (v) European Aria Research Training (AER): coordination of national and regional programs.

A European Program able to sustain variety of industrial context in the different local regions in a multinational perspective for extended inter-industry technology and competences portfolios (Cappellin et al. 2019).

To create an environment conducive to innovation coherent with Lisbon's Strategy able to develop the absorptive capacity of regions and smart cities:

- integration of both sectoral and intersectoral platform projects;
- creation of networks of excellence: research, production and sales;
- joining programs between the Commission and member states;
- promoting technology transfer;
- making risk capital available;
- intellectual property protection;
- human resources development;
- social capital consolidation;
- increasing global spending on R&D at 3%;
- mobilizing actors in a triangulation between three main integrated levels—regional, national, European.

These are translated in the European policy of innovation in 7th Framework Program 2007–2013 described in five main integrated elements:

I. Cooperation: 2/3 resources 7th Framework Program in collaborative research in 10 areas (health, food, telecommunications, nanoscience/nanotechnologies, energy, climate change, transport, human sciences, space, security),
II. Ideas: scientific research of excellence,
III. People: internal researcher mobility Union,
IV. Capacity: research and knowledge society,
V. Nuclear research: nuclear fusion. Joint research center.

A set of incentives, therefore, that allow us those eco-systemic alignments (network, supply chain, platform, and multi-district) in the diffusion/acquisition of innovations, codifying in a more systematic way the relations between products, services, and knowledge, between material and immaterial, between concrete and digital. Mechanisms that can allow us to raise the quality of our platforms by extending the intersectoral boundaries through new materials, reengineering, innovative design, hybridization of emerging needs under the banner of radical customization modeled by digitalization. In particular, applying medium-tech research in the biomedical, packaging, agro-industry, wood-furniture (from the house to the boats), software, recreational boating, sportswear and technical clothing, mechatronics, domotics, pharmaceuticals, of which we report some emerging cases not representative but significant for the hybridization processes in Italy and Europe (Pilotti 2017). In short, we can raise the level of quality to make our products inimitable if the corporate culture and the intertwining of intersectoral relations toward new thickening and densifications due to hybridization and generative contamination of superior variety and creativity change supporting exaptation trajectories. Transferring between medium-large companies and SME systems, between multisectoral platforms and between territories, skills, and know-how toward a new socioeconomic, competitive, and technological order, cumulatively reorienting information-knowledge toward new diversity and virtuous asymmetries (in exaptation meaning as described before), between: large and small, invention and application ideas, territories and needs. Toward a recombined new multilevel and multicentered integrations. Levers to raise our eco-systemic productivity through an increase in the rate of innovation and quality, but also with their diffusion in a cross-industry sense and that Industry 4.0 can facilitate and strengthen the intersectoral networking with extended exaptated conditions of contexts. Roads that lead precisely to the servitization of products, as in the car industry, where customers will pay ever more for the cost to get access to the services offered by a product rather than for the ownership of the product itself is codifying the transfer channels of the information toward a new diffusive order: product born with a function and now transformed in other function by digitalization.

In fact, according to the scheme of Hidalgo, proposed in *The Evolution of the Order*, we should be able to find a new order to the wealth of information and know-how that over the centuries have allowed us to become a creative, albeit messy and unequal as it is weak in the transfer of knowledge due to an excess of informality and individualism. Such as crossing the existing information assets channeling them to new knowledge platforms with actions of contamination and formal and codified hybridization to renew our creativity bases and continue to make good products even if more complex via servitization.

Today we are condemned to higher levels of complexity for "long" chains of progress that cannot be achieved in solitude and/or through hyper-local channels but exploring inter-industry division of labor as matching between physical and cognitive ones. We will be able to achieve this by injecting superior confidence and empowering intercompany and interpersonal relations, overcoming selfishness, individualism, and familisms that often slow down the transmission of information and knowledge useful for creating value, as decreasing exaptation conditions of growth or serendipity results. The family that has represented a nucleus of development—entrepreneurial and educational—fundamental of this country for a century until the first two decades of the second post-war period, now risks representing a heavy constraint especially in the transfer of information and knowledge, reducing variety and tacitness. For this reason, family networks should be open to "external" contributions and to the variety (of members, managerial skills and ideas) injecting confidence to renew knowledge bases to transfer useful information to innovation, increasing exaptation conditions to growth (also with *emotional organization—creative and intelligent* as described in Pilotti 2019). Complex innovations that today require greater sharing of risks on an extended basis and a "long" network-supply chain. Because we are often very good at doing—even quickly—in short networks and in contexts of creative proximity (only informally shared) but more limited and slow when we need to innovate or transfer the results because they are hampered in their sharing, especially if in team, on the net and/or in a community of subjects not characterized by family or clan ties. It is the current situation where the products are best identified through the double "layer" in the first place of the services that surround them to create and transfer them and, secondly, for the knowledge that makes it possible to innovate and transform in time and space through connectivity, accessibility, networking, and shared creativity. A trajectory of industrial policy where serendipity and exaptation can reemerge as fuelling of sharing creativity and open innovation crossing multiple level inter-industry: micro–meso-macro (Bianchi and Labory 2019).

This is a good frame to enhance strategy supporting *exaptation philosophy* of industrial policy in the European Union able to sustain the richness of a variety of SME, integration of multi-district manufacturing systems, and competitiveness of smart cities in coherent regional ecosystems looking for a new emergent Europe for the future.

8 Conclusion

The objective of this paper was to investigate the potential of exaptation as a tool for strengthening the competitiveness of regions through smart specialization strategy. In this perspective, we highlighted that exaptation is a spontaneous process in innovative intensive regions while it is not common in lagging-behind regions. Furthermore, we also show that the attitude toward exaptation is declining in some innovative intensive region. Therefore, there is a need for policymaking related to the role of exaptation as a tool of smart specialization. However, we highlight that the smart specialization strategy has only focused on the adaptive form of innovation, which is grounded in the recombination of knowledge across the different technological and lightly related fields of knowledge. Differently, exaptation has not been included as a tool to leverage smart specialization in regions. To this purpose, we highlight the main drivers of exaptation and the process through which exaptation emerges. Based on this analysis, in the last part of the paper, we drafted some initial policy indications to support exaptation in regions.

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